ece

4805/4806/2804

Virginia Tech ECE 4805/6 and Select Projects from ECE 2804

May 2020

VIRGINIA TECH™

The Major Design Experience provides each of our participating undergraduate and graduate students a culminating project experience. Each student contributes their collective knowledge and skills as part of an engineering project team to solve meaningful challenges for an exciting, real-world project. This semester, the students encountered significant unanticipated challenges (and opportunities) due to a global pandemic. After an extended Spring Break, our students did not return to campus nor to the MDE design studio for final product build and test. They did, however, analyze and react to an unanticipated event; reestablish remote, distributed communications; and conduct detailed project planning and refactoring to bring their project as close to completion as the situation allowed. Teams conducted remote video meetings, planning, and work sessions to share expertise and guide remote operations. Some shipped parts back and forth. While these are not our intended plan, the students thrived and rose to meet the challenges with a resilience that was impressive.

This year's Expo event is a purely virtual, asynchronous event. We still seek to showcase the teamwork, communications, project management, and engineering prowess of 104 students across 27 projects; but in new and meaningful ways, we also seek to highlight their adaptability and resilience. Each student team recorded, with dispersed participants, their final customer handoff meeting in lieu of a more formal technical presentation. Every team produced their final project poster; while some projects are complete or near complete; some focused more on documenting project current state and proposing a plan for a potential continuation project to their customers. We are excited to share our students work under these circumstances, and we offer this as evidence of the grit and resolve our emerging young engineers can produce and are now prepared to bring into your teams and organizations. They are our collective contribution to the next generation of engineers; ready to overcome global challenges.

This would not have been possible without the support of our industry partners, our subject matter experts, and a host of other professionals committed to providing our students with these exceptional educational engineering experiences. Thanks to all.

Congratulations to each of the students; their dedication and diligence are evidenced in these 27 projects. On behalf of these students, and from me personally, thanks again to our industry sponsors, our subject matter experts, and our MDE faculty for their tremendous support in developing our next generation of engineers.

Luke Lester
Roanoke Electric Steel Professor and Department Head
Bradley Department of Electrical and Computer Engineering

Welcome (virtually) to the Bradley Department of Electrical and Computer Engineering Major Design Experience Expo. The 2020 MDE Spring Expo is, not surprisingly, a significantly different experience for everyone. Not only has the COVID-19 global pandemic impacted both our semester and this Expo; but we are also excited to incorporate the best and brightest from one of ECE's newest sophomore design, build, and test courses, ECE 2804, Integrated Design into this showcase event. Our virtual Expo this semester is intended to celebrate the achievements of 113 ECE students working together on 31 project teams.

A key element of the MDE program goal is to provide our ECE students a "real-world" engineering experience and expose them to a first instance of engineering in a safe, controlled environment. This class did not receive that. The students were unexpectedly geographically dispersed and limited in their access to materials and equipment. Rather than stop work, the students refocused their efforts to reestablish communications; inventory and account for their people and their projects; and then they worked with their customers to refactor project objectives to mitigate these new conditions. This is not, by any measure, the project activities planned for the course, but this class understands risk and mitigation in ways previous classes only read about. The students adapted; they shipped equipment among sites; conducted planning, testing, and customer meetings via Zoom. They created shared collaboration sites and many thrived… producing well beyond expectations.

The students could not have adapted and delivered without the tireless efforts and support of our SMEs and customers. MDE is made possible with the dedicated support of our sponsors and subject matter experts whom we offer our most sincere appreciation and this semester amplifies this reality. Thank you for your commitment to shape and enhance the Virginia Tech ECE students as they prepare for next stage of their journey to make the world a better place by engineering and delivering meaningful solutions no matter what challenges they may encounter.

In addition to the MDE student presentations, this Expo welcomes four teams of sophomore ECE students who excelled in their newest sophomore team-based, design course. Nine students from a class of more than 200 stepped forward to tackle the optional challenge of presenting their project results at this Expo. Each team selected from one of three instructor defined, open-ended design project options. The represented teams provide examples of design, build, and test for a Smart Home project and for a Wind Turbine system.

The MDE program would like to thank Luke Lester and Gino Manzo for their collaboration to breathe life into the MDE program. Thanks to Gino, Toby Meadows, and Ken Schulz for your continued support of the program and for sharing your industry experience and expertise with students in the MDE program. Because of each of you, we are better indeed!

To our ECE students: Well done. You have met this challenge! Move forward and invent the future as only ECE Hokies can!!!

J. Scot Ransbottom
Major Design Experience Director

Sponsors

We greatly appreciate their support.

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Project Leadership

This class is only possible because of the commitment, dedication, and spirit of the following Customers and Subject Matter Experts. Thank you!

Sponsor	Customers	Project	Subject matter expert (SME)
Analog Devices, Greensboro, NC	Michael Jones	Phased Array Beamforming Using Inertial Measurement Feedback	Steven Ellingson
BAE Systems, Manassas, VA	Richard Berger	Processing Algorithms for Hazard Avoidance on an FPGA	William Diehl
Collins Aerospace, Rockford, IL	Chris Gili	Avionics RF Signal Recorder	Joseph Gaeddert
Collins Aerospace, Rockford, IL	George Cooley	HF Antenna Controller	Majid Manteghi
Collins Aerospace, Rockford, IL	Jonathan Kolbrak	Power Amplifier Test Controller	Peter Han
Collins Aerospace, Rockford, IL	Magdi Essawy	Temperature Differential Sensing	Dong Ha
General Motors, Detroit, MI and IEEE, Blacksburg, VA	Chengliang Lu, Moqi Zhang	IEEE Robot Electrical Team	Arthur Ball
General Motors, Detroit, MI and IEEE, Blacksburg, VA	Chengliang Lu, Moqi Zhang	IEEE Robot Embedded Team	Arthur Ball
Inmarsat, Reston, VA	Wendy Votaw, Carl Burris	Spread Spectrum Modem Design	Alan Michaels
Micron, Manassas, VA	Zuzana Steen, Nick Phucas	Hybrid Optical Electrical Nanoantennas	Wei Zhou
MITRE, McLean, VA	G. R. (Datta) Dattatreya, Jerry Kim, Dale W. Herdegen, Sara Burlein	Symbol Constellation Detection	William "Chris" Headley
NAVAIR, Cherry Point, NC	Michael Sparr	Drone Reconnaissance - Object Detection Team	Dan Stilwell
NAVAIR, Cherry Point, NC	Thomas Newhart	Drone Retrieval	Dan Stilwell
Teledyne Hastings Instruments, Hampton, VA	Doug Baker	Remote Monitoring Capability for Vacuum Gauge Tubes	Tim Talty

Sponsor	Customers	Project	Subject matter expert (SME)
Texas Instruments, Dalles, TX	Mark Easley	DIY Robotic Kit	Peter Han
TMEIC, Salem, VA	Matt Mandros, Thomas Tainer	Integrated Inertial Measurement Unit For Industrial Machinery	Ryan Gerdes
Virginia Tech ECE, Blacksburg, VA	Jaime De La Ree	Heartbeat – Recording & Transmission Device	Jaime De La Ree
Virginia Tech ECE, Blacksburg, VA	Jih-Sheng (Jason) Lai	International Future Energy Challenge	Jih-Sheng (Jason) Lai
Virginia Tech ECE, Blacksburg, VA	Luke Lester	Lincoln Head Cherry Picker	Creed Jones
Virginia Tech ECE, Blacksburg, VA	Greg Earle, Riya Sareen	Nano-Satellite Instrument	Greg Earle, Riya Sareen
Virginia Tech ECE, Blacksburg, VA	Yuhao Zhang	Power Device Tester	Yuhao Zhang
Virginia Tech Facilities, Blacksburg, VA	Rob Glenn	Advanced Metering Infrastructure (AMI)	Virigilo Centeno
Virginia Tech Facilities, Blacksburg, VA	Rob Glenn	VT Facilities – SCADA	Chen Ching Liu
VPT, Blacksburg, VA	Matt Strehle	Magnetic Suspension System – Alpha	Dan Sable
VPT, Blacksburg, VA	Chris Meka	Magnetic Suspension System – Beta	Dan Sable
VPT, Blacksburg, VA	Campbell Lowe	Magnetic Suspension System – Gamma	Dan Sable
Wiley Wilson, Lynchburg, VA	Walt Mendenhal, Steve Bowman, Mark Adkinson, Dan Morton	Zero Energy Data Center	Jaime De La Ree

Phased Array Beamforming Using Inertial Measurement Feedback

CHALLENGE

We developed a system to change the directivity of a linear antenna array scheme to keep a true bearing based on inertial feedback from the system.

LEFT TO RIGHT: Kevin Upton, Andrew Wilds, Griffin Fox | **SME:** Steven Ellingson

Andrew Wilds

Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: After graduation, I hope to work in the signals intelligence or space industry for a few years before obtaining a master's degree.

Class comment: I appreciate the opportunity to work on a complex project. It has helped me understand what it takes to work in teams and how to learn things to get the job done.

Griffin Fox

Winchester, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to have a career working with embedded systems and/or analog circuit design, preferably for medical or musical technology.

Class comment: Getting my hands on some professional technology, such as the FPGA, was exciting. It made the experience feel all the more real using these powerful systems.

Kevin Upton

Timonium, Maryland

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I want to contribute to the next generation of radar and communication systems for either defense or commercial applications. I would also like to eventually be a project manager in a systems engineering role to better understand how a project can come together.

Class comment: I appreciate the experience working with our customer and subject matter expert to better define the scope of the project and figure out certain details we overlooked in implementing our initial solution. I also appreciate the technical documents and practice sharing our ideas as this helped me to be better prepared for my career.

PROJECT SPONSOR: MICHAEL JONES

ANALOG DEVICES
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Processing Algorithms for Hazard Avoidance on an FPGA

CHALLENGE

We identified and implemented image processing and hazard avoidance algorithms using a Zybo Z7-10 FPGA.

LEFT TO RIGHT: Stephen Baron Crooke, Aidan Foley, Kelvin DeFeo | **SME:** William Diehl

Aidan Foley

Annapolis, Maryland

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After graduating, I am working for a large construction contractor and would like to pursue a career in the power systems industry.

Class comment: The hands-off nature of this class allowed me to explore options on my own, which made successes very satisfying. I really felt like all of the work done was the result of my team and me.

Stephen Baron Crooke

Charlotte, North Carolina

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I am searching for a job in the Charlotte area.

Class comment: I appreciate the opportunity to learn about FPGA and SoC based programming.

Kelvin DeFeo

West Grove, Pennsylvania

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to continue to expand my career opportunities in electrical engineering and circuit design while growing into leadership roles.

Class comment: I enjoyed the real-world challenges that came with this class as they certainly will help me transition into working in industry.

PROJECT SPONSOR: RICHARD BERGER

BAE SYSTEMS

Avionics RF Signal Recorder

CHALLENGE

We created a device to passively receive and store L-band frequencies related to ADS-B interrogations and responses to assist in troubleshooting transponder errors.

LEFT TO RIGHT: Michael Kraiman, Sierra Litwin, Nathan Bolha | **SME:** Joseph Gaeddert

Michael Kraiman

Aldie, Virginia

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I would like to have a career working on space systems.

Class comment: This class has helped me understand the process behind the engineering cycle. It has made me more comfortable as I transition to beginning my career in a couple of months.

Sierra Litwin

Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to use my technical education and life experiences to make a positive impact on society.

Class comment: I appreciated working with talented people and being exposed to their rigorous thought processes.

Nathan Bolha

Dayton, Ohio

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

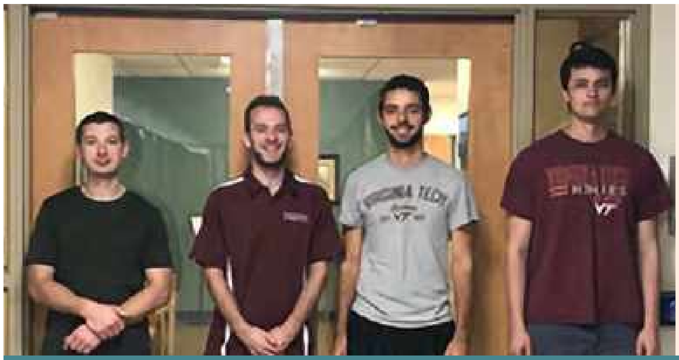
Aspirations: After graduation, I will be entering the Air Force as a Drone Pilot. Following that, I am considering leveraging my technical degree and operational experience to get involved in the future of unmanned flight.

Class comment: I have appreciated the opportunity to apply what we have learned to a real problem and meet the needs of a real customer.

PROJECT SPONSOR: CHRIS GILI

Collins Aerospace

High Frequency Antenna Controller



CHALLENGE

We implemented a high frequency antenna array that can be steered electronically by means of phasing. The design supports two, three, or four vertically polarized antennas and is controllable via a remotely operated laptop.

LEFT TO RIGHT: Jared Hoy, Cole Casteel, Nicholas Osborne, Dayton Engstrom | **SME:** Majid Manteghi

Cole Casteel

Falls Church, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to apply my electrical engineering knowledge to projects related to the environment.

Class comment: Learning some of the basics of project management (scheduling and budgeting) is helpful for working on longer projects.

Dayton Engstrom

Woodbridge, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to continue learning throughout my career.

Class comment: This course provided a good opportunity to work on a real-world problem.

Jared Hoy

Garwood, New Jersey

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to design and implement hardware-based solutions to current challenges in the field of RF engineering. I would also like to remain in a technical role for the foreseeable future.

Class comment: This was a great opportunity to work on a real-world problem by applying what we have already learned. This was a challenging process, but our SME and mentor helped us along the way.

Nicholas Osborne

Union Hall, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

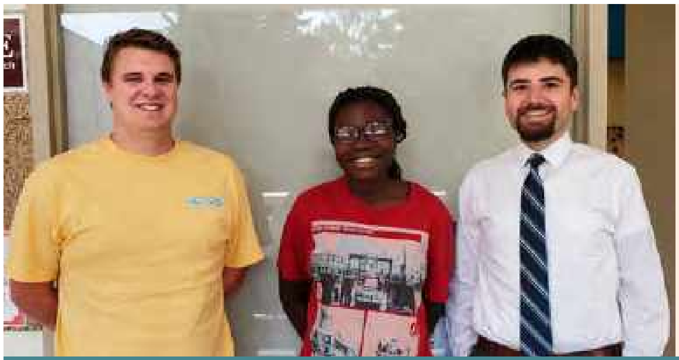
Aspirations: In my career, I hope to develop and maintain the next generation of electrical infrastructure that will power the nation for generations to come.

Class comment: This class helped me to become familiar with the technical documentation that accompanies working in the field of engineering and the recordkeeping process that goes along with large-scale technical projects.

PROJECT SPONSOR: GEORGE COOLEY

Collins Aerospace

Power Amplifier Test Controller



CHALLENGE

We designed a cost-effective automated test station controller in Python using a Raspberry Pi. The controller should automate common tests of RF devices while allowing flexibility to change equipment and tests.

LEFT TO RIGHT: Avery Neff, Oluwademilade Alabi, Michael McGruther | **SME:** Peter Han

Avery Neff

Lititz, Pennsylvania

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to use my electrical engineering knowledge in the aviation industry. Moving from an aerospace engineering degree to an electrical engineering degree, I have kept my passion for aviation and the industry surrounding it.

Class comment: I appreciated the opportunity to work on a real-world problem and interact with industry professionals. I have learned valuable skills from the project that have helped me gain opportunities for employment I did not have before.

Oluwademilade Alabi

Nigeria

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to use the knowledge and skills that I have gained in college to make a significant impact on the engineering industry. I also want to help advance the world around me with my current skills and the new abilities that I will gain as I continue to grow.

Class comment: I appreciate the close connection with our company sponsors and being able to understand the project's potential impact on their processes. I was also able to gain insight into what the industry is like and how people work together to accomplish goals.

Michael McGruther

St. Louis, Missouri

Bachelor of Science in Computer Engineering
Computer Engineering (general)

Aspirations: I plan to continue studying real-time embedded software while working in the aviation industry.

Class comment: The experience of working with a team, customer, and technical advisers taught me important communication and teamwork skills for my future career. Plus, designing and implementing a solution using what I've learned at Virginia Tech was a lot of fun!

PROJECT SPONSOR: JONATHAN KOLBRAK

Collins Aerospace

Temperature Differential Sensing

CHALLENGE

We designed a power supply system that uses the temperature differential within an aircraft engine to power sensors, electronics, and communication devices in a high temperature environment.

LEFT TO RIGHT: Ruoyang Yan, Mohammed Almagrab, Miki Bayarjargal, Ashley Chang | **SME:** Minh Ngo, Dong Ha

Ashley Chang

Roanoke, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to help develop new technologies while constantly learning. I would like to use my technical and leadership skills to advance society.

Class comment: I valued the hands-on experience that taught me more about designing, building, teamwork, and communication. This course helped me better understand self-responsibility and time management.

Miki Bayarjargal

Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work in the technical field for a few years and then obtain my master's in electrical engineering focusing on power electronics and power systems.

Class comment: I liked how the class exposed me to a real-life industry project. Now I have a better understanding of the business aspect of an engineering project.

Mohammed Almagrab

Al-Ahsa, Saudi Arabia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to hone my technical and other relevant skills while making a positive impact on society.

Class comment: I gained useful working experience that helped me test and apply my theoretical knowledge

Ruoyang Yan

Chengdu, Sichuan, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

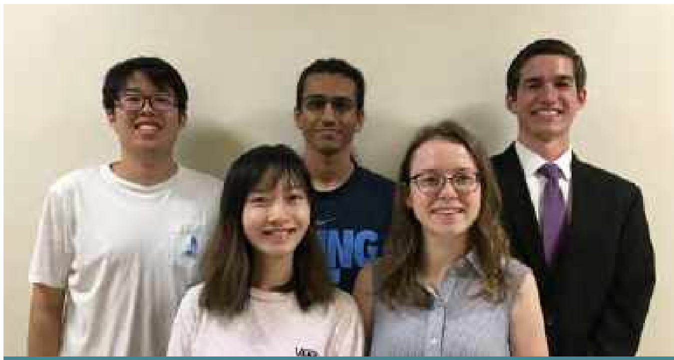
Aspirations: I want to be an electrical engineer in the future.

Class comment: I enjoyed the opportunity to work as a team and complete a hard project together.

PROJECT SPONSOR: MAGDI ESSAWY

Collins Aerospace

IEEE Robot Electrical Team



CHALLENGE

Our team designed, built, and tested a fully autonomous robot that will compete in the IEEE SoutheastCon 2020 Hardware Competition on Pi day. The competition involves stacking numbered Lego blocks and/or pushing numbered buttons in the order of Pi. We designed our robot to exclusively focus on pushing buttons in the correct order of Pi.

LEFT TO RIGHT: Zhe Liu, Ruilin Huang, Manpreet Dhaliwal, Alana Laferriere, Tanner Goins | **SME:** Arthur Ball

Alana Laferriere

Daleville, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I plan to pursue a career in the aviation industry developing my skills as an electrical engineer as I work to make aviation more sustainable.

Class comment: I appreciate the design freedom with which this class provided us. We were given a problem and we could use the knowledge we have gained over the course of our education and the tools at our disposal to come up with any solution.

Manpreet Dhaliwal

Petersburg, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: My career goal is to become a control engineer.

Class comment: I appreciate the career and corporate advice given to us in the class such as typical company structures and design procedures.

Ruilin (Ray) Huang

Chongqing, China

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I am seeking opportunities for work in control design or the automobile industry.

Class comment: I enjoyed working with the professors and the team members. Over the course of the year-long project, we practiced control system and mechanical design, and assembled and wired components. It provided us the opportunity to apply a problem-solving strategy in a real engineering working environment.

Tanner Goins

Hanover, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to use my knowledge from university and experience from co-ops to work in R&D in robotics, aerospace, or another industry related to electrical engineering.

Class comment: This class was a great opportunity to work on a design from start to finish, which included brainstorming, rapid prototyping, and documentation—all while working to meet the needs and specifications of our customer.

Zhe Liu

Beijing, China

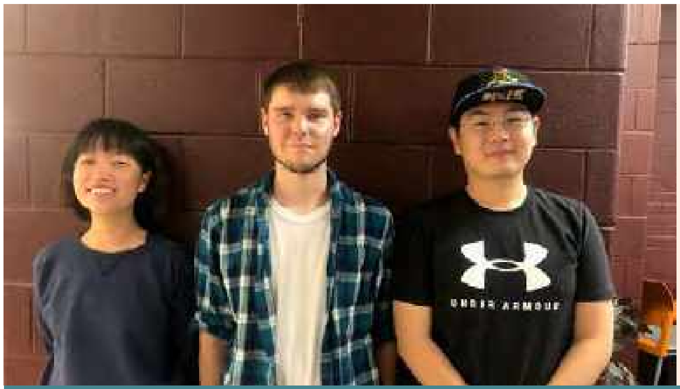
Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I would like to be successful in the field of electrical engineering and specialize in unmanned vehicle operations and adaptive control systems.

Class comment: The Senior Design class takes you through a hands-on project from beginning to end. I really enjoyed working as a team to overcome challenges. Seeing how powerful and complicated a robotic system is has inspired me to pursue further research opportunities.

PROJECT SPONSORS: CHENGLIANG LU, MOQI ZHANG

IEEE Robot Embedded Team



CHALLENGE

Our team designed and built a robot for the 2020 IEEE SoutheastCon Hardware Competition. The competition is composed of two separate challenges. The first challenge is stacking LEGO blocks. The second challenge is pressing buttons. The challenges may be executed in any order, or it is permissible for a robot to only do one of the challenges and skip the remaining challenge.

LEFT TO RIGHT: Yahui Zhao, Drew Harlow, Jielong Cong | **SME:** Arthur Ball

Jielong Cong

Beijing, China

Bachelor of Science in Computer Engineering
Computer Engineering (general)

Aspirations: I would like to work on the newest technologies, such as AI, robotics, or 5G. I also want to contribute to my country's success.

Class comment: I appreciate the experience of working on a real team for a real company. It will help me get a good start in my future career.

Drew Harlow

Millboro, VA

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: My career goals include the research and development of collaborative robots to improve safety and productivity in high-risk working environments.

Class comment: This course provided me with the opportunity to work as part of a team with diverse skillsets and areas of expertise on a long-term project with multiple deliverables.

Yahui Zhao

Anshan, Liaoning, China

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I want to use my knowledge of computer engineering to create new technologies.

Class comment: I appreciate the hands-on opportunity of defining and exploring solutions to a problem that this class offers. My project helped me learn how to work with other engineers, communicate with supervisors and customers, and focus on individual responsibilities.

PROJECT SPONSOR: CHENGLIANG LU, MOQI ZHANG

Spread Spectrum Modem Design

CHALLENGE

We developed a modem for spread spectrum communication implemented on the Xilinx Zedboard, an FPGA Software Defined Radio platform. To accomplish this, many factors had to be considered including the user data rate, spreading ratio, and synchronization of the transmitter and receiver.

LEFT TO RIGHT: Shannon Lilly, Evance Gyabaah, Isaac McDaniel | **SME:** : Alan Michaels

Evance Gyabaah

Alexandria, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to become an expert in telecommunication systems.

Class comment: Our subject matter expert was very helpful and knowledgeable.

Isaac McDaniel

Chantilly, Virginia

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I would like to design large scale integrated circuits for use in difficult problems such as RF applications.

Class comment: This class provided an opportunity to test my skills against the challenges and expectations of engineering projects in a business environment.

Shannon Lilly

Sykesville, Maryland

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I am interested in signal processing as it relates to our nation's defense. After graduation, I will be working for Northrop Grumman in the hardware department.

Class comment: I appreciated learning the importance of communicating with the various stakeholders and making sure that everyone is in agreement. I also enjoyed applying classroom learning to a specific real-world problem.

PROJECT SPONSOR: WENDY VOTAW, CARL BURRIS

inmarsat

Hybrid Optical Electrical Nanoantennas

CHALLENGE

Currently, biological specimens undergo two separate tests for sensing of optical and electrical properties. We designed a device that enables simultaneous electrical and optical sensing of biological specimen and evaluated its effectiveness.

LEFT TO RIGHT: Bumsu Kim, Collin Hood, Steven Parker, Will Banner, Shubham Dawda | **SME:** Wei Zhou

Bumsu Kim

Gwacheon, South Korea

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: My dream is to discover the fundamentals of our world, and I believe the hints to that discovery can be found in every single aspect of our life.

Class comment: I am very thankful for the opportunity to participate in this project, which is one of the best experiences Virginia Tech offers to the electrical engineering students.

Collin Hood

Brandy Station, Virginia

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: My ideal career would be to work on nano-technology or as a packaging engineer.

Class comment: I appreciate the realistic work environment as well as the clean room experience that I probably wouldn't have had without this project.

Shubham Dawda

Mumbai, India

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I'm interested in developing novel technologies to broaden the horizons of human knowledge. I would like to research and develop a technology that can improve biomedical imaging, making it faster and cheaper.

Class comment: I am grateful for the opportunity to work in the field of plasmonics. The practical and theoretical knowledge that I have acquired from this project will be extremely helpful in my future endeavors.

Steven Parker

Princeton, West Virginia

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: After graduating, I will be pursuing a Ph.D. at Duke University. I will be specializing in the field of biophotonics.

Class comment: This course gave us the opportunity to gain experience with high-level equipment that I wouldn't have access to otherwise.

William Banner

Charlottesville, Virginia

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: Ultimately, I would like to work as a research group leader in the nascent quantum computing industry.

Class comment: I appreciate the opportunity to work on an interesting research project and build up my professional research experience before I go to graduate school.

PROJECT SPONSOR: ZUZANA STEEN, NICK PHUCAS

Micron

Symbol Constellation Detection

CHALLENGE

Our team developed an algorithm that detects the APSK modulation scheme used in an unknown signal and corrects the incoming signal for ambient white gaussian noise and a constant phase shift distortion.

LEFT TO RIGHT: Benjamin Hecker, Jade Sabourin, Ethan Goldenberg | **SME:** William "Chris" Headley

Benjamin Hecker

S. Glastonbury, Connecticut

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to work in the field of RF and communications to help explore the space frontier.

Class comment: I enjoyed working with my classmates in a professional environment to solve a real-world problem. Through this project, I developed a stronger interest in communications. It also set me up to have a great start to my career in the field.

Ethan Goldenberg

Falls Church, Virginia

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: Although I've studied communications technology and math extensively, I'm pursuing a career in Fire and EMS. I hope to use the skills I gain from engineering school to help keep people safe.

Class comment: I enjoyed the opportunity to use the digital modulation knowledge I've acquired through my coursework. This project made a somewhat abstract subject more real to me.

Jade Sabourin

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: The fields of RF communications systems and medical imaging technology both fascinate me, so I would like to work in one or both of those areas.

Class comment: I have wanted to become an engineer since middle school, because I have always wanted to be able to build something from the ground up that I could be proud of and that could impact others. As I have progressed through this senior design experience, I can, without a doubt in my mind, say that I have accomplished this feat. The work I have done in this senior design experience has been difficult, but it has also been enriching, and I know I can point to my work over the past year and be proud of what I have accomplished.

PROJECT SPONSOR: G. R. (DATTA) DATTATREYA, JERRY KIM, DALE W. HERDEGEN, SARA BURLEIN

MITRE

Drone Reconnaissance – Object Detection Team

CHALLENGE

We simulated military target identification and reconnaissance missions using two drones that communicate with each other, with one drone performing object detection and the other drone performing object retrieval.

LEFT TO RIGHT: Xukai Hu, Jonah Orevillo, Austin Fuller, Srinidhi Rao | **SME:** Daniel Stilwell

Austin Fuller

Naples, Florida

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I hope to have a career in embedded programing specializing in machine learning, AI, and robotics.

Class comment: I enjoyed that this class presented us with a problem that was technically challenging and rewarding.

Xukai Hu

Ningbo, Zhejiang, China

Bachelor of Science in Electrical Engineering

Aspirations: Technology changes lives.

Class comment: The experience of this project is really meaningful for me, which provides me more opportunities to acknowledge real applications of programming.

Jonah Orevillo

Roanoke, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to become an avionics engineer and flight test engineer in the aerospace/defense industry working with cutting-edge technologies such as autonomous systems, flight controls, electric propulsion, and GPS navigation. I want to be at the forefront of the future of flight!

Class comment: This course and project helped me improve my ECE technical knowledge, my confidence working in a team, and my ability to utilize the plethora of resources available today. I gained practical experience and solidified my aspiration to go into industry. I want to thank Virginia Tech and NAVAIR for this worthwhile culmination to my engineering degree and steppingstone to my full-time career.

Srinidhi Rao

Reston, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I hope to apply what I have learned at Virginia Tech and serve as a leader in a field that emphasizes innovation and creativity.

Class comment: I learned a lot about how to communicate and work with a team and multiple supervisors. It was really eye opening to see how important it is to work effectively and efficiently, especially when things may not turn out the way you expect—but that's real life!

PROJECT SPONSOR: MICHAEL SPARR

NAVAIR

Drone Retrieval

CHALLENGE

NAVAIR is developing a dual drone system that relies on a surveillance and retrieval drone that communicates with a centralized ground server system. Our job is to deliver fully autonomous software that recognizes and retrieves several objects and returns them to a ground server system based on GPS coordinates received by the surveillance drone.

LEFT TO RIGHT: Nicholas Sileu, Ethan Brooks, Brett Pollman, Mary Benden | **SME:** Daniel Stilwell

Brett Pollman

Virginia Beach, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I plan to work as an automation/control systems engineer.

Class comment: I appreciated that this class made us face real issues that would come up in a company and then allowed us to solve the problems we had on our own with some guidance.

Ethan Brooks

Springfield, Virginia

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Computer Engineering (general)

Aspirations: Following graduation, I hope to use my skills to produce technologies that help those in need. I hope to eventually be the manager of a project within my company.

Class comment: The class taught me to appreciate how much goes on behind the scenes of a project, both in terms of paperwork and customer communication. It also allowed me to combine all of the skills I learned in other classes to complete a single definable project that I will be able to showcase for years to come.

Nicholas Sileu

Chesapeake, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I plan on becoming a robotics/automation engineer.

Class comment: I really enjoyed the task of working with real engineering companies to complete a complex project over the course of a year.

Mary Benden

Woodford, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: After graduation, I hope to work in electronic warfare or a related field. I would also like to work with embedded programming and software design, preferably for the Department of Defense.

Class comment: In this class, I learned that good communication and trust with your team is vital. I also learned that planning ahead, keeping an organized schedule, and always having a back-up plan is critical for success on any project, especially one this complicated.

PROJECT SPONSOR: THOMAS NEWHART

NAVAIR

Remote Monitoring Capability for Vacuum Gauge Tubes

CHALLENGE

We developed a Bluetooth converter module that can be mounted onto the newly released HVG-2020 vacuum gauge such that users can access and control the gauge wirelessly from a mobile device.

LEFT TO RIGHT: Joshua Hall, Brady Ingham | **SME:** Tim Talty

Brady Ingham

Centreville, Virginia

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: Following graduation I aspire to work in the space industry focusing on antennas and electromagnetics.

Class comment: This class was very beneficial in preparing me to work in a professional environment. It exposed me to many skills desired of electrical engineers in the workplace, both technical and non-technical, that are not traditionally taught in lecture-based classes.

Joshua Hall

Baltimore, Maryland

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: My goal is to work for NASA and to help make impactful discoveries that will further our scientific understanding of the universe.

Class comment: I learned valuable lessons on teamwork and how to deal with conflict in a professional manner.

PROJECT SPONSOR: DOUGLAS BAKER

TELEDYNE TECHNOLOGIES
Everywhereyoulook™

DIY Robotic Kit

CHALLENGE

We improved TI-RSLK by adding capabilities, such as GPS, distance sensors, speakers and microphone, IMU, modular connector, and robotic arm to existing hardware to meet current market trends.

LEFT TO RIGHT: Qingshuai Mao, Zachary Kaplan, Ashley Barclift, Zhuqing Zhao | **SME:** Peter Han

Ashley Barclift

Yorktown, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I will receive a commission into the Air Force as an electrical engineer after graduation and pursue a career in the power electronics industry after the military.

Class comment: I enjoyed getting to learn new hands-on skills that are not taught in lectures.

Robert (Qingshuai) Mao

Wenling, Zhejiang, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I am planning to go to graduate school to study robotics systems. I also want to pursue a career in robotics.

Class comment: The experience with teamwork was very useful. I also appreciated the professional guidance and experience.

Zachary Kaplan

Richmond, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I want to continue my career as an engineer focusing on Controls, Robotics and Autonomy and improve my project management skills.

Class comment: Through this process, I have improved my leadership and management skills. I also gained experience dealing with setbacks and learned to improve my customer service skills through communication.

Zhuqing Zhao

Jinan, Shandong, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to attend graduate school.

Class comment: I appreciated the opportunity to learn from professionals.

PROJECT SPONSOR: MARK EASLEY

TEXAS INSTRUMENTS

Integrated Inertial Measurement Unit for Industrial Machinery

CHALLENGE

We designed and built an integrated inertial measurement unit that generates accurate pose estimates of an industrial crane by measuring and processing acceleration and angular velocity. The device should withstand various extremes in weather, shock, and durability.

LEFT TO RIGHT: Kevin Jacobson, Yichun Huang, Cody Bright | **SME:** Ryan Gerdes

Cody Bright

Mechanicsville, Virginia

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I want to work on projects in the communications field that will bring people closer together and improve lives around the world.

Class comment: I value the lessons learned from working with my teammates to solve a difficult, complex problem for a real customer.

Yichun Huang

Hangzhou, Zhejiang, China

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I will work in engineering design.

Class comment: I appreciated how nice and professional my group members were.

Kevin Jacobson

Charlottesville, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work in the telecommunication industry.

Class comment: I enjoyed the challenge of working in a group to solve a real world problem and I am grateful for the lessons I learned from this experience

PROJECT SPONSOR: MATT MANDROS, THOMAS TAINER

TMEIC We drive industry

Heartbeat – Recording & Transmission Device

CHALLENGE

We designed a circuit and control software to record and transmit a heartbeat to medical professionals for review and characterization.

LEFT TO RIGHT: Li Song, Ryan Golshahi, Matthew Gill, Bruno Saldana, Luyi Wang | **SME:** Jaime De La Ree

Li Song

Springfield, Virginia

Electrical Engineering

Aspirations: I aspire to use what I have learned at Virginia Tech and apply it to real-world problems while continuing to develop my professional and technical skills.

Class comment: I enjoyed working with a diligent team to develop solutions. This course closely emulated a work environment which has helped me prepare for my career.

Bruno Saldana

Lima, Peru

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to improve military technology and help our troops do their job in a more efficient manner.

Class comment: I truly enjoyed the real-world experience that this class offered. Meeting deadlines, working with teams, recognizing skills from your own teammates and having meetings with customers are some of the things I will encounter in the real world, and I'm glad that I got to experience them in this class.

Luyi Wang

Guangzhou, Guangdong, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to apply what I have learned to projects that will serve humanity.

Class comment: This class gave me an opportunity to learn how to cooperate with a team. This class also helped me apply my knowledge to real-life problems.

Matthew Gill

Alexandria, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan on continuing my career at Epic Systems as an Epic Server Systems Engineer. In the future, I want to continue using my skills to make an impact on individuals through the advancement of the health care industry.

Class comment: I appreciate the leadership skills and planning required to be successful in this type of work environment. It has helped me see that not everything in the industry can be as black and white as it seems, and that dealing with uncertainty is a constant.

Ryan Golshahi

Dunn Loring, Virginia

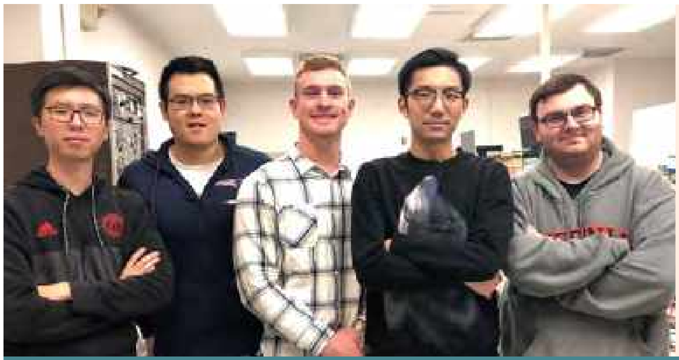
Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to apply my math and scientific knowledge to help oversee and solve specific business and technological problems.

Class comment: I appreciate the effort put into preparing students to succeed after graduation by exposing them to challenges they may face throughout their career.

PROJECT SPONSOR: JAIME DE LA REE

International Future Energy Challenge



CHALLENGE

We designed a power supply that draws power from a solar array and provides power to various loads. The supply can charge/discharge a battery bank and meets specified size, efficiency and cooling restrictions.

LEFT TO RIGHT: Jinrui Zhang, Linxuan Zhou, Ryan Nickerson, Mian Liao, Thomas Muglia | **SME:** Jih-Sheng (Jason) Lai

Jinrui Zhang

Shenzhen, Guangdong, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to work as a power engineer in the field of power electronics.

Class comment: I appreciated the support from our ECE department, especially the support from our SME and mentor, which was essential for this project to come alive. The course lets us apply the skills we learned over the course of our undergraduate education here at Virginia Tech.

Linxuan Zhou

Charlottesville, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I am pursuing a career in power electronics and power systems. I gained a lot of valuable experiences through the Wind Turbine Team and Energy Challenge.

Class comment: I really gained a lot of knowledge taking ECE 4205 Electric Circuit Design by working on lots of real-life power electronics and analog circuit design problems.

VT ECE Future Energy Challenge Team was selected in the Top 10, and chosen to move on to the final competition in Denmark in November.

Mian Liao

Zhenjiang, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to be a professor in the area of power electronics after I earn a Ph.D.

Class comment: This class helped me learn to organize a group to do research. I have learned both research and communication skills.

Ryan Nickerson

Wall, New Jersey

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I hope to continue my development as an electrical engineer by working in the rapidly growing aerospace industry.

Class comment: I'm grateful for the close bonds my team members and I formed.

Thomas Muglia

Bridgewater, New Jersey

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to work on public sector engineering projects centered around power engineering work needed for transportation projects.

Class comment: The ability to design and build a device using professional tools, software, and best practices, has been vital to my professional development.

PROJECT SPONSOR: JIH-SHENG (JASON) LAI

Lincoln Head Cherry Picker

CHALLENGE

We designed, built, and tested an all-inclusive coin imaging and sorting system that has the image processing capabilities to identify and grade high-value Lincoln wheat cents.

LEFT TO RIGHT: Sumved Ravi, Mika Murphy, Jonathan Hawes, Ramzy Hudson | **SME:** Creed Jones

Jonathan Carter Hawes

Ashburn, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to work with power electronics and power systems, ideally within the context of the renewable energy industry. Later, I would like to leverage that expertise to move into a systems engineering or technical leadership role.

Class comment: I appreciated the opportunity to learn and challenge myself by working in a field that I had no prior experience with—image processing and computer vision.

Mika L. Murphy

Cherry Hill, New Jersey

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I hope to go into the field of robotics and eventually earn a master's degree in electrical engineering.

Class comment: I gained hands-on experience applying what I have learned over the course of my education and solved challenges along the way. The experience working in a professional setting with a team had a large impact on my understanding of real-world issues outside the classroom setting.

Ramzy Hudson

Chesterfield, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to learn more about power creation and distribution.

Class comment: I enjoyed the opportunity to solve a novel problem by applying both what I have already learned and what I learned over the course of the project.

Sumved Ravi

Aldie, Virginia

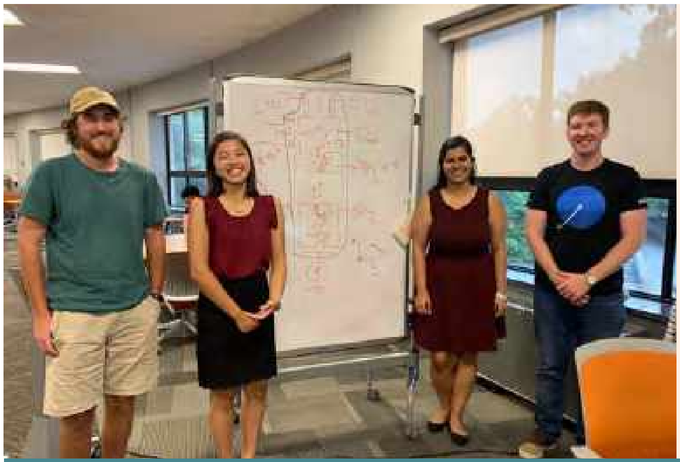
Bachelor of Science in Computer Engineering

Aspirations: I would like to help advance the fields of autonomous driving and virtual reality through computer vision and machine learning.

Class comment: The class has provided valuable insight into customer-client interactions as well as practical experience with communication and documentation.

PROJECT SPONSOR: LUKE LESTER

Nano-Satellite Instrument



CHALLENGE

We created a 1U CubeSat that can characterize neutral particle density in Low Earth Orbit (LEO). The electrical subsystems assist in the construction of an I-V curve that models the neutral particle density of LEO orbits to be used in flight planning for future spacecraft missions. The Ram Energy Distribution Detector (REDD) senior design goal is to provide the voltage biasing circuitry necessary to power the various CubeSat subsystems, develop a method to isolate the neutral particles of interest from the space environment, and provide a means to transfer the generated I-V data to an onboard flight computer.

LEFT TO RIGHT: Tyler Krochmalny, Havy Pham, Riya Sareen, Kristofer Stone | **SME:** Gregory Earle, Riya Sareen

Havy Pham

Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I would like to work in the space industry after I graduate, apply the knowledge I learned in my classes to my job, and learn new things about the industry. After I retire from industry, I would like to go back to academia and teach the next generation of STEM majors.

Class comment: I appreciate the opportunity to learn how to work with an outside organization. The project was spaced out through the year, so it never felt as though we were rushing to meet deadlines.

Kristofer Bryant Stone

Charlottesville, Virginia

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I will be starting full-time at Boeing Satellite Systems in El Segundo, CA. I plan to continue my summer internship work on the O3b communications satellite constellation to bring the internet to those who are less fortunate than myself across Africa and the Middle-East!

Class comment: This class has allowed me the opportunity to add to my design experience gained from industry internships by designing actual hardware and applying embedded system design fundamentals to a functioning satellite system.

Riya Sareen

New Delhi, India

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I want to work in the space electronics industry, specifically in the spacecraft instrumentation area.

Class comment: I appreciate the industry experience I got from this class. It introduced us to the more managerial aspect of engineering, such as reporting, cost analysis, etc.

Tyler Krochmalny

Gainesville, Virginia

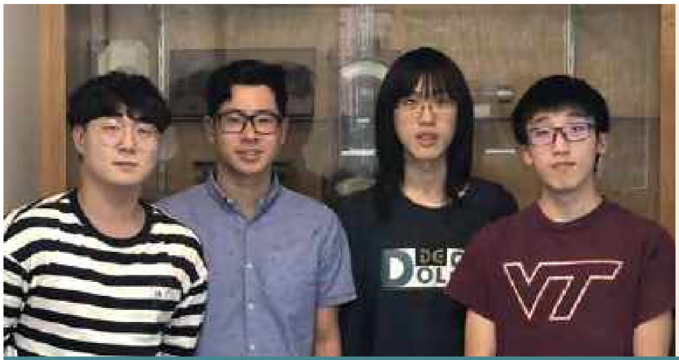
Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I would like to start a long-term career with a reputable organization.

Class comment: The class was useful as an introduction to an iterative design process.

PROJECT SPONSOR: GREGORY EARLE, RIYA SAREEN

Power Device Tester



CHALLENGE

We developed a power electronics device tester capable of testing the reliability of a device with a double pulse test and an unclamped inductive switching and short circuit withstand capability test.

LEFT TO RIGHT: Taehyeong Kim, Haoshen Yang, Zhengrui Wang, Keyue Shan | **SME:** Yuhao Zhang

Haoshen Yang

Guangzhou, Guangdong, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I am looking for a position that will allow me to apply my knowledge about power electronics system to developing and improving real-life technologies, such as EV cars.

Class comment: This class allowed me to apply my knowledge from previous courses and learn more about power electronics devices and systems.

Keyue Shan

Urumqi, Xinjiang, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to study in-depth how to further increase the efficiency, power density, reliability, and functionality of power electronics.

Class comment: Senior Design gives us experience that is so unique. It introduces us to the real problem-solving process starting from doing research (reading datasheets and theses) to soldering and testing. I especially appreciate the opportunity that the power device tester project gave me to learn to use Altium Designer. It will be extremely helpful in my future career when I am drawing PCB.

Taehyeong Kim

Ulsan, South Korea

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work on semiconductors and exploitation.

Class comment: What I most appreciated was getting to work on semiconductor design and testing.

Zhengrui Wang

Beijing, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to become an expert in a field.

Class comment: This class gave me the opportunity to learn useful skills in real-word circuit designing, and to talk to an expert in the field.

PROJECT SPONSOR: YUHAO ZHANG

Advanced Metering Infrastructure (AMI)

CHALLENGE

We provided a recommendation as to whether VT Electric Services (VTES) should implement an AMI metering system in their service territory using established research and perspectives from surrounding utilities.

LEFT TO RIGHT: Austin Morris, Jose Rosa Alicea, Abdulrahman Almulhem, Daniel Webb, Ryan Edwards | **SME:** Virgilio Centeno

Abdulrahman Almulhem

Dammam, Saudi Arabia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I aspire to be a leading engineer in designing infrastructure for renewable energy sources.

Class comment: Through this course, I enhanced my communication skills by interacting with my team members and mentors. It was a first step to my professional life, in which group projects and design teams will play a prominent role.

Austin Morris

Elkton, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I plan to continue my professional development by working as an electrical contractor providing a range of services such as industrial and commercial construction and SCADA development and integration.

Class comment: This class taught me how to schedule meetings.

Daniel Webb

Vinton, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I hope to become a power engineer and work on modernizing the electric grid and integrating new sustainable technologies that will benefit generations to come.

Class comment: I enjoyed learning more about AMI technologies and doing work that will likely affect the entire Blacksburg community in future years.

Jose R. Rosa Alicea

Caguas, Puerto Rico

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I would like to get a challenging position that will allow me to continue learning and expand my skillset while making a difference and a positive impact on society.

Class comment: The course gives us experience in an industry setting coordinating with engineers, customers, a SME, vendors, and other personnel to accomplish a task.

Ryan Edwards

Amelia, Virginia

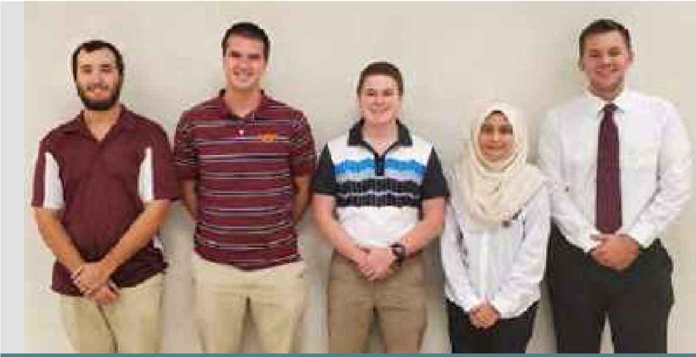
Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to be an electrical engineer at an electric energy distribution cooperative.

Class comment: In this class I learned how to schedule and coordinate meetings with people in industry.

PROJECT SPONSOR: ROB GLENN

VT Facilities – SCADA



CHALLENGE

Virginia Tech Electrical Services (VTES) is looking to expand its Supervisory Control and Data Acquisition (SCADA) system with an emphasis on cyber-security. Our team recommended upgrades that will improve reliability, restoration of service times, and other data monitoring that benefits VTES' operations.

LEFT TO RIGHT: Hayden Mabalot, Alexander Ford, Bradley Snyder, Wan Nur Liyana Wan Halim, Colton Stump | **SME:** Chen-Ching Liu

Alexander Ford

Roanoke, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: Upon graduation, I will begin a career in electrical power distribution.

Class comment: I enjoyed the interactions the team had with the customer, SME and mentor. I believe it gave us a small taste of what work in the real-world will be like.

Bradley Snyder

Dumfries, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I will work with others to build meaningful products and continue learning new skills and knowledge.

Class comment: I appreciated the opportunity to gain professional experience working for a customer that would benefit from our work.

Colton Stump

Chesterfield, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I am very interested in the development and implementation of the proposed smart grid. I'd also like to work with renewable and sustainable energy production and distribution.

Class comment: I appreciated the opportunity to work with a client who was able to share real-world experiences and lessons over the course of these past two semesters.

Hayden Mabalot

Pungoteague, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to make a positive impact on the world after I graduate.

Class comment: I really appreciated working closely with our customer and learning more about teamwork with the "SCADAculous" team.

Wan Nur Liyana Wan Halim

Bayan Lepas, Malaysia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I hope to be able to apply what I learned and experienced at Virginia Tech on my journey as an electrical engineer.

Class comment: This course introduced me to a real-world problem and allowed me to apply my knowledge to solve it with guidance from professionals in the field.

PROJECT SPONSOR: ROB GLENN

Magnetic Suspension System – Alpha

CHALLENGE

We created a suspension system with multiple solenoids that has a creative design and levitates an object.

LEFT TO RIGHT: John Garmon, Heyan Sun, Chase Murphy, Robert Crnkovich | **SME:** Dan Sable

John Garmon

Centreville, VA, USA

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave Engineering

Bachelor of Science in Physics

Math Minor

Aspirations: I am going to Yale University as a Ph.D. student in Physics specializing in experimental quantum computing. I love teaching, and hope to one day become a professor and come back to Virginia Tech.

Class comment: I appreciated the out of class bonding with my classmates and learning to work as a team.

Chase Murphy

Danville, Virginia

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I would like to work in the defense industry, get an M.B.A., and move into management.

Class comment: I enjoyed getting experience with the non-technical aspects of engineering through this class. Learning to write professional reports, understand deadlines, and manage budgets will help me a lot in my future career and is not something I have been exposed to before.

Heyan Sun

Hangzhou, Zhejiang, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to make this world more enjoyable.

Class comment: This class helped me prepare for a career in the workplace of the future.

Robert Crnkovich

McLean, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to apply my intellect in practical ways to better my family, my country and humanity. In the near future I will do this by working with power converters at VPT.

Class comment: I appreciate being forced to work on a project from start to finish. It has been a blast and a terrific learning experience.

PROJECT SPONSOR: MATT STREHLE

Power Your Critical Mission Today

Magnetic Suspension System - Beta

CHALLENGE

We designed and demonstrated a magnetic suspension system using multiple electro-magnets to allow a user to move a levitated object horizontally while suspending it vertically.

LEFT TO RIGHT: Matt Nicklas, Maggie Garrity, Zhengming Hou, Nhi Bui | **SME:** Dan Sable

Maggie Garrity

Titusville, New Jersey

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to have a positive impact on the future of power electronics while expanding my knowledge and earning a higher degree.

Class comment: I appreciated the two-semester timeline that gave us the chance to go more in-depth in the project and experience and understand the changes in team dynamics that occur over longer periods of time.

Matt Nicklas

Vienna, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I am looking to pursue a career in power electronics in the defense industry.

Class comment: I appreciated the opportunity to work with industry professionals on a project with practical applications in the real world.

Nhi Bui

Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to apply my knowledge and experience in electrical engineering and develop products that are useful to the society.

Class comment: This class allowed me to gain real hands-on experience, as well as technical and communication skills, by working on a project in a team setting. It provides a good start for young engineers to experience the industry world.

Zhengming Hou

Wuxi, Jiangsu, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to become a great power electronics engineer specializing in electric vehicles.

Class comment: I appreciate the chance to work on amazing projects.

PROJECT SPONSOR: CHRIS MECKA

VPT
Power Your Critical Mission Today

Magnetic Suspension System – Gamma

CHALLENGE

We designed, built, and tested a stable magnetic levitation system that can suspend a magnet and move it vertically and horizontally using both analog and digital control circuitry.

LEFT TO RIGHT: Samuel Washburn, Renad Bougis, Isaias Noda | **SME:** Dan Sable

Isaias Noda

Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After graduation, I plan on pursuing a career in power electronics with a focus on clean energy.

Class comment: This class helped me to experience what it means to be an engineer in industry by solving a challenging problem with a team and interacting with a client.

Renad Bougis

Makkah, Saudi Arabia

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I aspire to use my electrical engineering knowledge to develop biomedical devices and bio sensors.

Class comment: This class gave us the chance to apply our coursework to solve a real-life engineering problem. I appreciated the professional guidance we had throughout the year that helped us achieve our goal.

Samuel Washburn

Poquoson, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to work for an engineering company in which I can develop my technical skills and collaborate with other engineers. One day, I would like to start my own engineering company.

Class comment: I learned how to independently brainstorm and implement a solution to a problem that my team and I were confronted with. This was stressful at first but highly valuable.

PROJECT SPONSOR: CAMPBELL LOWE

VPT
Power Your Critical Mission Today

Zero Energy Data Center

CHALLENGE

We designed the electrical distribution and infrastructure for a data center in Lynchburg, Virginia with the goal of achieving near net zero energy consumption and six nines electrical availability.

LEFT TO RIGHT: Jack Langford, Nicholas Luca, Paul Benedict, Gareth Li, Connor Kerr | **SME:** Jaime De La Ree

Jack Langford

Great Falls, VA

Bachelor of Science in Electrical Engineering

Aspirations: I will be working for NAVAIR out of Pax River, MD and hope to continue in the aviation field in the future.

Class comment: I really enjoyed the real-world applications of the class and the insights it provided on the entire process of responding to a proposal.

Connor Kerr

Ashburn, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to work in the field of power engineering and eventually receive my professional engineering license in the field of power.

Class comment: This class has been a good steppingstone towards working in industry. We gained experience with aspects of working in the real world while still benefiting from the guidance of professors in the ECE department.

Gareth Li

Midlothian, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to support cleaner energy production through work in the field of renewable energy generation, integration, and development.

Class comment: The most meaningful aspect of this class was the opportunity to work with, and learn from, experienced professionals and mentors.

Nicholas Luca

West Chester, Pennsylvania

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work in the field of power systems to help protect the grid and find new sources of energy.

Class comment: This project gave me professional experience I wouldn't have received outside of an internship. Furthermore, due to the complexity of designing a data center, I have learned a lot of new information about power electronics that I will be able to apply in my career.

Paul Benedict

Christiansburg, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work for a company that designs green energy systems. This will make the world cleaner and energy more sustainable.

Class comment: I enjoyed the realistic work experience that this class offers. We got to work alongside real-world companies to gain real-world work experience.

PROJECT SPONSOR: WALT MENDENHAL, STEVE BOWMAN, MARK ADKINSON, DAN MORTON

Wiley|Wilson Constant Progress

Project Contributor Acknowledgements

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Greg Atkins
for developing an outstanding class website.

Mary Brewer, Nicole Gholston, Kimberly Johnston, JoAnna Lewis, Susan Broniak, Minerva Sanabria, Jamie De La Ree, Paul Plassmann, and Laura Villada
for setting up information sessions and guiding students into the class.

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Project posters

Linear Phased Antenna Array

Created by: Andrew Wilds, Griffin Fox, and Kevin Upton

Sponsor: Analog Devices

SME: Dr. Ellingson   Mentor: Mr. Schulz

Purpose

The ability to communicate while moving is crucial to many vehicles. When using wireless methods to send information, the signal must accurately point at its target to transmit data efficiently. While mechanical devices are capable of physically pointing the antenna, they are often to slow. Using a Linear Phased Antenna Array allows for near-instantaneous adjustments to signal direction and can be applied to many moving systems such as aircrafts. This is accomplished by changing the phase shift at each antenna input.

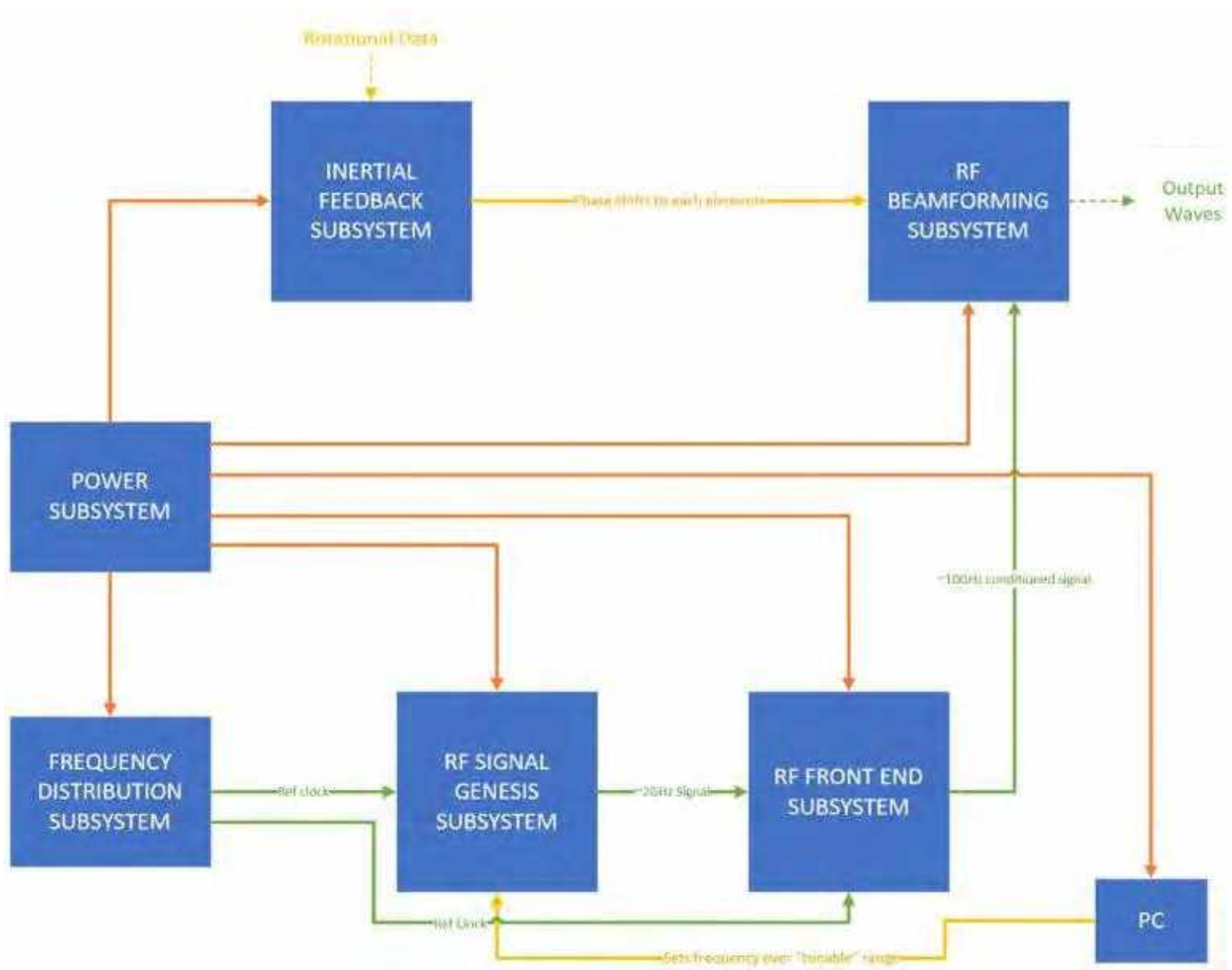
Another factor to consider in wireless data transmission is choosing a band of frequencies. As more people decide to use wireless communications, the more likely it is for signals at similar frequencies to interfere with one another. Therefore, it is necessary to choose unoccupied frequency bands to send data through. Given that more availability is found at higher frequencies, it is advantageous to send signals in the Gigahertz range.

Objectives

- Design an array of antennas to rapidly adjust the direction of the beam
- Design for the X-Band (8 to 12GHz)
- Beam direction adjustments will be based on platform rotation
- Utilize ADI parts to complete the system

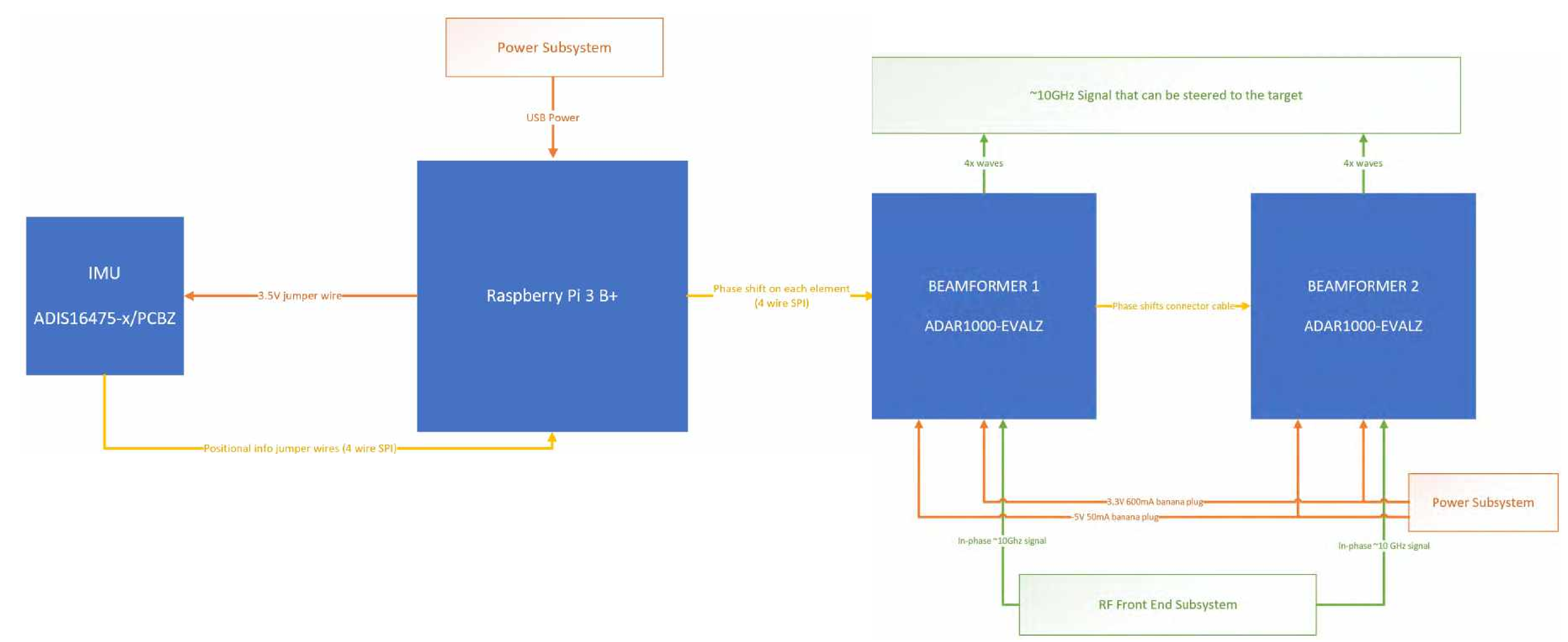
System Overview

- System is made up of six subsystems
- System senses the rotation and changes the direction of the beam
- The message signal is created by the system and processed to output at the desired frequency



Inertial Feedback to Beamforming Subsystems:

- The change in rotation (ΔΘ) is generated by the IMU
- That data is then summed to create a true heading (reset upon new target declaration)
- Pi converts the summed data to a phase shift to be passed on to the beamforming subsystem
- Phase shift is based on beamforming strategy



Beamforming Strategy

Based on isotopically radiating antennas

Standard wave equation: $I_n = A_n e^{j\alpha_n}$

Phase shift for each antenna base on distance: $\alpha_n = -\beta D_n \cos(\theta)$

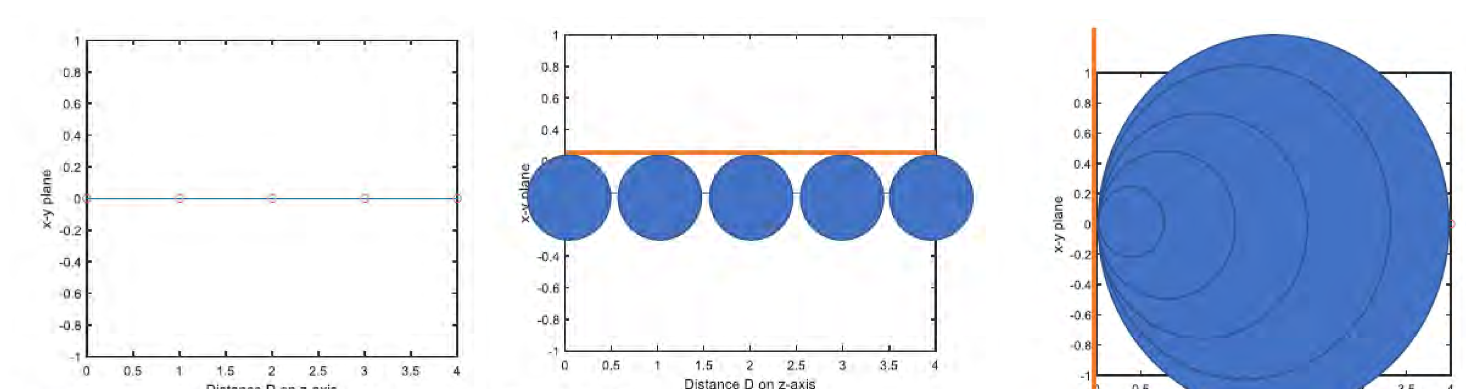


Figure 1: Antenna Array with Equal Spacing on Z-axis *Figure 2: θ is 90°* *Figure 3: θ is 0°*

Conclusions

With the given task, we were able to take a systems engineering approach to create a linear phased array antenna system. Physical implementation of the entire was not seen due to unforeseen circumstances of a nationwide quarantine. With the chosen products and written out methods of subsystem integration, this project could be further developed to achieve the intended goal. The Signal Genesis and Beamforming subsystems have been tested individually to prove their capabilities sufficient for the system specifications.

Within the Front End are two passive filters, that we could expect to not require extensive testing procedures. The Mixer and PLL would have a set factor for frequency multiplication, so once it was set accordingly it would not be expected to change. Going forward, our main task to complete would be creating software for the Raspberry Pi that could use values from the IMU to give the Beamformer commands for phase adjustment. This would be the missing piece for fully successful integration of our design.

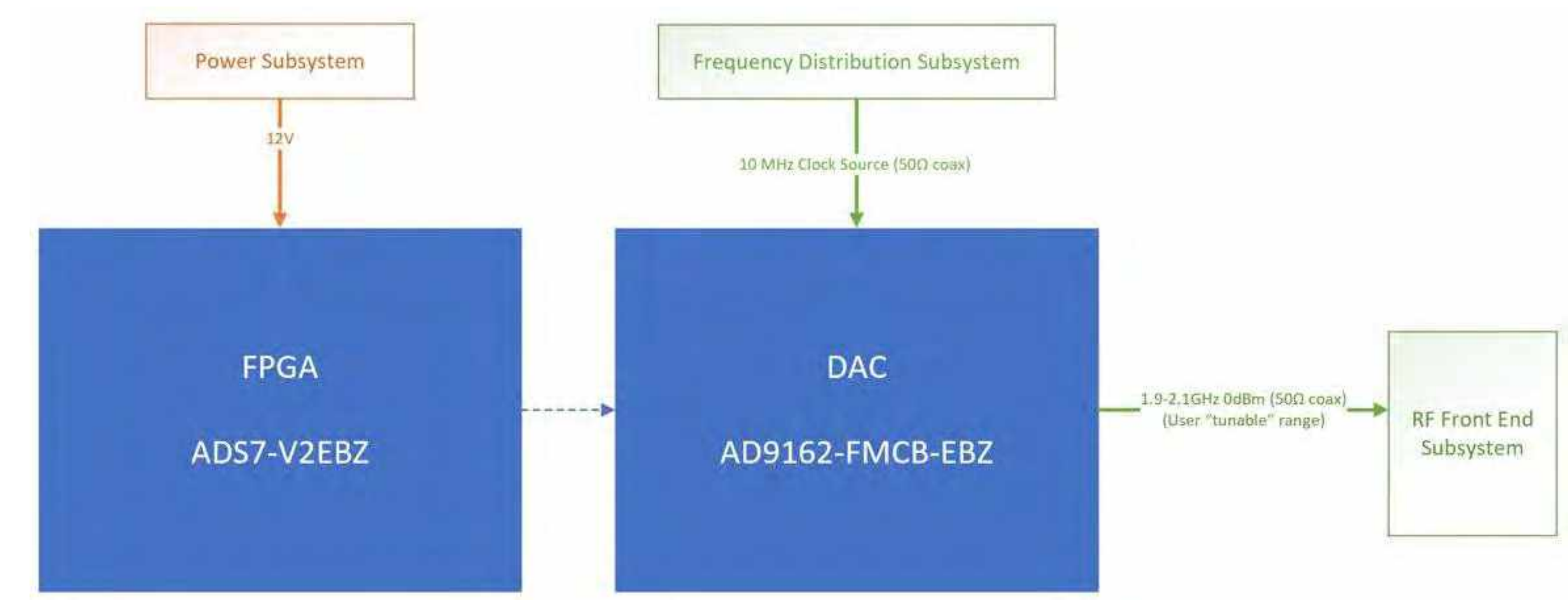
Acknowledgments

Array of Hope would like to thank Analog Devices and Virginia Tech for this design experience and provided equipment. Specifically, we would also like to mention our SME, Dr. Ellingson, our Mentor, Mr. Schulz, and our Customer Contact, Mike Jones. Thank you for the guidance and assistance during this project that allowed us to progress and learn.

Signal Genesis Subsystem

Purpose: Generate desired analog message signal between operating range (1.9-2.1GHz)

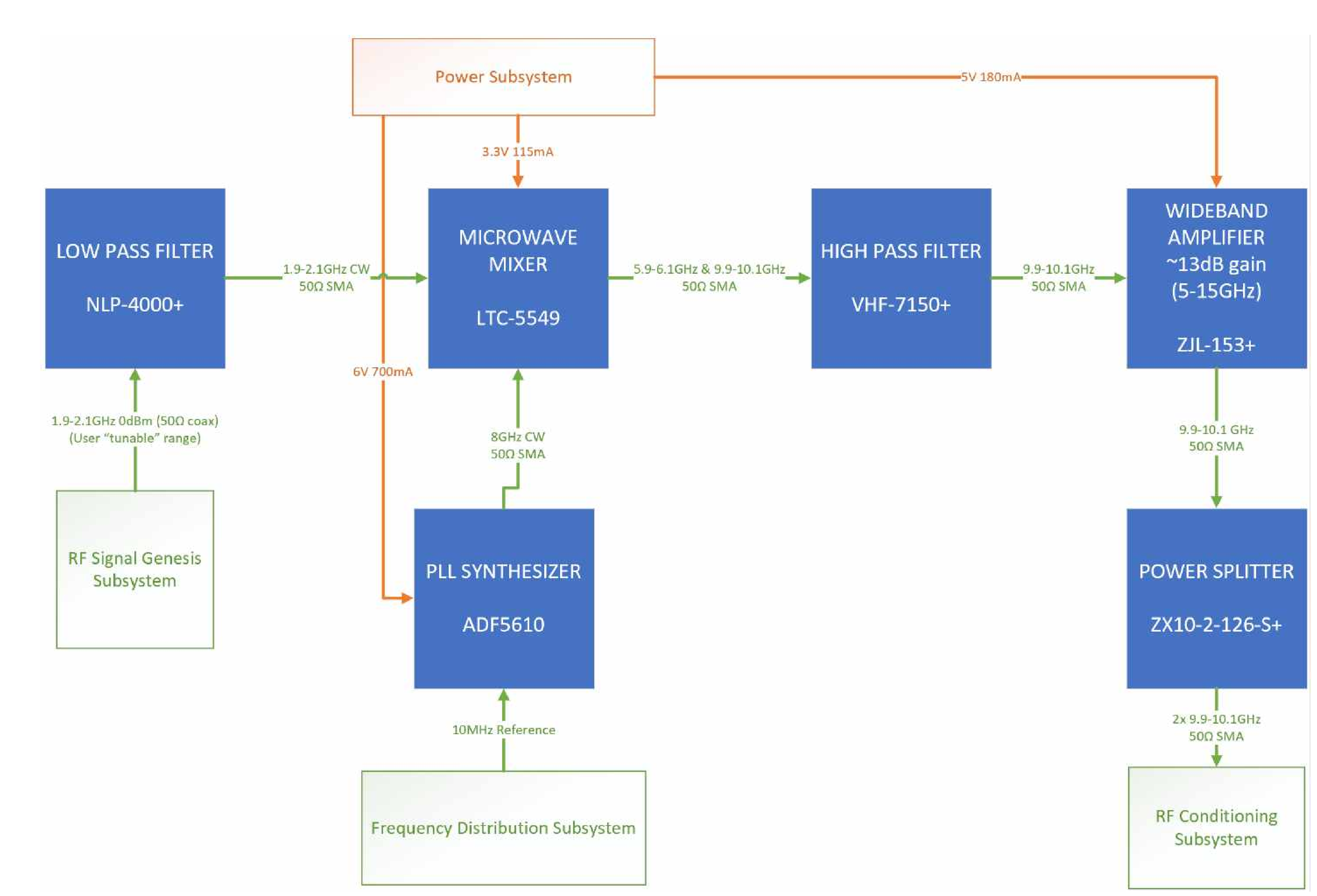
- The FPGA and DAC work together to produce desired message signal within the 1.9-2.1GHz operating range
  - Message Signal controlled by Analog Devices Software ACE and DPG Downloader.
- An onboard sampling clock within the DAC is set to 6 GHz, more than twice the highest frequency in our operating range (2.1GHz) to satisfy the Nyquist Sampling Theorem.
  - An external clock source is set to 10 MHz and is used as a reference clock for this subsystem and the Phase Locked Loop to keep the two sampling clocks coherent.



RF Front End Subsystem

Purpose: Convert Message Signal from 1.9-2.1GHz to 9.9GHz-10.1GHz by mixing the message signal with an 8GHz Sinusoid generated by a Phase Locked Loop Synthesizer.

- **Low Pass Filter:** Filter out the inevitable high frequency signals (>2.4GHz) in the message signal from the DAC above our desired 1.9-2.1GHz range
- **Microwave Mixer:** Convert message signal to 9.9-10.1GHz by mixing the message signal with an 8GHz sinusoid from a PLL Synthesizer.
- **PLL Synthesizer:** Generate 8GHz sinusoidal signal using a sample clock referenced to the same external 10MHz clock as the DAC.
- **High Pass Filter:** Filter out inevitable unwanted mixing products below the desired range of 9.9-10.1GHz
- **Wideband Amplifier:** Due to signal power loss in the cables and previous components, the signal power is increased by about 13dB to make sure the minimum power level is met to the beamformer.
- **Power Splitter:** The design requires two separate beamforming chips which each have an RF input, so a power splitter converts one signal into two coherent outputs.



Processing Algorithms for FPGA Hazard Avoidance

Team Members: Aidan Foley, Kelvin DeFeo, Baron Crooke **Customer:** Richard Berger, BAE Systems
SME: Dr. William Diehl **Mentor:** Prof. Gino Manzo

Objective

To create an algorithm capable of detecting hazardous items in the path of a moving object in real time by utilizing Field Programmable Gate Array (FPGA) technology.

Procedures

- Use sensor(s) to receive data about the surrounding environment and load images on to an FPGA circuit board
- Create image recognition and image processing software to single out all objects present
- Write a set of hazard avoidance algorithms capable of recognizing hazards in the image data and plotting a proper course to avoid obstacles

Materials

Pcam 5C **Zybo Z7-10**

We compiled programs on the Zybo-Z7-10 board from Digilent. The board hosts an all programmable system-on-chip architecture and an ARM Cortex A9 processor. Our sensor of choice was the Pcam 5C camera, a product from Digilent that is directly compatible with the Zybo-Z7-10.

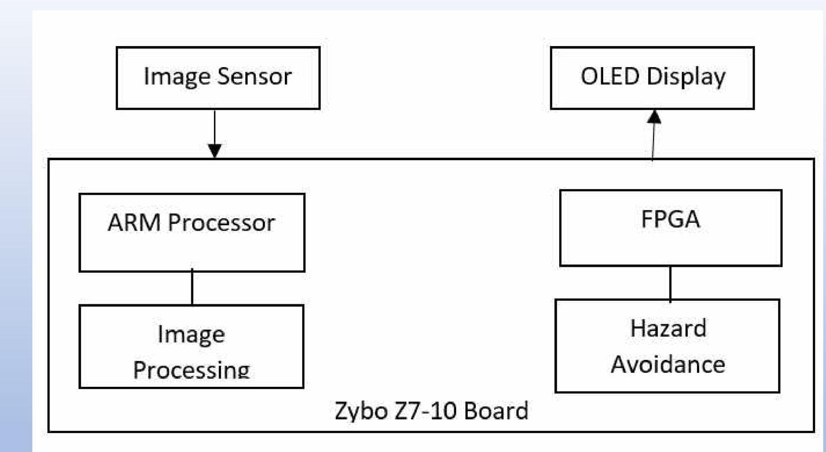


Figure 1: Project Layout

Shown here is a layout of how our project will function on our circuit board.

Hazard Avoidance

Proper hazard avoidance was accomplished by splitting up the processed image in to nine sections. White pixels are counted in each section and the section with the fewest number of white pixels is considered the safest route. These tasks were accomplished in C.

Image Processing

To break down images and determine the specific placement of objects, we wrote an image processing algorithm in C. The program would read in an image and, using edge detection, would transform all edges to white and everything else to black. This made objects more distinct and easier to detect.

Figure 2: A test image (left) put through the image processing code and outputted (right)

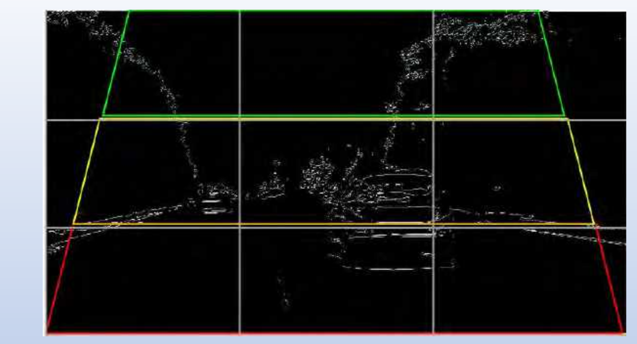


Figure 3: A processed image put through a 3x3 grid. Our hazard avoidance algorithm records the number of white pixels in each section to determine the optimal path.

Conclusion

In this project we have been able to interface a camera to an FPGA board, read in and manipulate images from the camera, created an image processing algorithm, and lastly created a hazard avoidance program able to determine the best path given presented hazards.

Future Plans

Due to time constraints as a result of COVID-19, we were unable to complete this project using FPGA. We would like to rewrite our current hazard avoidance algorithm using FPGA in order to reduce latency. We would also like to create multiple other kinds of hazard avoidance algorithms and cross compare algorithms to determine the absolute fastest way to process hazards.

Acknowledgements

We would like to thank the following people for their help on this project

- Richard Berger (Customer Point of Contact)
- Dr. Diehl (Technical Advisor)
- Professor Manzo (Class Advisor)

Controller for phased array of four 28.5 MHz antennas

Team Members: Jared Hoy, Cole Casteel, Dayton Engstrom, Nick Osborne

Customer: George Cooley **SME**: Dr. Majid Manteghi **Mentor**: Kenneth Schulz

Motivation

Consider a vertical antenna aligned with the z-axis as shown in fig. 1. This arrangement produces a radiation pattern that has a maximum intensity in all directions perpendicular to the antenna's length. This ensures a transmitted signal will propagate evenly in all directions horizontally from the antenna. A simple vertical antenna works fine for many applications involving radio transmission and reception, but there are times when a radio operator would like to focus their signal and transmit in only one direction.

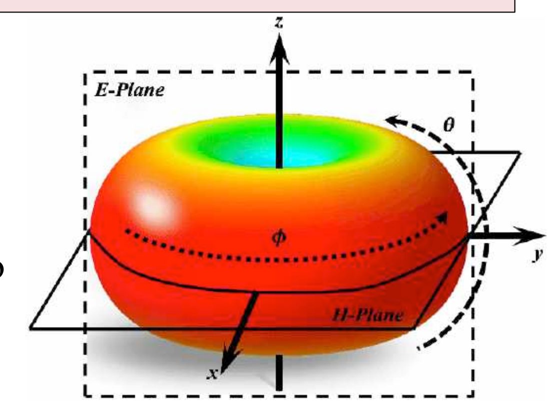


Fig. 1. Vertical antenna pattern

The most common way to focus a signal in a particular direction is to employ the use of a directional antenna. A directional antenna takes the energy that would normally be dispersed as in fig. 1 and focuses it which effectively increases the power density of the signal in one direction such as that shown in fig. 2.

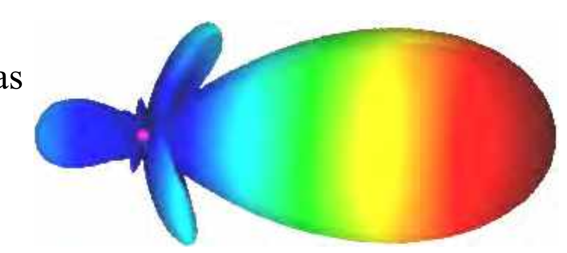
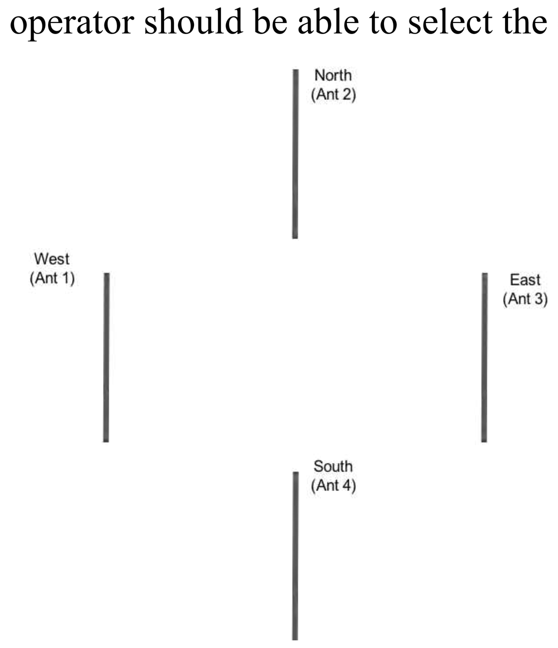


Fig. 2. Directional antenna pattern

At very high frequencies (VHF) and above directional antennas such as a Yagi, log period, or parabolic dish can be mechanically rotated to change the direction of the signal. Unfortunately, at lower frequencies such as HF (30MHz and below) antenna sizes can become too large and unwieldy to rotate mechanically. For this reason, another method of focusing a signal is needed below 30MHz.

Objectives

- Design a system that will allow a radio operator to automatically rotate the main beam of an RF transmitter by means of a phased array composed of 4 vertically polarized antennas arranged in a square pattern.
- Ensure the system is small and lightweight.
- Control the switching network by means of a low-cost microcontroller that is connected to a remote computer via a Bluetooth connection.
- Power the microcontroller and switching network by means of solar power and a battery.
- The operator should be able to select the direction of propagation based on the table in fig. 3 below.



Antenna element number		1	2	3	4
Direction of maximum gain	N	0°	-90°	0°	+90°
	E	+90°	0°	-90°	0°
	S	0°	+90°	0°	-90°
	W	-90°	0°	+90°	0°
	NE	0°	-90°	-90°	0°
	SE	0°	0°	-90°	-90°
	SW	-90°	0°	0°	-90°
	NW	-90°	-90°	0°	0°
		Respective phase			

Fig. 3. Antenna configuration and phase shift required to achieve each direction

Method

A basic block diagram of the system was constructed which incorporates the anticipated components as shown in fig. 4. A transmitter provides RF power to the phase shifting network over coaxial cable. The phase shifting network delivers the necessary 0°, +90°, and -90° to their respective antennas by means of a relay network. The relays are switched by an Arduino which is powered by a rechargeable battery and solar panel. The radio operator controls the Arduino by means of a laptop via a Bluetooth connection. The laptop presents the user with a convenient and intuitive graphical user interface (GUI) which provides an option to select the desired direction of propagation.

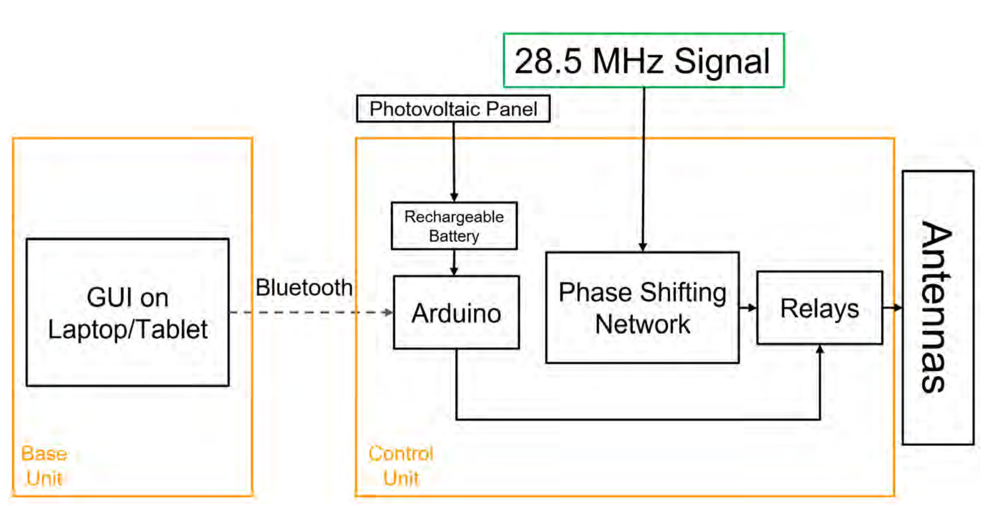


Fig. 4. Overall system layout / block diagram

Many different methods of phase shifting signals exist such as phase delay lines, LC networks, branchline couplers, coupled line quadrature couplers, Lange couplers, Schiffman phase shifters, and more [1]. Each of these designs has its merits and drawbacks, but the largest shortcoming was the size and weight associated with each design when implemented at HF. These methods did not meet the criteria for a small and light weight system.

Design

The lumped element version of the coupled line quadrature coupler as shown in Fig. 5 and originally documented by Reed Fisher of Bell Labs was found to be a great option for implementing the phase shifter [2] [3] [4]. This version sacrifices bandwidth, but provides a smaller foot print while still being very simple and easy to implement.

The Reed Fisher coupler has the following traits:

- Equal power division among ports
- Phase shift is largely frequency independent
- Isolated port is very well decoupled
- Small and light weight
- Inexpensive and simple to manufacture
- An overall elegant solution

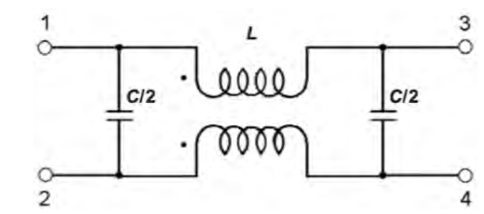


Fig. 5. Schematic of phase shifting network

$$L_1 = L_2 = \frac{Z_0}{2\pi f_c} \quad (1)$$

$$C_1 = C_2 = \frac{1}{4\pi f_c Z_0} \quad (2)$$

The Reed Fisher coupler provides a 0° and -90° phase shifted signal at ports 2 and 3 when port 1 is fed with RF energy. Port 4 is isolated into a dummy load having characteristic impedance Z_0 to absorb reflections caused by mismatches at ports 2 and 3. A +90° phase shift can also be realized with the addition of a phase inverting transformer. Fig. 6 shows the schematic of the phase shifting network designed to meet the phasing requirements of fig. 5. Equations 1 and 2 were used to find the values for L_1, L_2, C_1, and C_2.

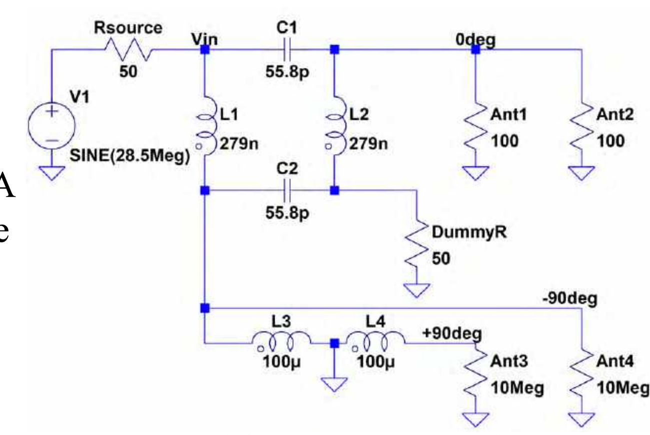


Fig. 6. Schematic of phase shifting network

The design also included a Darlington pair current amplifier to allow the Arduino to drive the relays' coils. The latching relays only draw power when switching, which reduces the load on the battery supply and solar generation as compared to traditional relays. The relay and solar cell used are shown in fig. 7.


Fig. 7. Latching relay and solar panel used in the design

A screenshot of the interface that the user employs to select their desired direction of propagation for the signal is shown in Fig. 8. The back-end of the program sends the selection to an Arduino in the control unit via Bluetooth communication. The Arduino then uses that information to activate the correct relays thereby sending the proper phase shift to each antenna. The GUI uses the logic illustrated by the flow diagram in fig. 9.

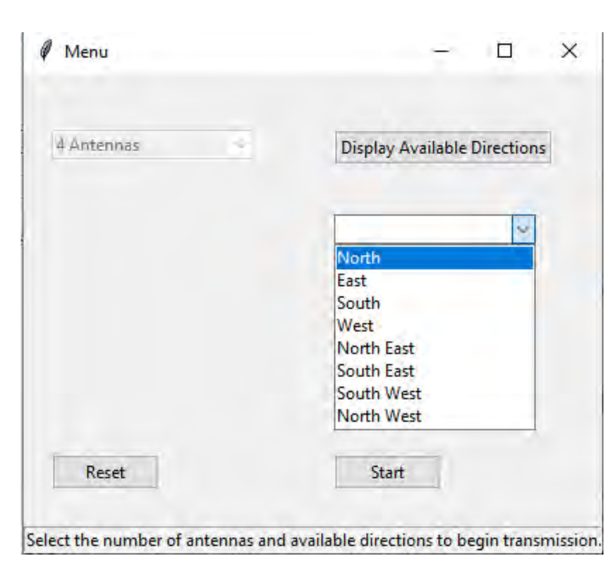


Fig. 8. A screenshot of the GUI to control the propagation direction

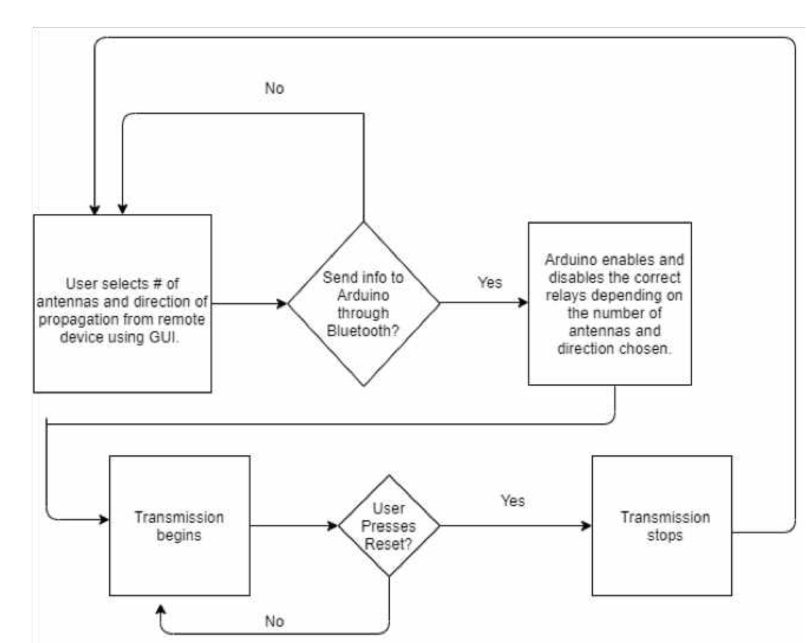


Fig. 9. Logic diagram for the GUI

Results

Fig. 10 shows the simulation results for the circuit as constructed in fig. 6. From this, it is clear that there is 90° of phase separation between the 0° port and both +/-90° ports of the phase shifter at 28.5 MHz as noted by the blue and red double ended arrows. The incoming power is also divided equally between the 4 antennas at this point. This helps to confirm what was already expected based on the literature.

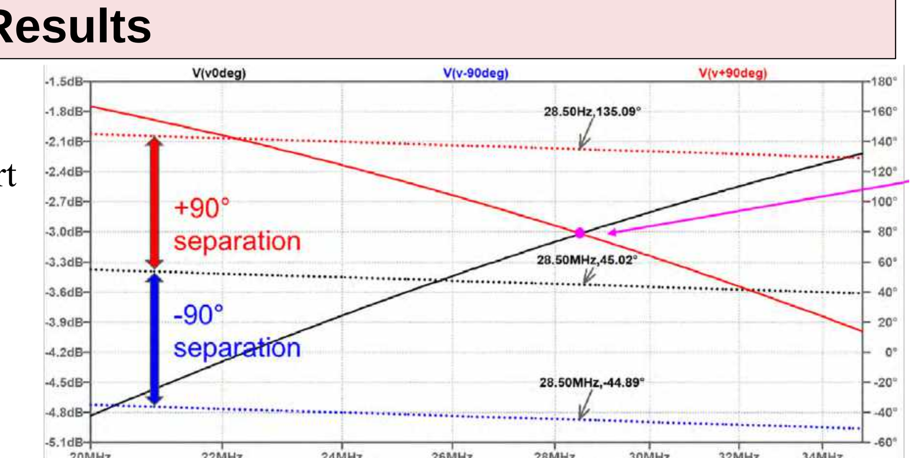


Fig. 10. Simulation results of the phase shift circuit


Fig. 11. Test setup with signal generator and oscilloscope

A preliminary test of the lumped element quadrature coupler was performed by feeding a test circuit with a signal generator as shown in fig. 11. Inspection of Fig. 12 indicates a phase shift of about 80° with a slight mismatch in the output amplitudes. This is likely due to excessive lead length on the prototyping board. Creating a properly constructed circuit board using microstrip traces should help to alleviate the problem associated with stray capacitance and inductance.

Fig. 12. Phase difference between the two output ports

Results Continued

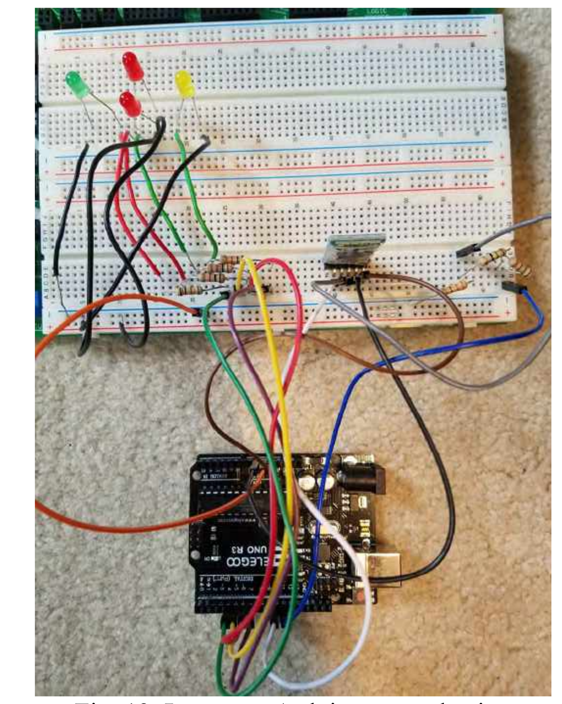


Fig. 13. Laptop to Arduino control using LEDs to simulate relay selection

A quick test of the GUI and Arduino functionality was performed by connecting the Arduino to it's Bluetooth module and a set of four LEDs (each representing the cardinal directions North, South, East, and West) as shown in fig. 13. Fig 14 demonstrates the selection of switches associated with a phasing pattern that would produce an eastwardly propagating radio signal. This test helped to ensure that the Python code on the laptop was able to successfully connect to and control the Arduino over Bluetooth. This also shows that the code in the Arduino was performing properly as well and providing enough power to illuminate the LEDs.

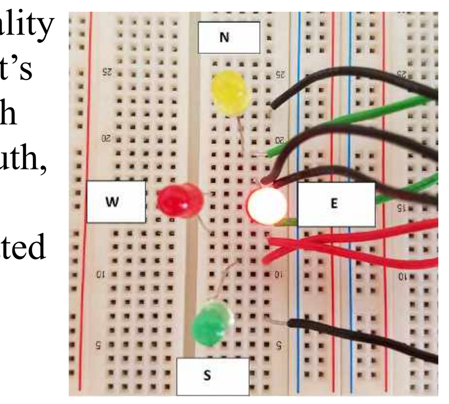


Fig. 14. LEDs simulating relay selection

KiCad was used to generate a full schematic incorporating the phase shifter, phase inverter, relay network, and relay power driver. Included in this schematic were test points and taps used to isolate certain parts of the circuit for testing and troubleshooting after cutting a PCB.

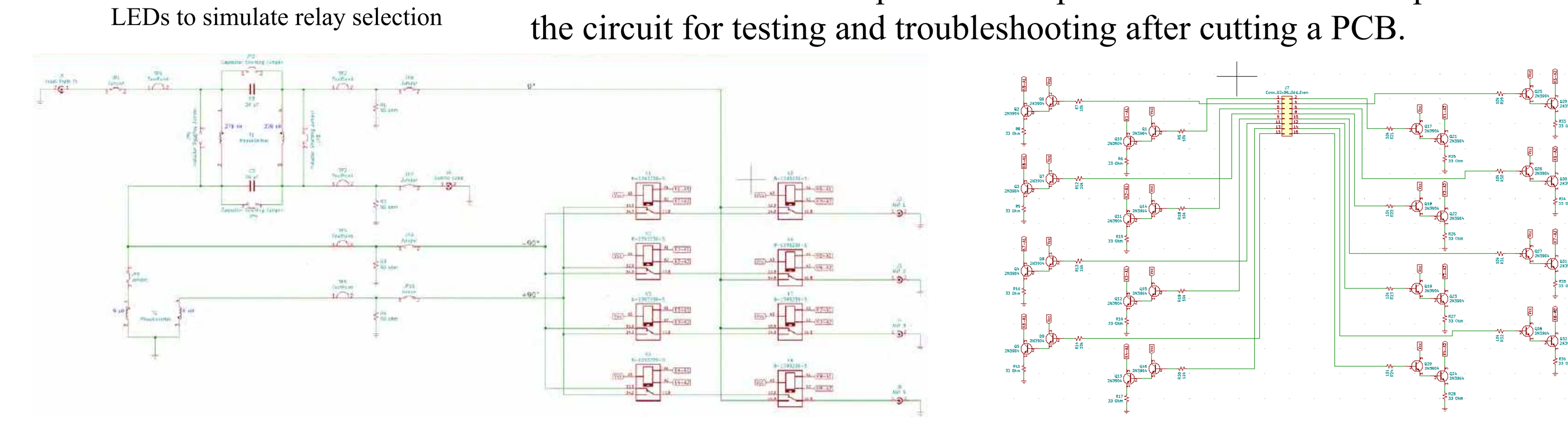


Fig. 15. Schematic of complete circuit

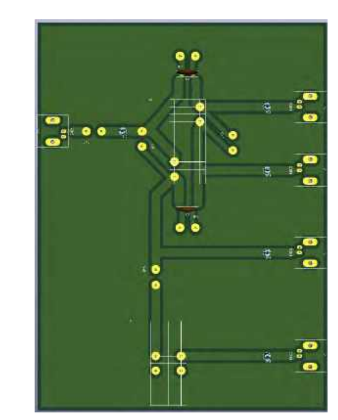


Fig. 16. 3D rendering of PCB implementing a test board (top view)

An earlier schematic was used to give generate a 3D model of the circuit board to give an indication of the size and trace routing as shown in fig. 16 and fig. 17. This was also helpful in identifying the placement of parts such as the toroids used to implement the phasing sections. Trace widths were taken into account to minimize skin effect losses while attempting to maintain the characteristic impedance of 50 ohms between trace and ground plane. Since high voltages can be developed between the traces, trace separation also had to be considered.

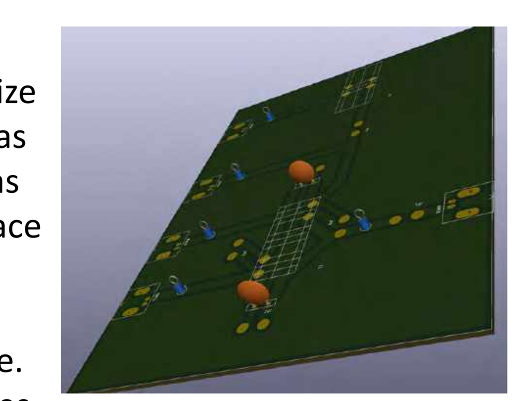


Fig. 17. 3D rendering of PCB implementing a test board (Oblique view)

Conclusions

Based on the initial simulation and test circuit results, we believe that a fully constructed circuit would perform the functions that are required.

- Preliminary results indicate that a physical implementation will phase shift the signal as needed albeit with a possible mismatch in output magnitude.
- Using a coupled line hybrid quadrature coupler in lumped element form will ensure a small and light weight package.
- Arduino tests with LED's used to simulate relays performed as expected ensuring the user can rotate the signal into the desired direction.

Acknowledgements

We would like to thank the following people for their support during this effort:

- Dr. Dennis Sweeney educated us on winding toroidal transformers
- Owen Davies from Amidon Corp suggested a toroidal material
- Randall Nealy provided valuable information and contacts
- Kevin Sterne lent us a 1kW transmitter for testing
- Ripun Phukan and CPES let us use their impedance analyzer
- Minh Ngo helped us evaluate our PCB traces for current handling capability
- Our SME, Mentor, and Customer for their continued support throughout the project

References

[1] D. Jorgesen, "Top 7 Ways to Create a Quadrature (90°) Phase Shift," 15 April 2015. [Online]. Available: https://www.markimicrowave.com/blog/top-7-ways-to-create-a- quadrature-90-phase-shift/. [Accessed 21 February 2020].

[2] R. E. Fisher, "Broad-Band Twisted-Wire Quadrature Hybrids (Short Papers)," *IEEE Transactions on Microwave Theory and Techniques,* vol. 21, no. 5, pp. 355 - 357, May 1973.

[3] R. E. Fisher, "Twisted-Wire Quadrature Hybrid Directional Couplers," *QST,* pp. 21 - 23, January 1978.

[4] G. Breed, "Transmission Line and Lumped Element Quadrature Couplers," November 2009. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.399.4579 &rep=rep1&type=pdf. [Accessed 19 October 2019].

Building a Signal Recorder for Aviation Transponders

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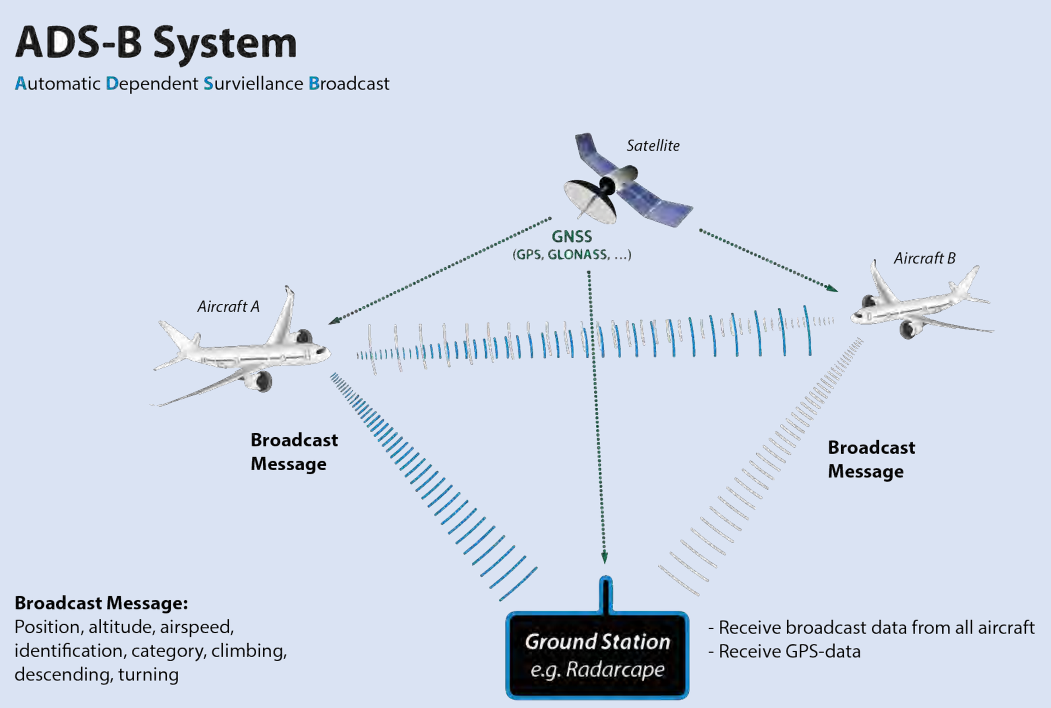
Safety System on Aircraft Manages Collision Avoidance

Air traffic within the United States is subject to many regulations by the federal government. Traffic is physically separated by type (commercial, recreational and military) by airspace and flight level, but it remains essential for all traffic to be able to communicate. Aviation communication is subject to a detailed set of regulations facilitating safe flight. By communicating position (latitude and longitude), altitude and heading, several integrated systems strive to mitigate the possibility of one flight path disrupting another. A phenomenon called wake turbulence disrupts air flow for up to a quarter mile radius of a commercial airliner, which creates a flying hazard, so there is significant calculation in preventing overlap of flight paths that could be dangerous or fatal. Current communications systems aid greatly in this pursuit and greatly help to keep the skies safe.

A primary mode of aviation communication is called Automatic Dependent Surveillance – Broadcast (ADS-B). ADS-B signals are radio signals transmitted to satellites, ground stations, and other aircraft to keep track of position and location. These signals are sent and received by transponders, which are standard in every aircraft control panel. The Aircraft Collision Avoidance System (ACAS) uses the information to calculate safe distances between aircraft and prompt rerouting accordingly. Therefore, transponders are critical hardware on any aircraft.

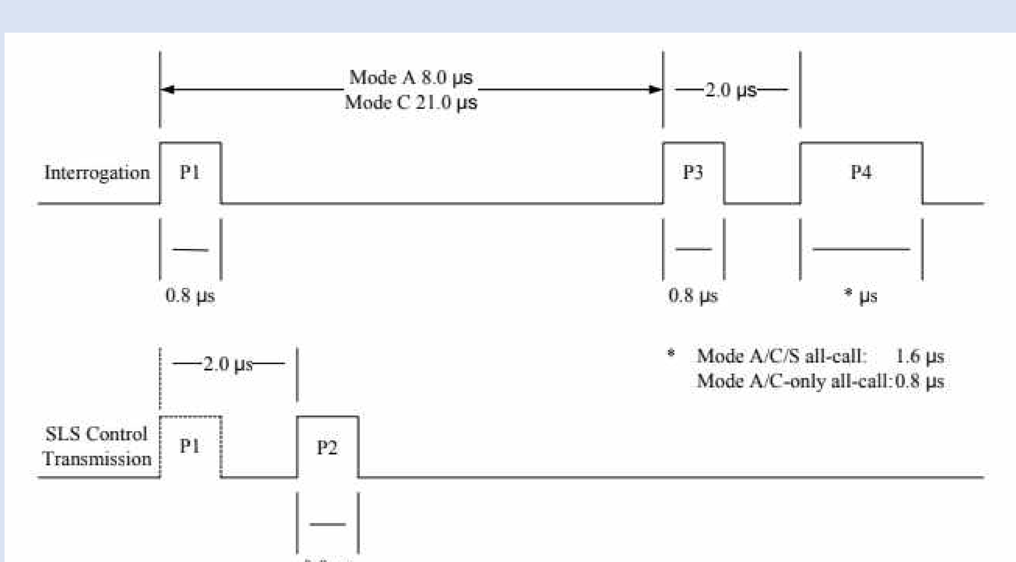


Collins Aerospace builds transponders for commercial airliners. For the Class of 2020 Major Design Experience in Virginia Tech's electrical engineering department, Collins sponsored a student-led project to aid in the testing of Collins transponders. The team created a design for a portable transponder signal environment capture and record unit. The device is placed in an overhead bin or closet in the forward part of the aircraft, is switched on easily by flight crew, captures the signals the transponder sends and receives during the flight, and is switched off post flight. It is designed to be portable and straightforward to operate.

Transponder Signal and Radio Frequency Environment

As of January 2020, all aircraft are required to produce an ADS-B out signal, allowing better tracking and integration of a complete in-flight environment. The transponders transmitting this signal operate in three modes: A, C, and S - which offer increasingly detailed information about the aircraft. Commercial airliners must use Mode S, the most sophisticated mode. Mode S uses either 56 or 112 bits, employs squitter (impulsively transmitted) messages to indicate location, altitude and heading, and is the basis for the ACAS system.

Mode S Pulse Amplitude Modulation Pattern Interrogation



The transponder signal environment operates over two frequencies. One frequency, 1030 MHz, has a maximum bandwidth of 4 MHz for radar beacon signals. The other frequency, 1090 MHz, is significantly narrower, with a maximum bandwidth of 50 kHz. Interrogation patterns send 500-1200 fifteen pulse replies per second in Mode S. Signal power alternates between classes of aircraft. Class 1 aircraft signals are transmitted at 125 Watts, and Class 2 aircraft transmit at 70 Watts. Commercial airliners are Class 1 aircraft.

Approach to System Design and Subsystem Integration

In the first step, the signal is received by standard quarter wave monopole antennae. The design allows for parallel reception on each frequency from two antennae, but it is possible to use the same antenna for both frequencies. They are close together, so the size of the wavelength is similar. (Wavelength and frequency have an inverse relation according to the equation **$c=v\lambda$**, where c is the speed of light, v represents frequency and λ represents wavelength.)

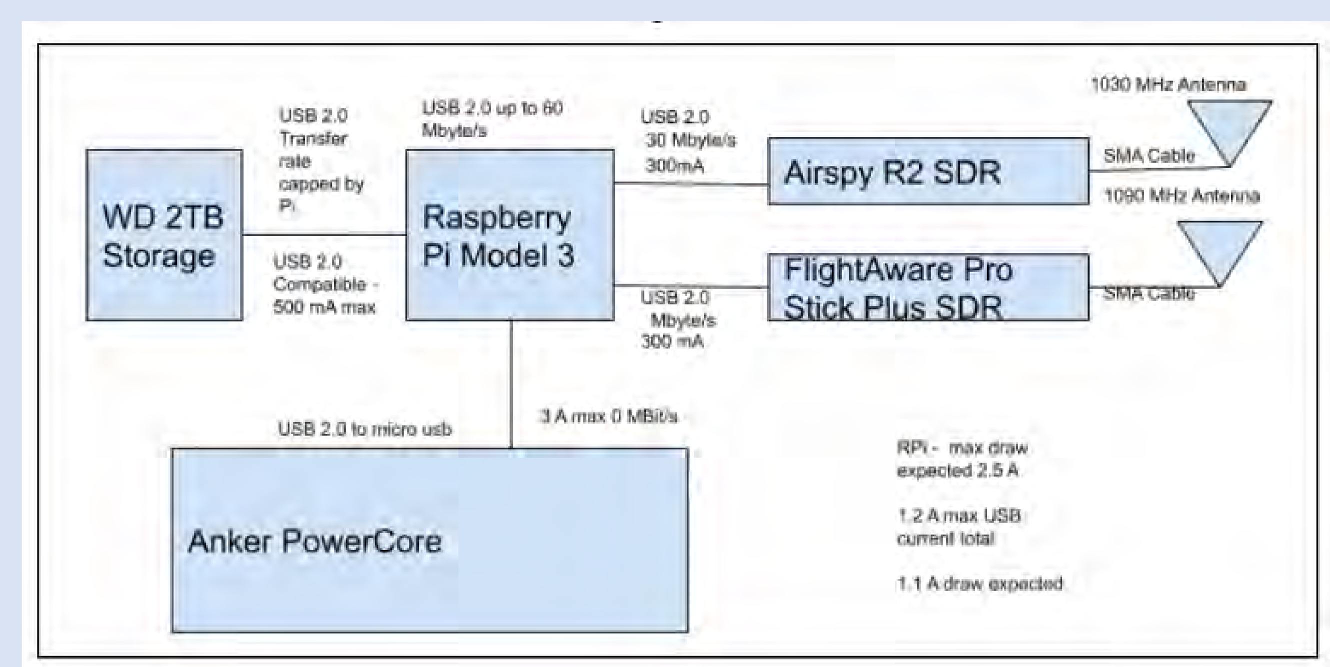
The antenna is connected via an N-type connector to two separate SDRs. Careful consideration was used in the selection of the SDRs. There was a cost to performance tradeoff which was optimized among a variety of commercially available options. Ultimately, the ideal option for the 1030 MHz frequency was an AirSpy SDR, while the best option for the 1090 MHz frequency was a FlightAware ProStick. The AirSpy is programmable to a variety of needs and allows for the greater bandwidth, while the ProStick is tailored to receive Mode S signals for ADS-B.

FlightAware ProStick SDR (Internal)

The SDRs connect via USB directly into a Raspberry Pi microcontroller. Raspberry Pi is a cost-effective way to implement the desired programs. It was necessary to install several programs and Python scripts on the Pi. These included a startup protocol (so that when the interface switch is flipped on, the program starts recording data), a program to capture the raw 1030 MHz data, and a program to capture and record data on the 1090 MHz bandwidth. The data is stored on a 2 TB hard drive.

Each component was analyzed for current draw and added into calculations for run time. Collins asked for a run time between 6 and 72 hours; this design implements a run time of over 24 hours.

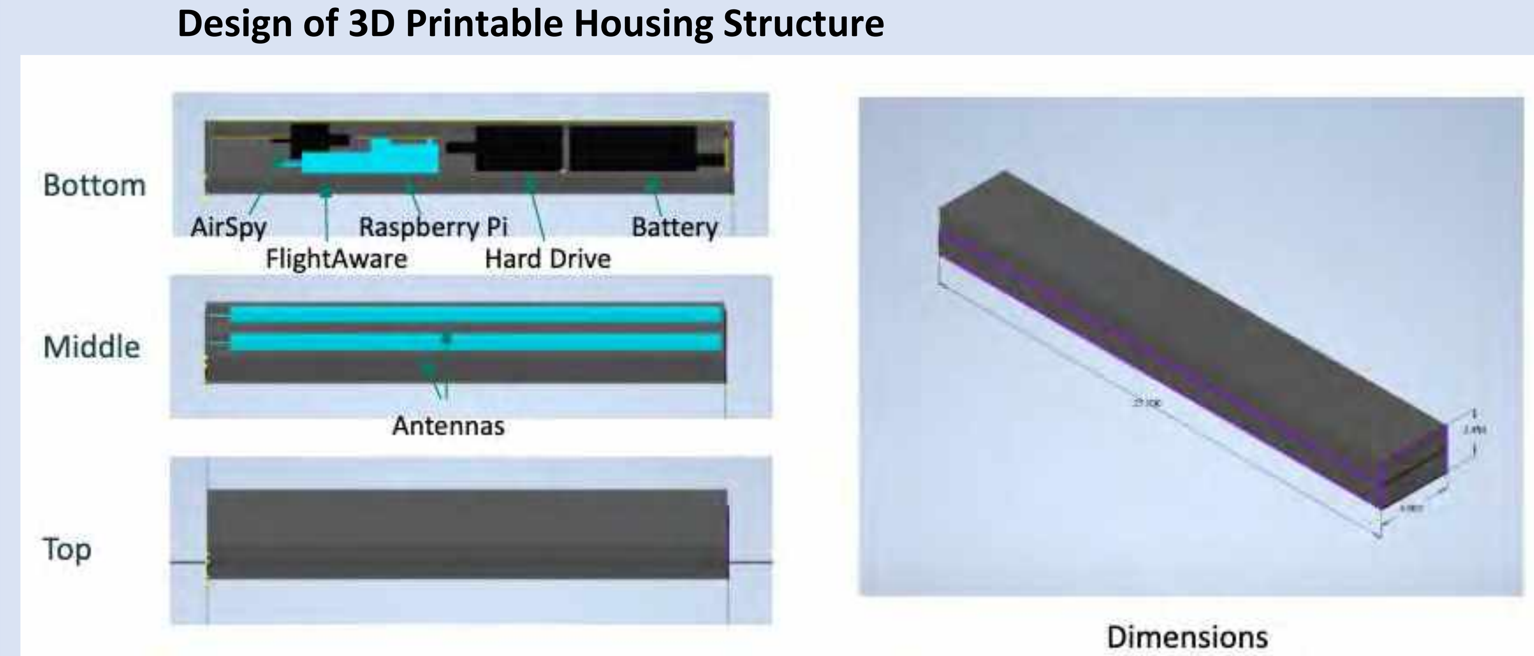
Model of System Requirements and Interface



3D Printable Housing Design for Minimal Interference

Assembling the components into a portable box is most practical with a customized housing case. Diimensions register around 27x4x2", leaving it steamlined enough to put into an overhead bin with ease. This graphic was CAD generated for a 3D printer. The sturdy plastic housing also eliminates the potential signal interference caused by a metal box.

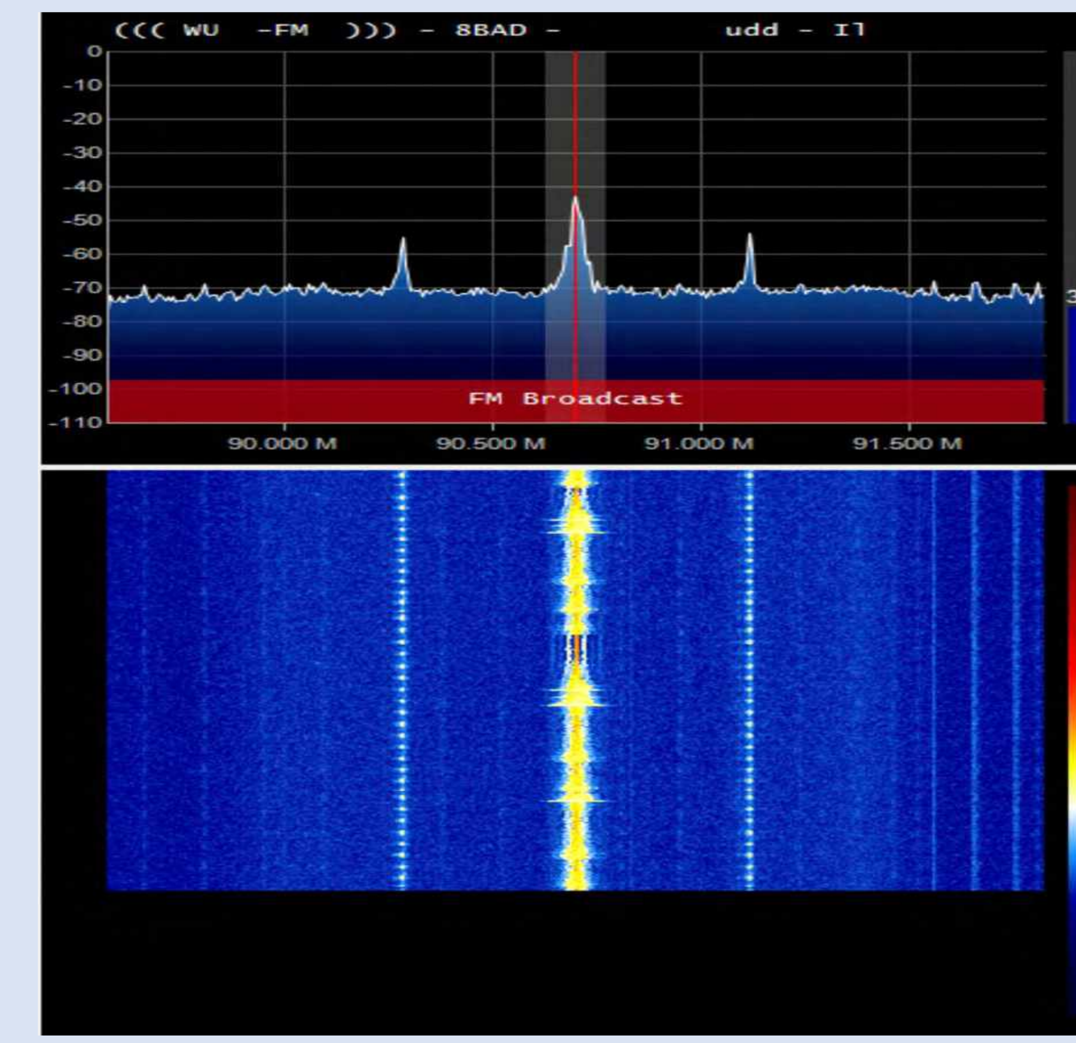
Design of 3D Printable Housing Structure



Signal Capture, Results and Analysis

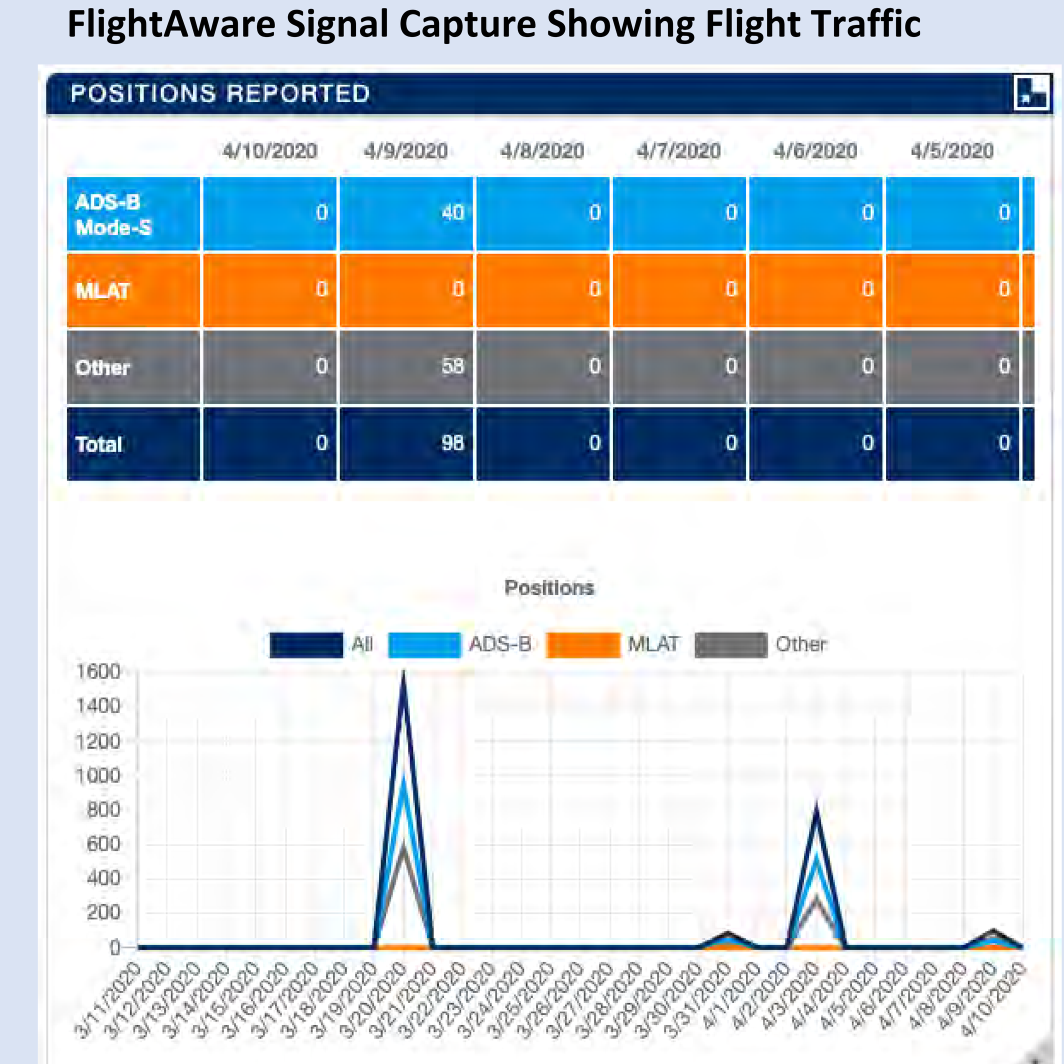
Ultimately the AirSpy signal was captured by writing a Python program for the Raspberry Pi. It was customized due to the frequency's wide bandwidth. The program was tested on an FM radio signal and gave the following waveform output, proving the utility of the program and signal capture.

FM Waveform Signal Capture on Raspberry Pi



Similarly, the ProStick signal was captured through FlightAware, logging hundreds of individual aircraft data in under a minute. It provided information on latitude and longitude, altitude, descent rate, and heading. The range of the signal is nearly 200 nautical miles. The greater aviation environment was also affected during this semester by a decrease in commercial airline traffic, and these signals will increase in future seasons.

FlightAware Signal Capture Showing Flight Traffic



	4/10/2020	4/9/2020	4/8/2020	4/7/2020	4/6/2020	4/5/2020
ADS-B Mode-S	0	40	0	0	0	0
MLAT	0	0	0	0	0	0
Other	0	58	0	0	0	0
Total	0	98	0	0	0	0

Final considerations in integration included sampling efficiency to mitigate draining the battery, but also avoid aliasing. Clock rate was also considered in the Pi programs, as the Pi runs at 600 MHz, while similar systems run at over 1 GHz. There is a trade off as overclocking improves performance but increases system volatility.

This project was sponsored by Collins Aerospace. The team wishes to thank Chris Gili, Joseph Gaeddert, Ken Schulz, and the Virginia Tech ECE Department.

Power Amplifier Test Controller

Team Members: Oluwademilade Alabi, Michael McGruther, Avery Neff
Customer: Jonathan Kolbrak SME: Peter Han

Motivation

Performing standard testing of radio frequency (RF) devices can be tedious and time consuming.

Our team set out to design and create a cost-effective automated test station controller using a Raspberry Pi and Python. The controller will automate testing of RF devices.

Objectives

- Focus on creating a scalable solution
  - Accommodate different electronic instrument manufacturers and models
  - Allow user to add and modify DUT tests
- Use modular code
  - Maintain independent modules for future customer modifications to source code

Hardware

Platform for test station controller: Raspberry Pi 2 Model B

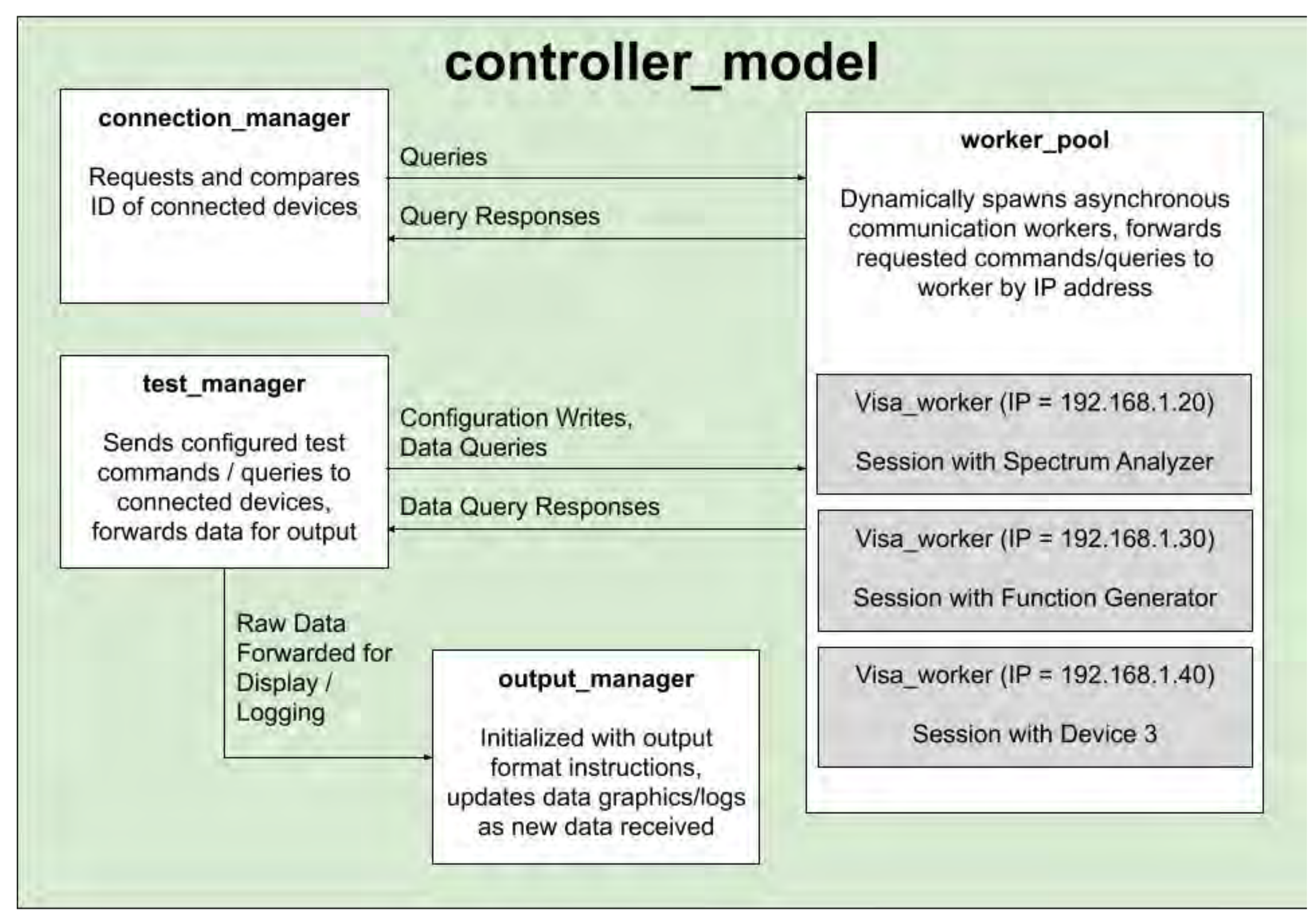
- Popular, affordable System on Chip
- Includes needed connectivity: 10/100 Mbit/s Ethernet, 4 USB 2.0, HDMI (rev 1.3)
- Meets customer requirement of no wireless capabilities
- 900 MHz quad-cor ARM CPU
- 1GB RAM
- Full HDMI port
- Remains in production until at least January 2026

Software Basis

- Python
- PyVISA library
  - Instrument Connection
  - Derivative of NI-VISA library
- PyQt library
  - GUI design
  - Qt Designer program
    - .ui file development
- Pandas Library
  - Output data manipulation

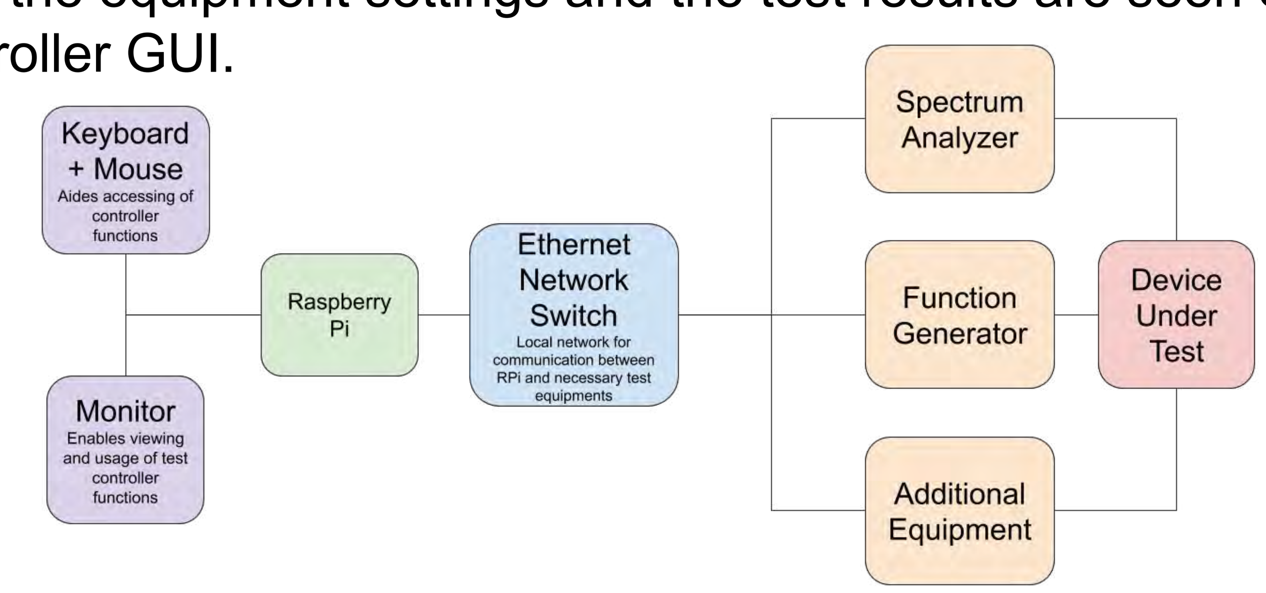
Software Approach

- Object-oriented programming to create independent modules
- Asynchronous network communication through dynamically spawned worker threads



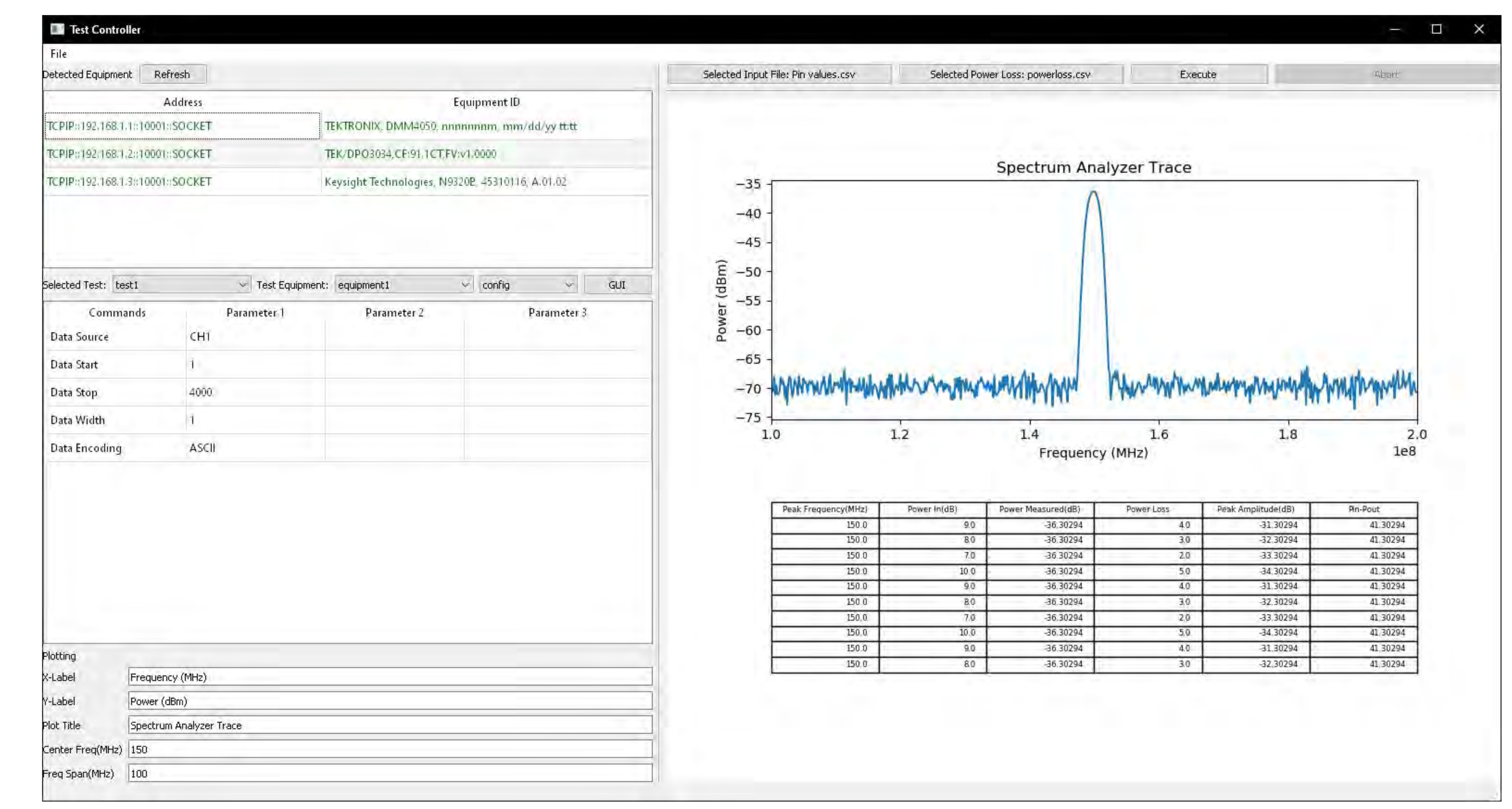
Test Configuration

- The test controller communicates with with connected electronic test equipment on an Ethernet network.
- Once all the parameters are set up, the desired test is run and both the equipment settings and the test results are seen on the controller GUI.



Test Results

- Real time output generated by connected Spectrum Analyzer for Pin vs Pout test.
- Data displayed in tables on GUI and logged in .csv file
- Axes are configured and labelled based on customer input for plotting parameters.



Screen capture of test controller after test execution

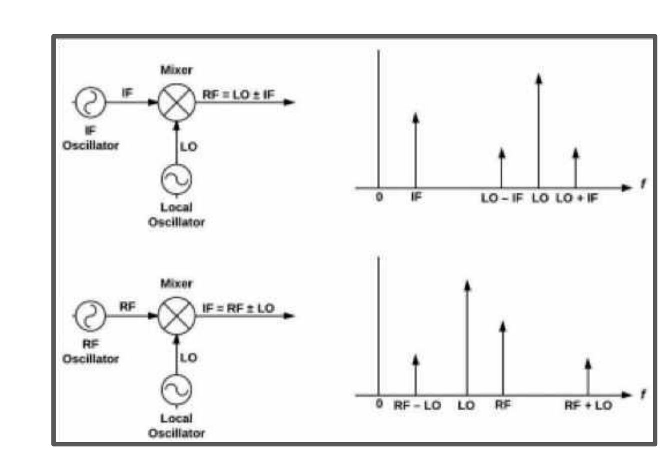
```
power_out.csv
[150.   7.   -36.30294  1.   -35.30294  42.30294]
[150.   8.   -36.30294  2.   -34.30294  42.30294]
[150.   9.   -36.30294  3.   -33.30294  42.30294]
[150.   7.   -36.30294  1.   -35.30294  42.30294]
[150.   8.   -36.30294  2.   -34.30294  42.30294]
[150.   9.   -36.30294  3.   -33.30294  42.30294]
[200.   7.   -36.30294  4.   -32.30294  39.30294]
[200.   8.   -36.30294  5.   -31.30294  39.30294]
[200.   9.   -36.30294  6.   -30.30294  39.30294]
[200.   7.   -36.30294  4.   -32.30294  39.30294]
```

Data log stored in .csv file

Future Plans

Test station controller implementation could be extended to include:

- Create JSON configurable data output modules
- Incorporate error logging to assist user debugging
- Add controller demo for Mixer Spur Table Test



Acknowledgements

We would like to thank these people for their support:

- Peter Han (Subject Matter Expert)
- Professor Kenneth Schulz (Mentor)
- Jonathan Kolbrak (Collins Aerospace)
- Anthony Brocato (Collins Aerospace)
- George Cooley (Collins Aerospace)

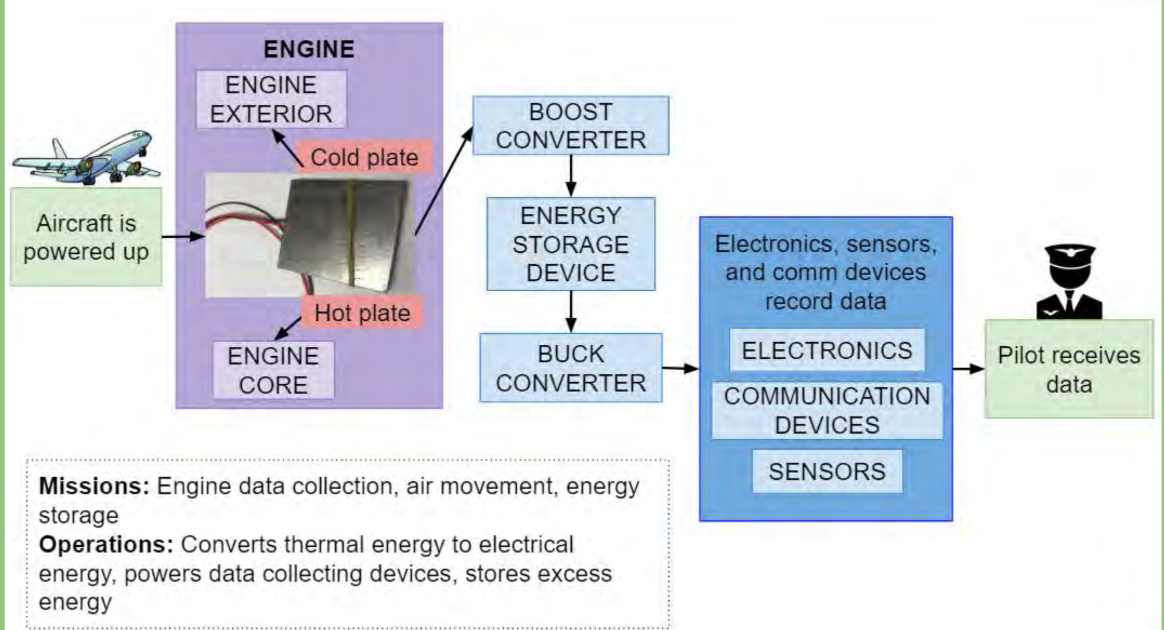
Temperature Differential Power Control

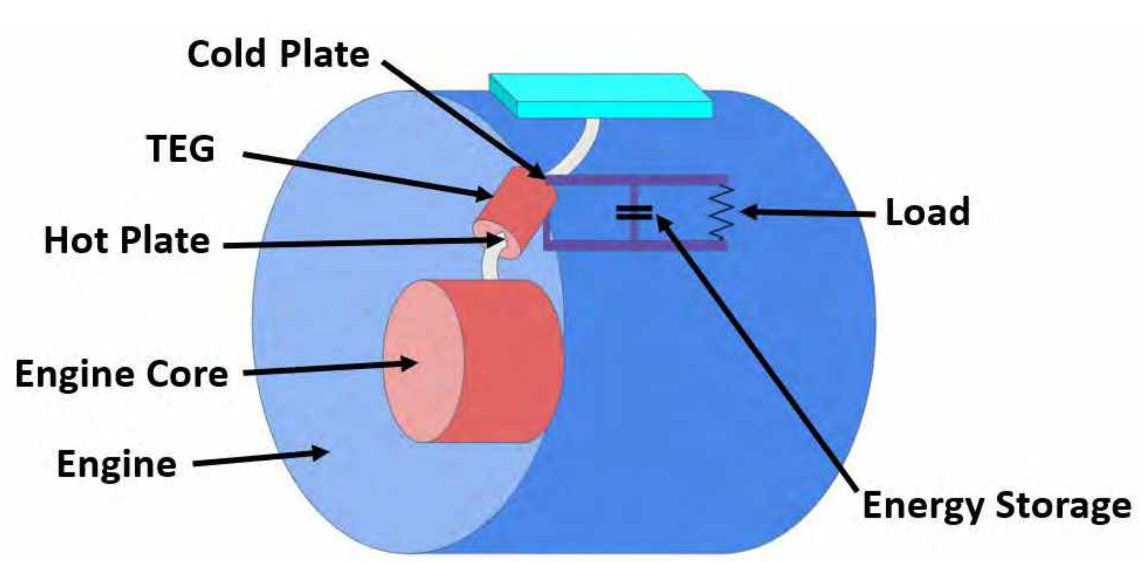
Team Members: Mohammed Almagrab, Miki Bayarjargal, Ashley Chang, Ruoyang Yan **Customer:** Magdi Essawy, Collins Aerospace

SME: Dr. Dong Ha, Minh Ngo **Mentor:** Prof. Kenneth Schulz

Introduction

To prevent aircraft engine failure, sensors and other communication devices monitor the engine and notify the users of any warnings. These electronics collect engine core data, so they need to be placed as close to the engine core as possible to gather the most accurate information on temperature and pressure. These devices are typically placed outside the engine because their power source circuit cannot withstand the engine's high temperature environment [1].





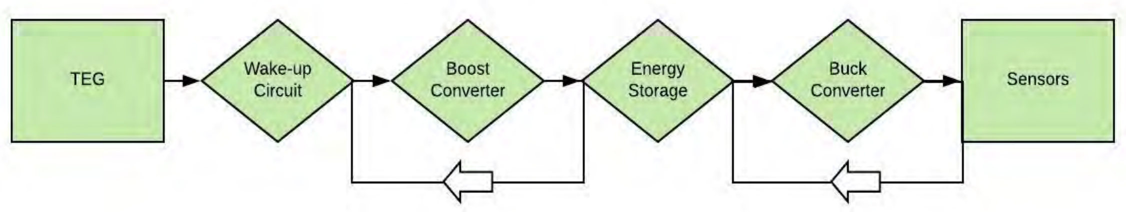
Objectives

- System must be able to withstand a high temperature environment with an ambient temperature of 125℃.
- System must be reliable and last for 15-hour long flights in an aircraft engine.
- Design must have a control scheme to make adjustments if the input varies during flight.

Requirements

- Output power: ≥ 5W
- Operating output voltage: 3-5V
- Efficiency: 15-20%
- Components ambient temperature: ≥ 125℃
- TEG temperature gradient: 270℃

Method

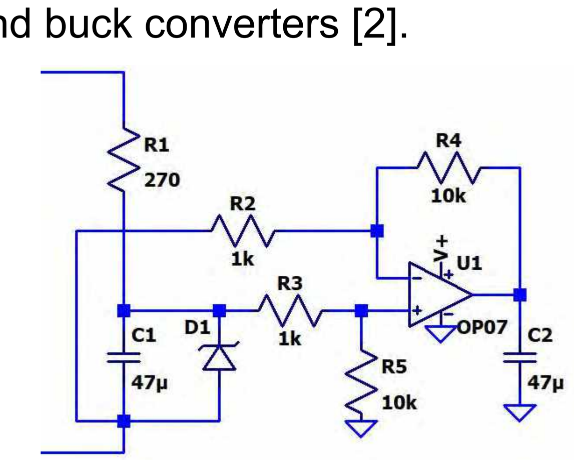


TEG:

Output voltage varies depending on the temperature difference the TEG is exposed to during ascension and descension of the aircraft. Using Marlow TG12-8-01LS.

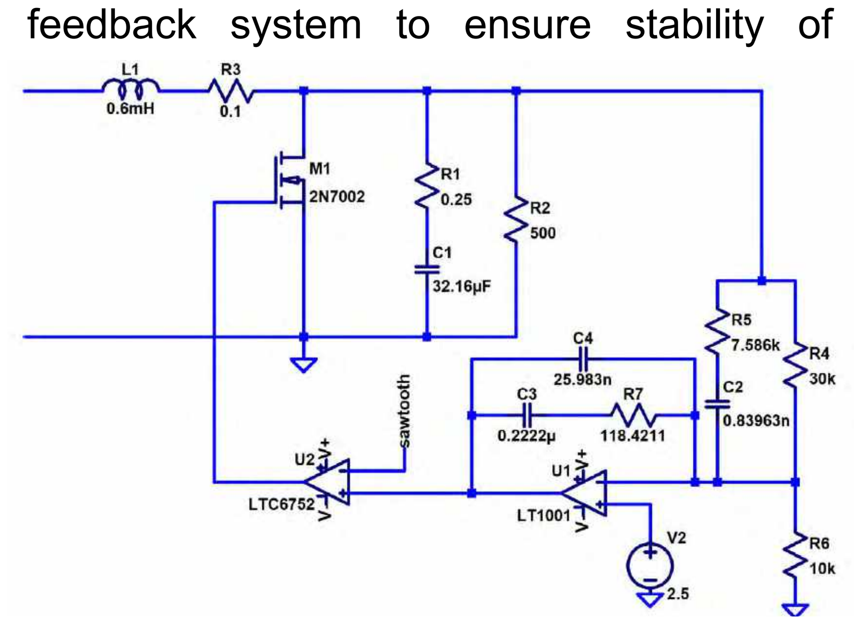
Wake-up Circuit:

The output voltage of the boost converter is *V+*. The wake-up output voltage will bias the control schemes for the boost and buck converters [2].



Boost Converter with Type III Compensator:

Boost converter used to increase the output voltage of the TEG to 10V to be stored in the tantalum capacitors with a positive feedback system to ensure stability of the system.

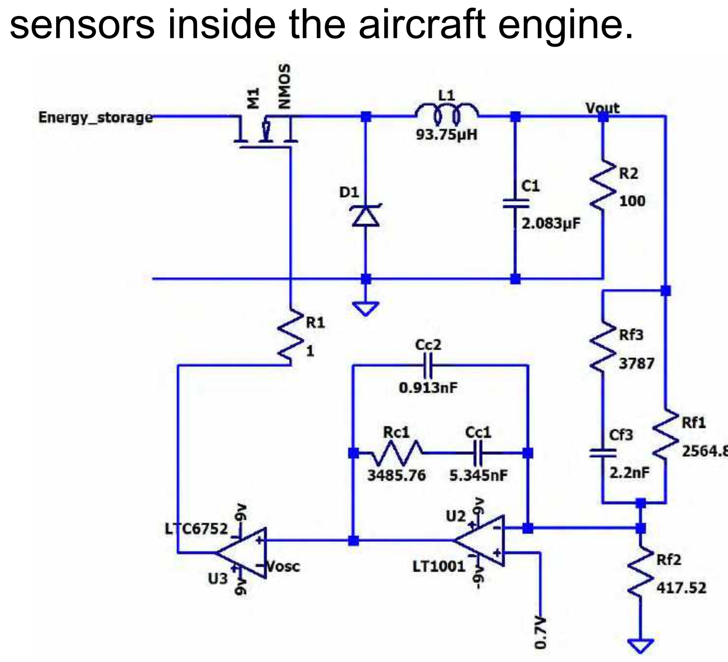


Energy Storage:

The energy storage device is to provide voltage to the buck converter and work normally under ambient conditions of 125℃. Twenty 47uF tantalum capacitors connected in parallel will store 0.8 J of electrical energy.

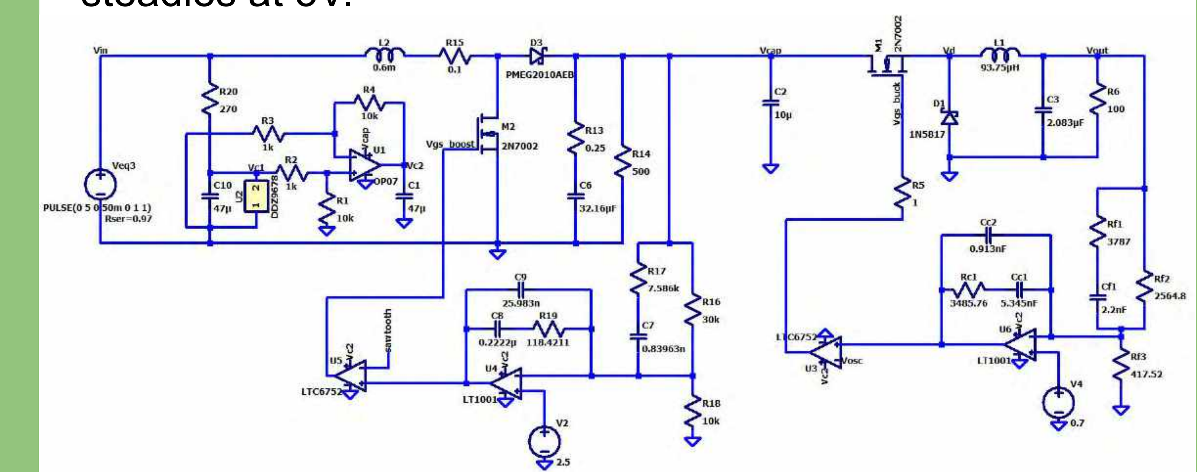
Buck Converter with Type III Compensator:

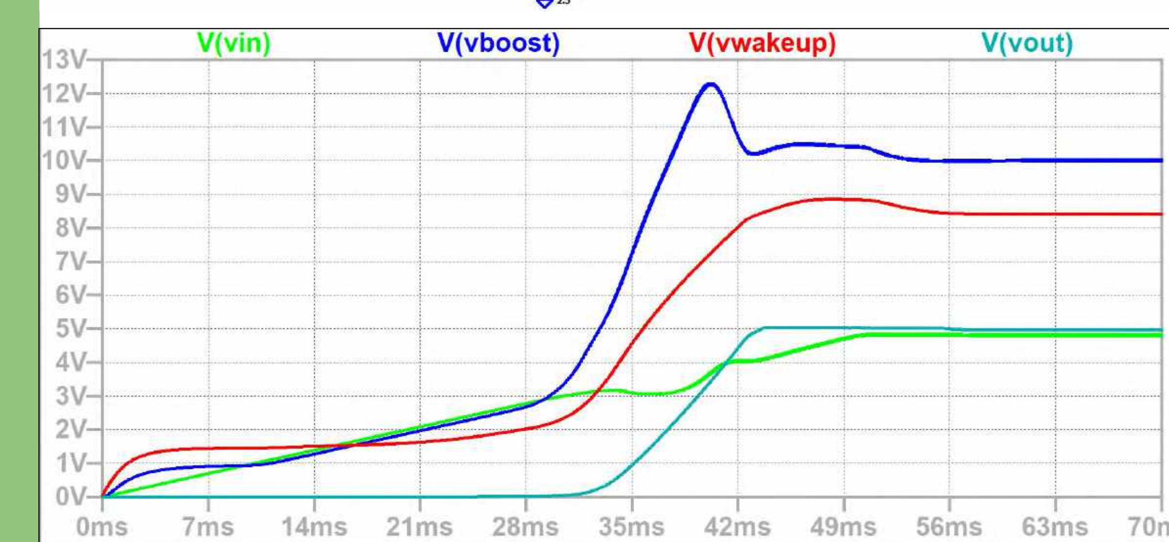
Buck converter used to regulate the output voltage to 5V wireless sensors inside the aircraft engine.



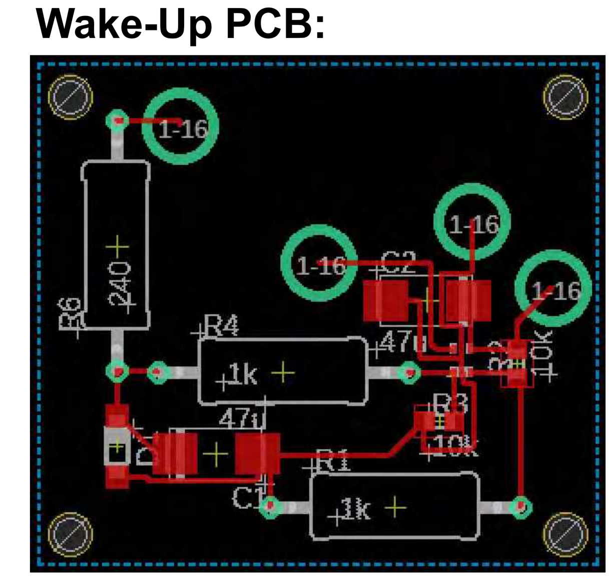
Results

The ramp input voltage, *Vin*, increases from 0 to 5V. Once 3V is reached at 40ms, the wake-up circuit turns on the converters. The boost converter output, *Vboost*, spikes at 12V but steadies at 10V. The buck converter output, *Vout*, steadies at 5V.

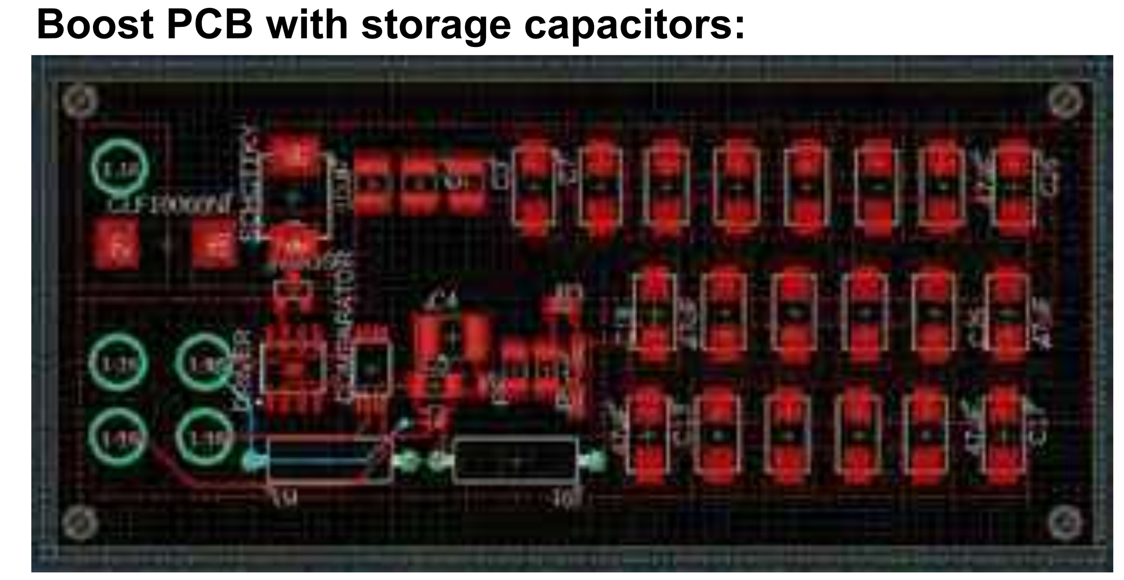




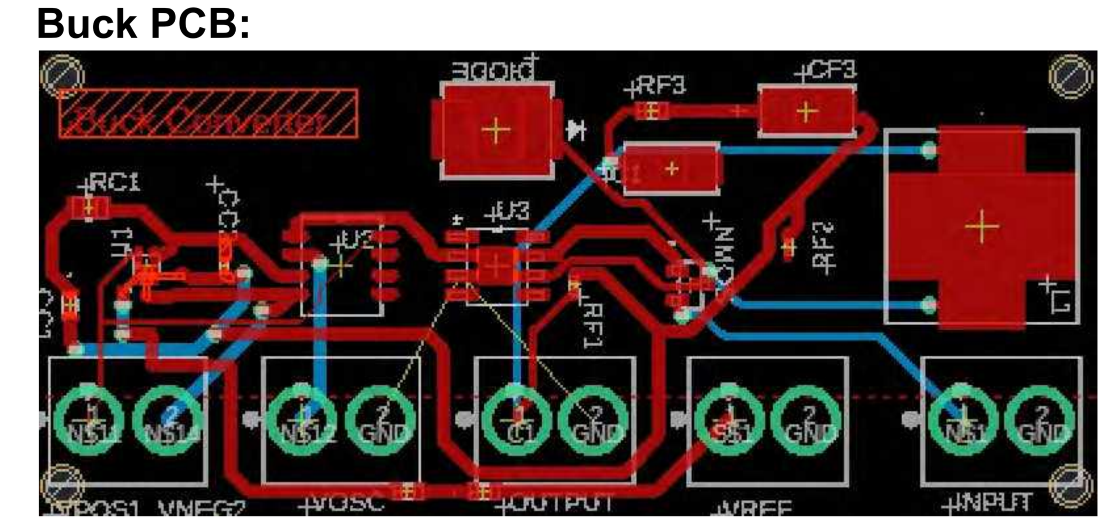
Wake-Up PCB:



Boost PCB with storage capacitors:



Buck PCB:



Conclusion

The project was successful in completing all aspects of the design.

- Design and components rated for at least 125℃
- System stable for 15-hour long flights
- Wake-up circuit ensured that the control system did not drain the energy storage; the converters turned on when there was enough input
- Boost with respective voltage-mode controller was able to supply constant 10V to load capacitors, even through perturbations
- Buck respective voltage-mode controller was able to output constant 5V to load

Challenges

- Acquiring high temperature parts for design
- Choosing energy storage device with budget and storage constraints
- Limited access to labs to build and test circuit after COVID-19

Future Plans

- Increase efficiency through different conduction modes
- Design one PCB for the entire system for improved testing and noise interference
- Create an electronics load that would apply to aircraft application

References

[1] P. Sturesson, "Sense, Actuate and Survive - Ceramic Microsystems for High-Temperature Aerospace Applications," Ph.D. thesis, Uppsala University, Sweden, 2018.

[2] J. H. Hyun, L. Huang, and D. S. Ha, "Vibration and Thermal Energy Harvesting System for Automobiles with Impedance Matching and Wake-up," in 2018 IEEE International Symposium on Circuits and Systems (ISCAS), 2018, pp. 1-5.

Acknowledgments

We would like to thank the following people for their support throughout the project:

- Minh Ngo (Technical Expert)
- Magdi Essawy (Customer Contact)
- Dr. Dong Ha (MICS Lab Manager)

IEEE Robotics Hardware Team

Alana Laferrière, Manpreet Dhaliwal, Ruilin Huang, Tanner Goins, Zhe Liu

Customers: Moqi Zhang, Xiyuan Li *SME:* Dr. Arthur Ball *Mentor:* Kenneth Schulz

Objective

Cooperate with the software team to design and build an autonomous robot for the IEEE SoutheastCon Hardware Competition within a $1000 budget. The aim of the competition was to press as many digits of pi as possible on a set of 10 pushbuttons. Robots had to start each round in a one-foot-cubed starting zone. They then had to line up with the wall-mounted buttons (seen in Figure 1) and score as many points as possible in a three minute match.

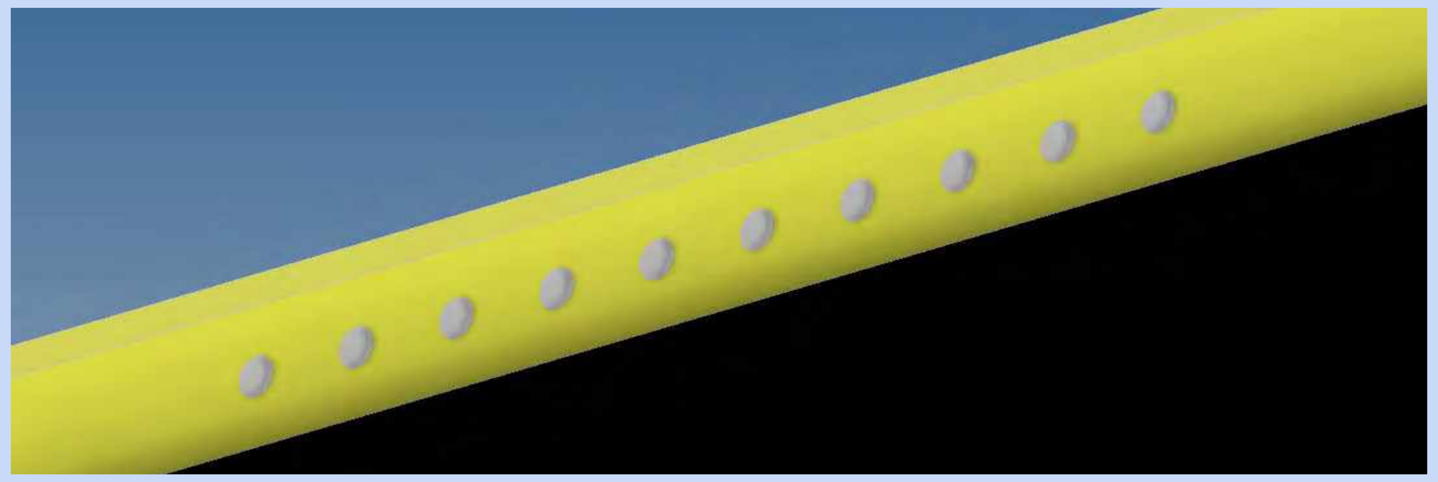


Figure 1. Array of LED buttons on arena, floor painted black

Methods

Robot was split into four subsystems (Figures 2 and 3)

- Chassis and drivetrain
- Arms and button actuators
- Control system
- Power distribution

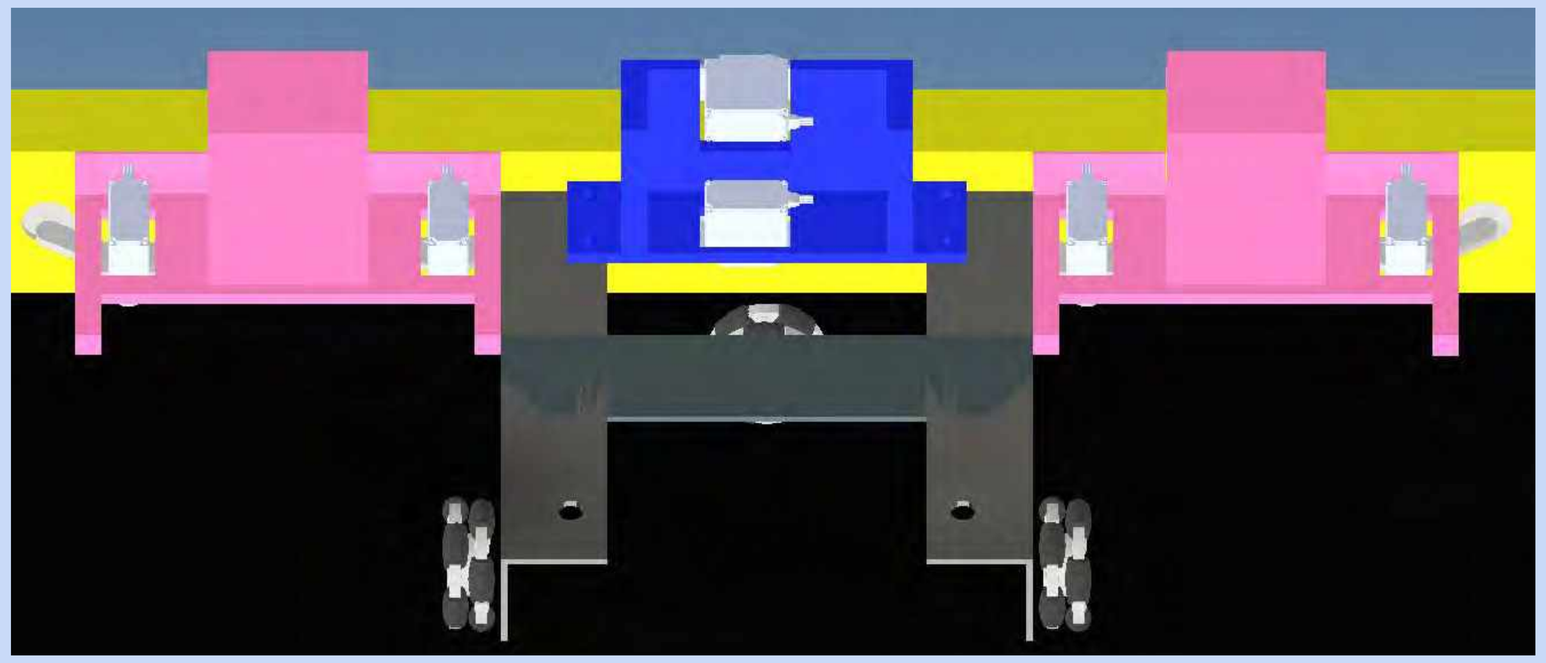


Figure 2. CAD model of chassis, arms, and button actuators

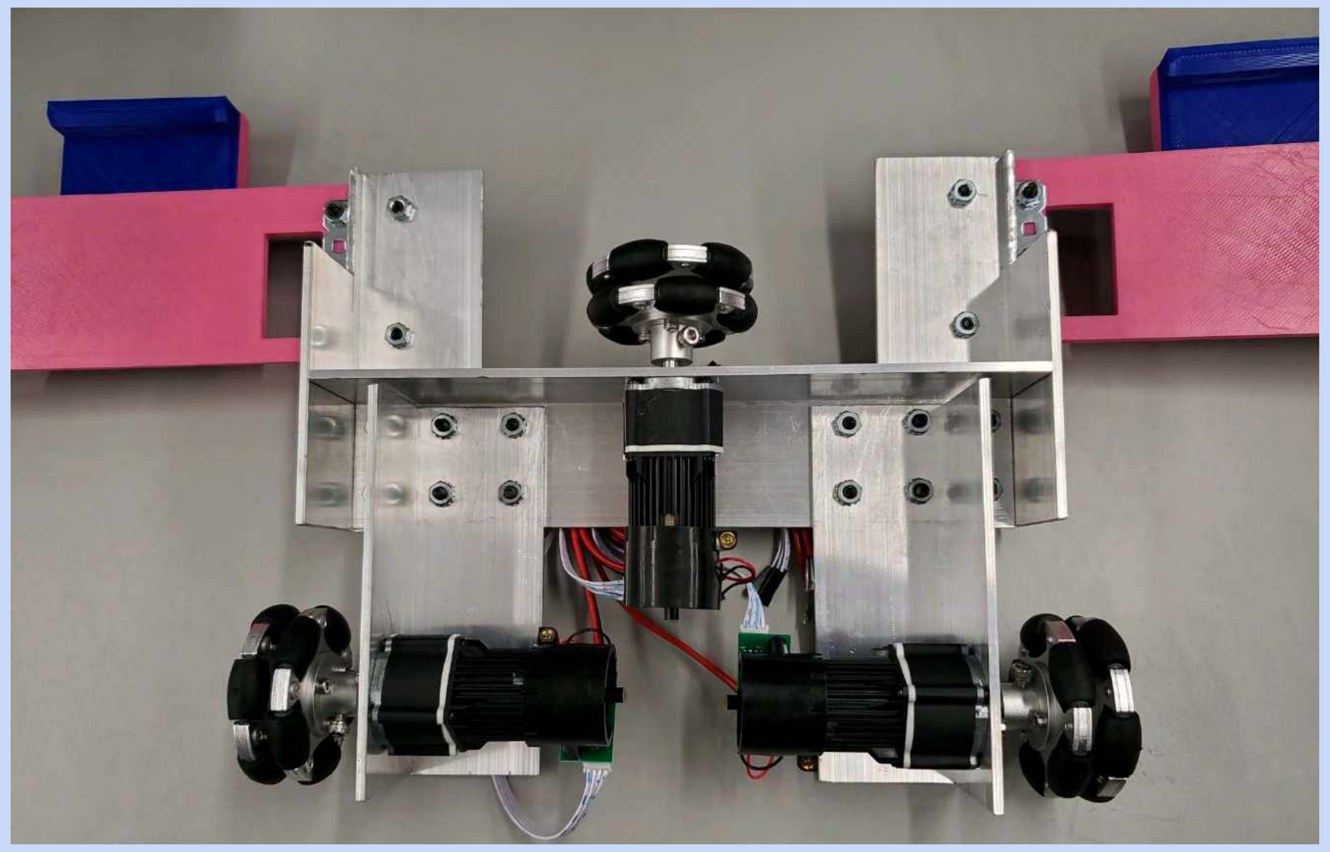


Figure 3. Underside of robot. Notice the wheel motors and actuator arms

Methods Continued

The power system was split in two to eliminate noise (Figures 4 and 5)

- Large battery powered motors and servos
- Small battery powered Arduino and its peripherals
- Both systems included a power switch for safety and to comply with competition rules

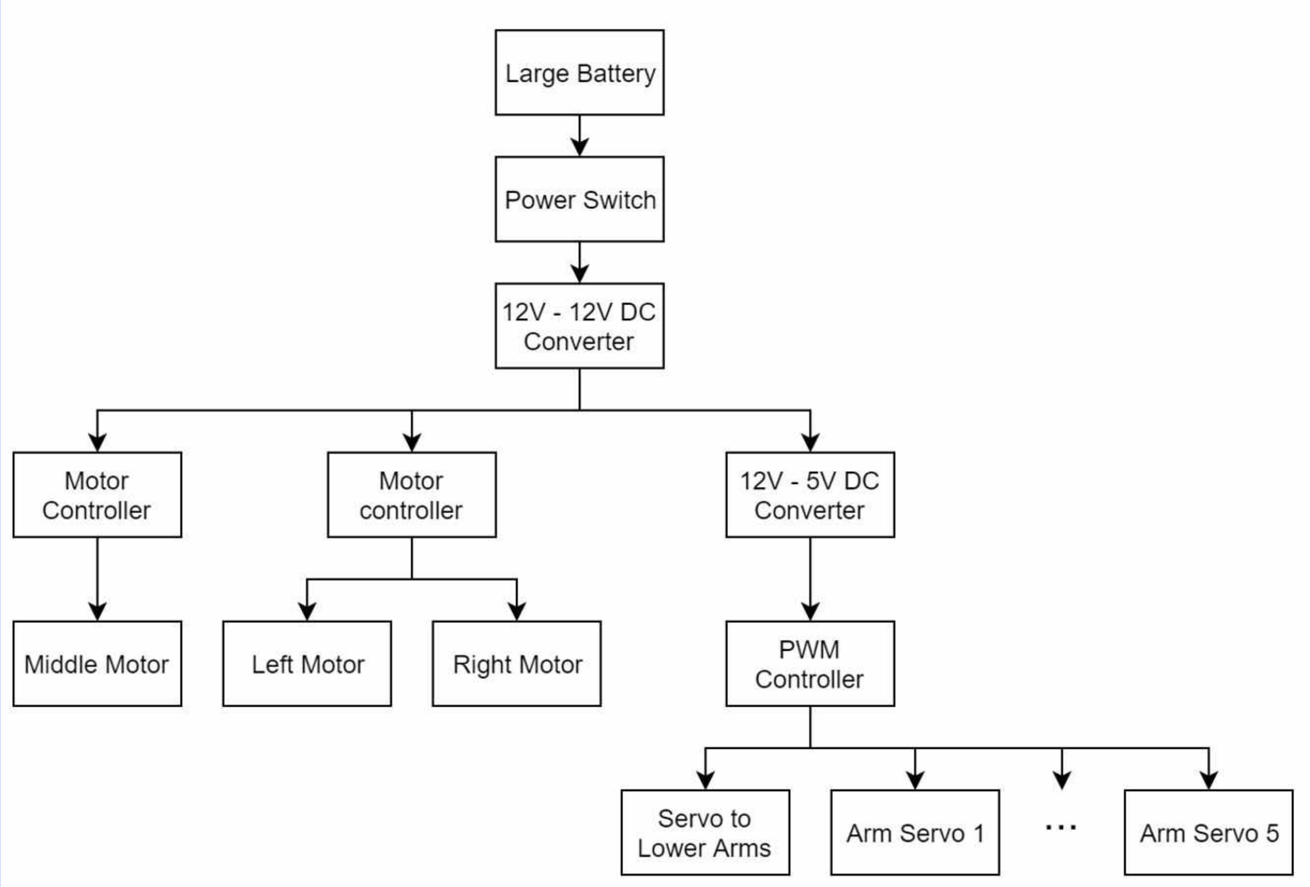


Figure 4. Large battery power distribution system

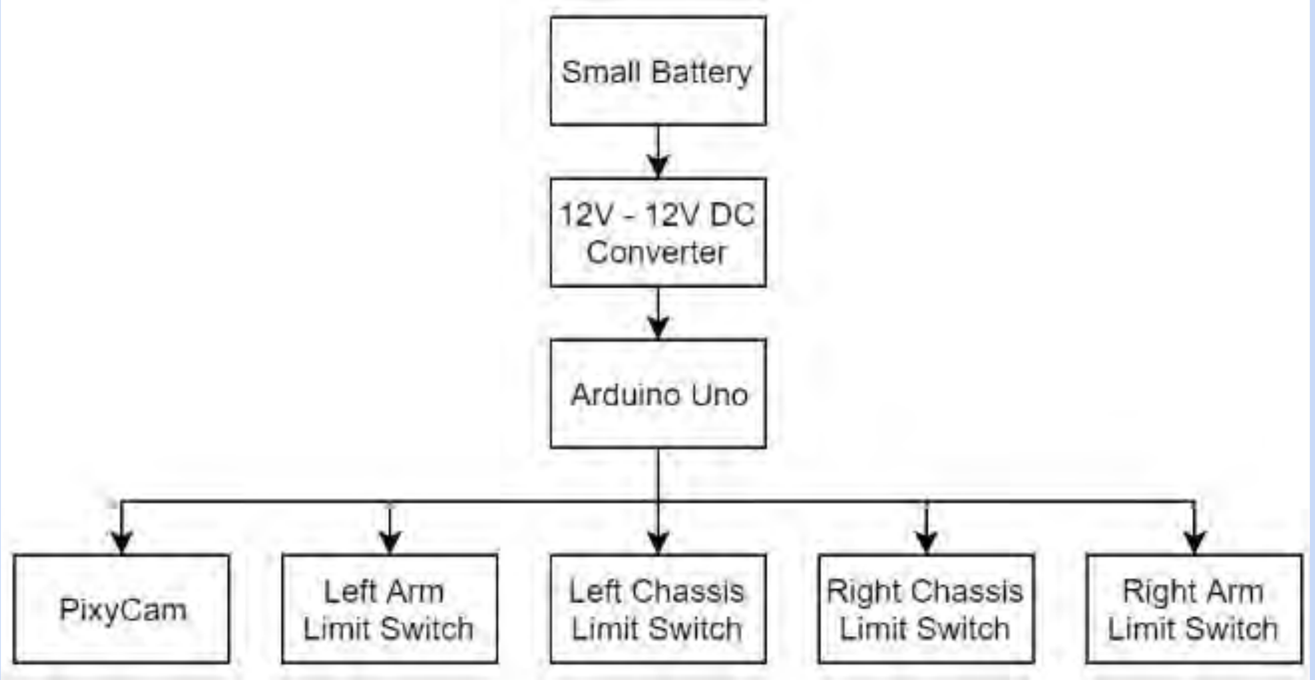


Figure 5. Small battery power distribution system

The control subsystem combined and integrated our hardware with the code produced by the embedded team, shown in Figure 6

- Arduino controlled motors, arms, and paddles
- Visual inputs from the PixyCam were used to align with the buttons
- Physical inputs from the limit switches were used to align the robot with the wall

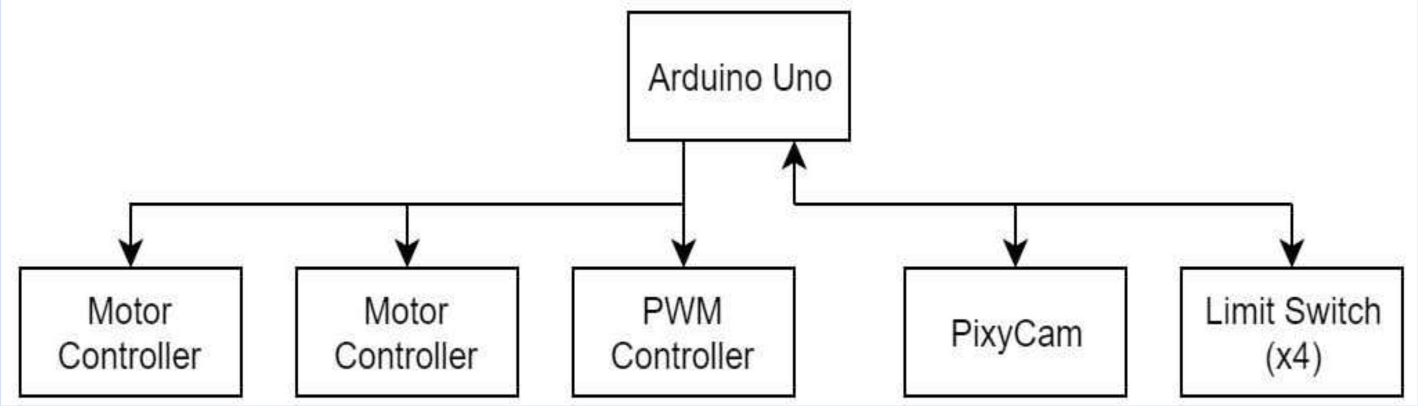


Figure 6. Control system inputs and outputs

Results

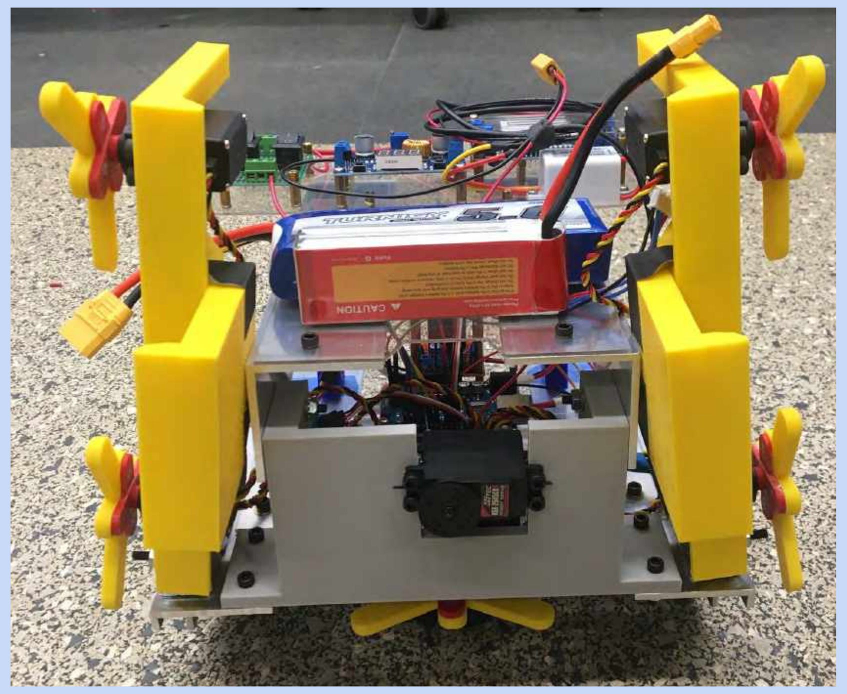


Figure 7. Front view of robot and paddles

The resulting robot, shown in Figure 7, provides a unique approach to solving the challenges presented by the competition. The drivetrain consisted of three Omni wheels for precise forward and lateral driving. Folding the arms upward allowed for the robot to stay within size tolerances, and deploying the arms after the match started allowed the robot to properly fit to the button array. When the robot lined up with the buttons using its PixyCam, the paddles were able to rotate quickly and precisely enough to score many valuable points.

Conclusions

Our team was able to integrate all of the subsystems to create a fully autonomous and competition ready robot, shown in Figure 8.

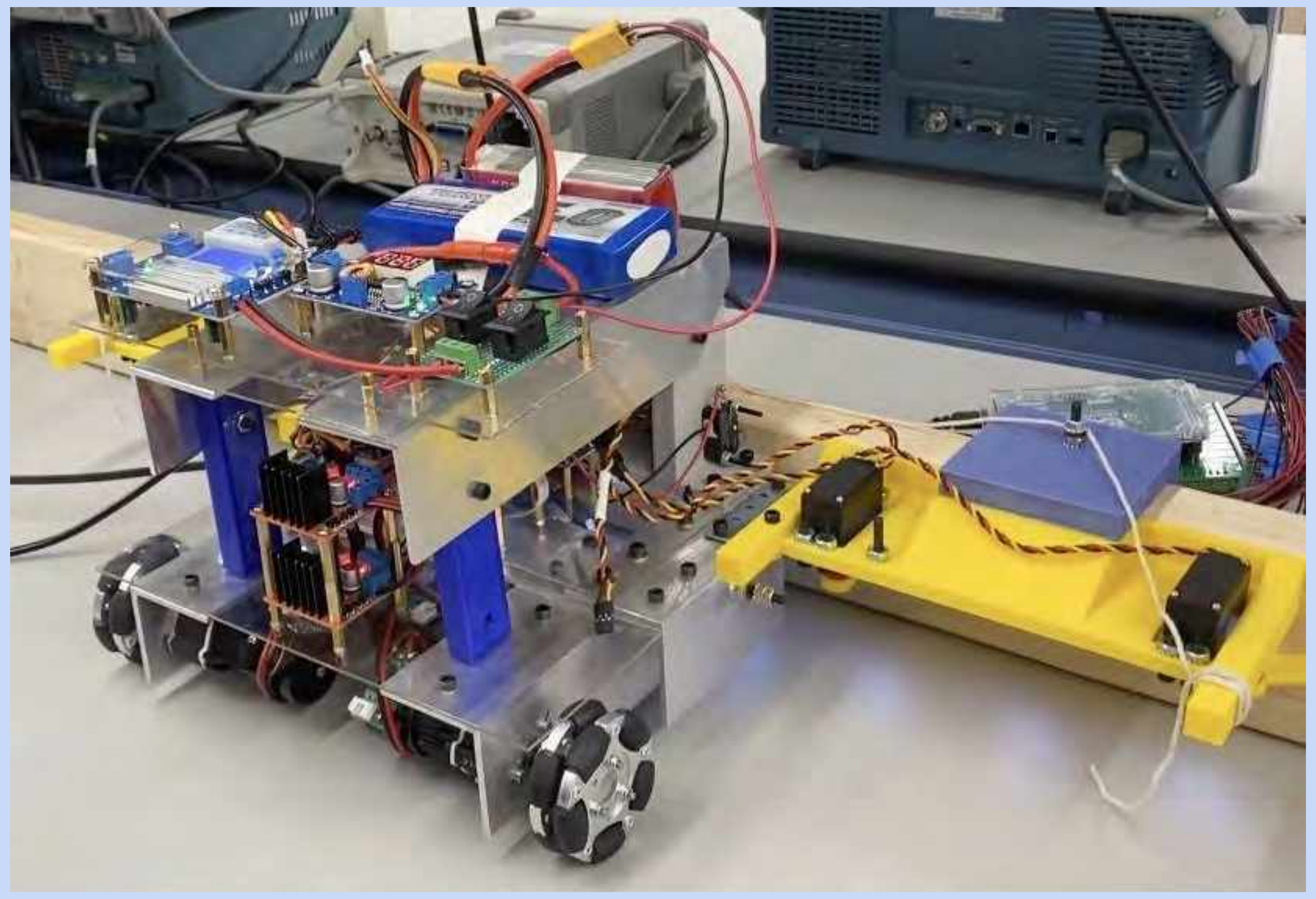


Figure 8. Completed Fully Functioning Robot

Acknowledgements

We would like to thank the following people for their support over the course of this project:

- Dr. Arthur Ball, SME
- Professor Schulz, mentor
- Professor Ransbottom, facilitator
- Professor Meadows, MDE studio manager
- Moqi Zhang and Xiyuan Li, 2020 customers
- Chengliang Lu, 2019 customer

IEEE Robotics Embedded Team

Jielong Cong, Drew Harlow, Yahui Zhao
Customers: Moqi Zhang, Xiyuan Li SME: Dr. Arthur Ball Mentor: Kenneth Schulz

OBJECTIVES

Our team's goal was to design and build a robot for the 2020 IEEE SoutheastCon Hardware Competition. The competition challenge is pressing buttons to demonstrate how many digits of Pi sequence your robot can enter. The robot had to start at right side of the field in a one-foot-cubed starting zone. Then it needs to line up with the wall-mounted buttons and score as many points as possible in a three minutes match. This is a two teams project and General Motors is the sponsor. The Embedded team focused on the software parts of the robot.

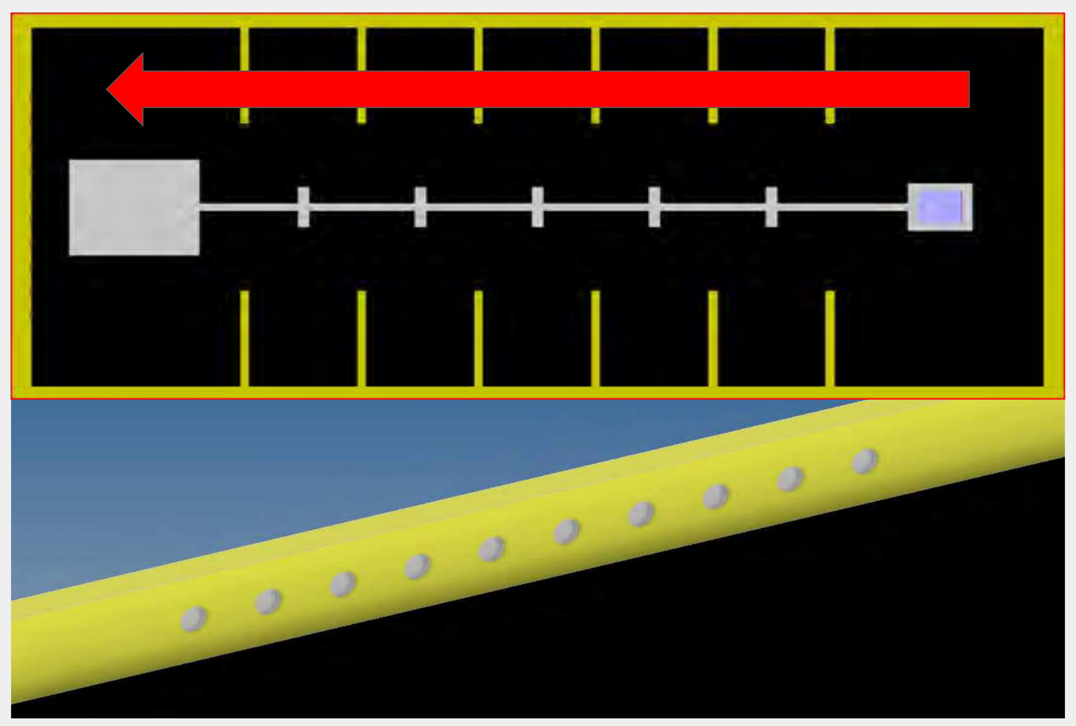


Figure 1, Competition field and buttons mounted on the left side wall

Method of Pixy-Cam

The PixyCam is used to detect the relative location of the first button that needs to be pressed. Using a light intensity based object detection algorithm derived from Otsu's method. The PixyCam returns a relative horizontal axis coordinate to the Arduino, which then commands the horizontally mounted motor to move in the direction to align the pushing paddle with the button. When the paddle is aligned, the PixyCam is disabled and the robot begins to press buttons in the order of the digits of the pi constant.

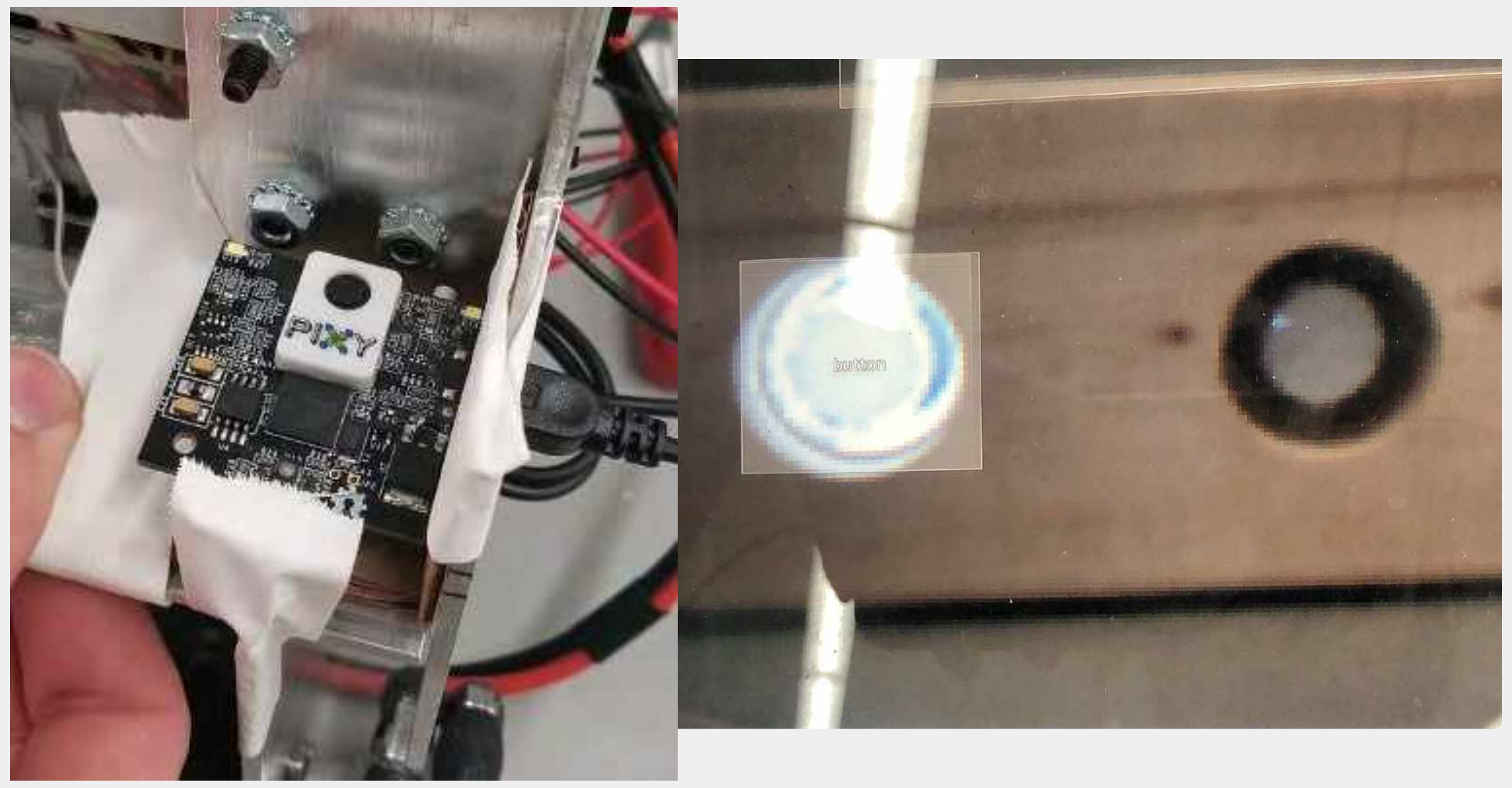


Figure 2. The PixyCam on the left and its identification of an illuminated button on the right.

Robot Overview

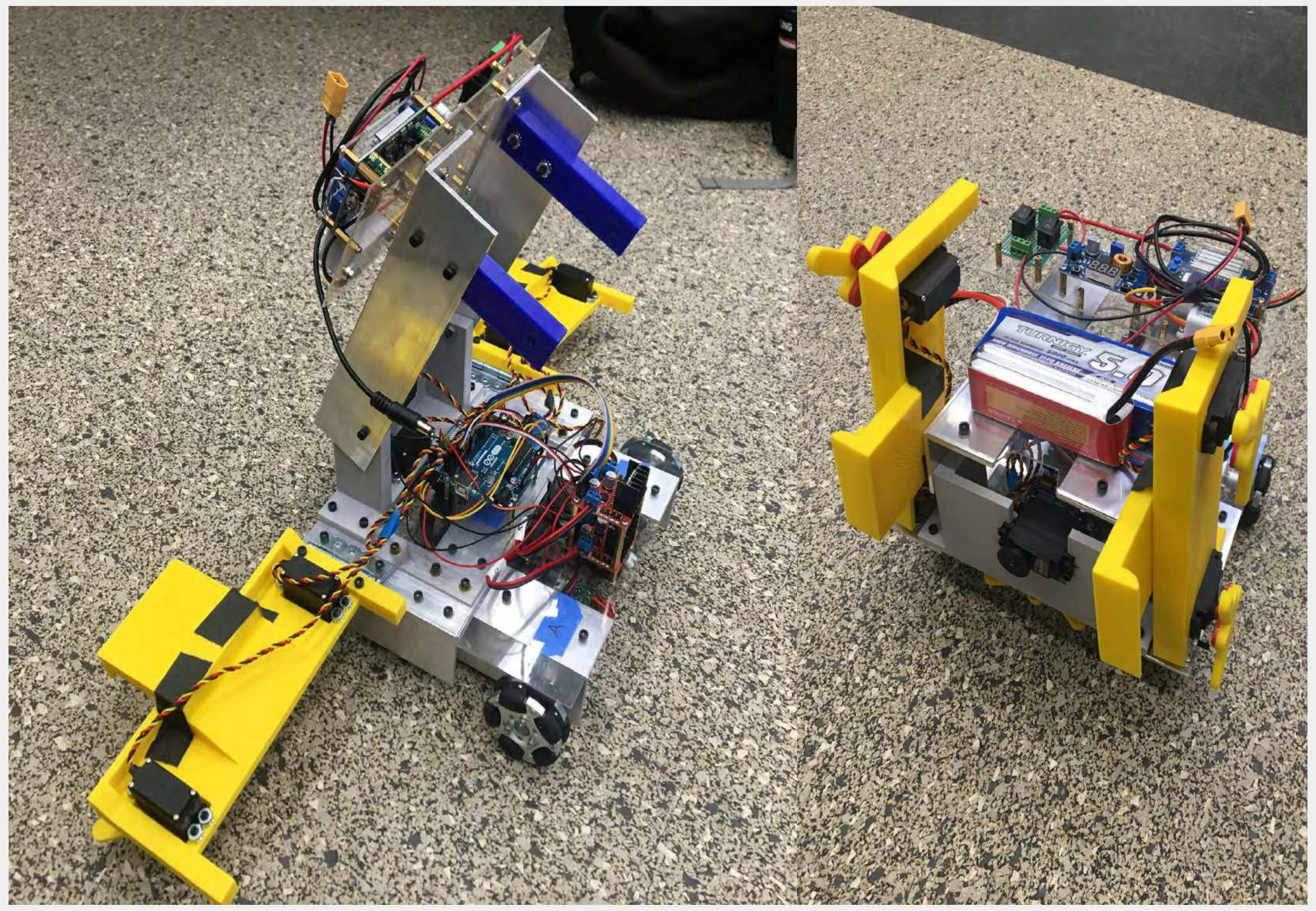


Figure 3, photo of the folded / unfolded robot.

Control system Overview

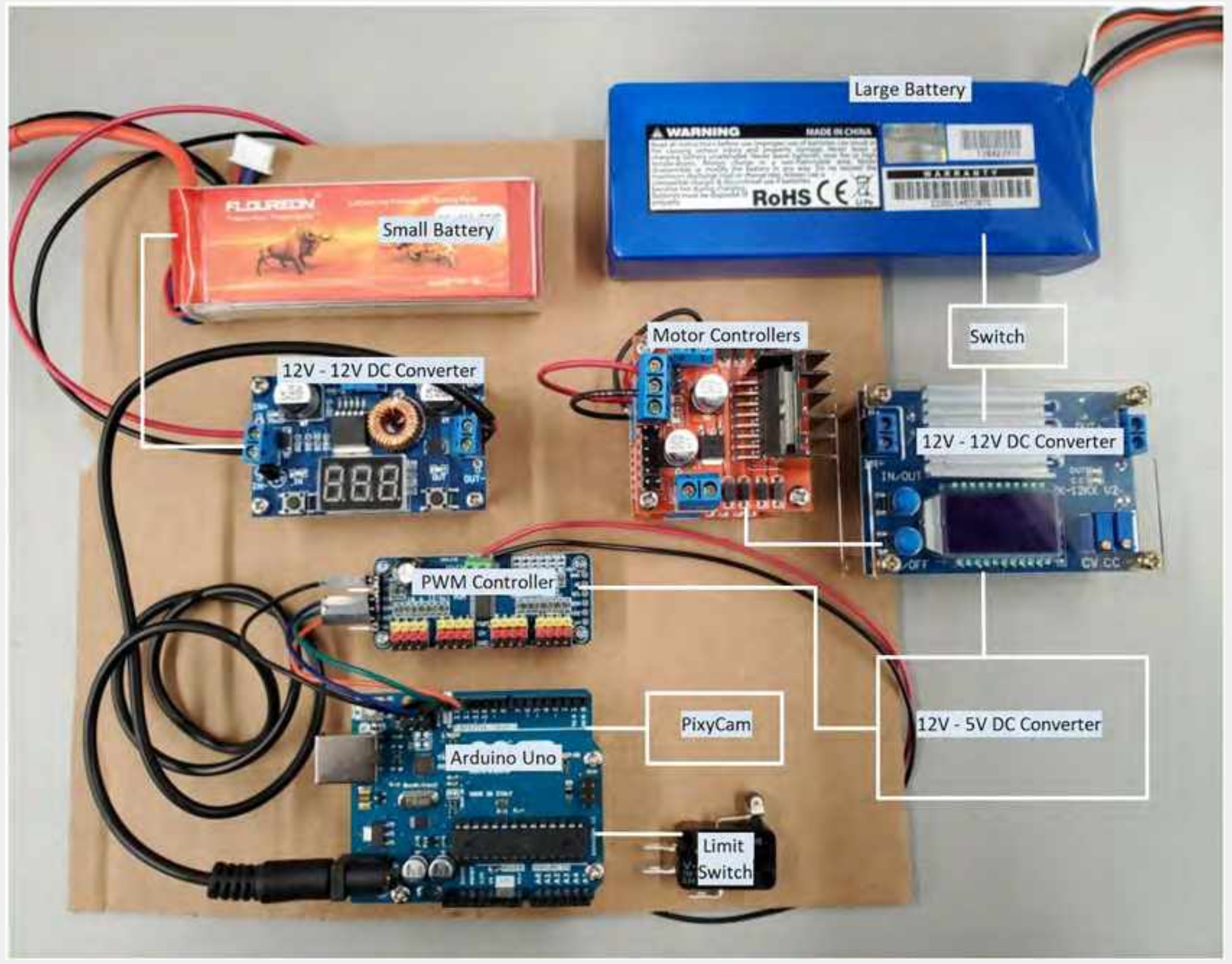


Figure 4, Control system diagram of the embedded software

Method of Motor-controller

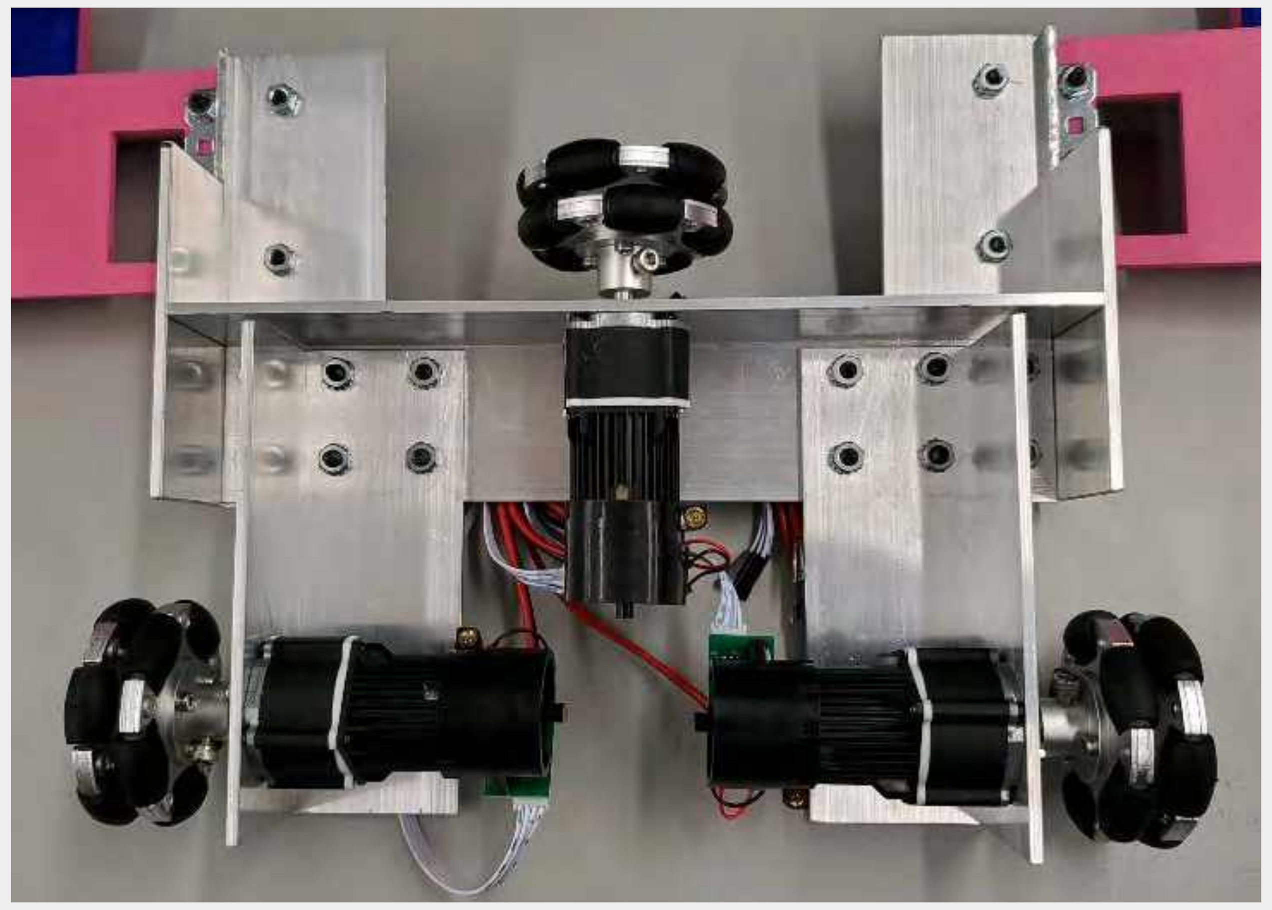


Figure 5, The orientation of the omni-wheels

RESULTS AND CONCLUTION

The robot operates as designed. It can move perfect to reach the wall that mounted the buttons and them use the PixyCam to line up with the correct button. Due to the COVID-19 pandemic, the competition event was unfortunately cancelled and the robot was not able to compete. The robot was ready to compete as it was able to score points operating under competition conditions.

Based on the performance on the test field, the PixyCam alignment system was unnecessary because the robot was able to line up with the button arry with no horizontal adjustment. It seems like the motor-controller can perfectly send the robot to the wall that mounted the buttons. However, the real competition field may use different material for the floor. That means the frictional coefficient will be changed, and the PID for the motor-controller also needs to change. However, this could be compensated for with only slight adjustments to the robot's software.

Acknowledgements

We would like to thank these individuals for their support over the course of this project:

- Dr. Arthur Ball, SME
- Professor Schulz, mentor
- Professor Ransbottom, facilitator
- Professor Meadows, MDE studio manager
- Moqi Zhang and Xiyuan Li, 2020 customers
- Chengliang Lu, 2019 customer

Spread Spectrum Modem

Team: Evance Gyabaah, Shannon Lilly, Isaac McDaniel
Customer: Wendy Votaw and Carl Burris
SME: Dr. Alan Michaels
Mentor: Prof. Gino Manzo

The Bradley Department of Electrical and Computer Engineering

Introduction

Inmarsat Gov asked for the design of a spread spectrum modem for communication with their satellite platform.

To complete this project, one Xilinx Zedboard System on Chip development platform and one radio mezzanine were purchased.

Due to the university shutdown, the design will be tested by simulation only.

Objectives

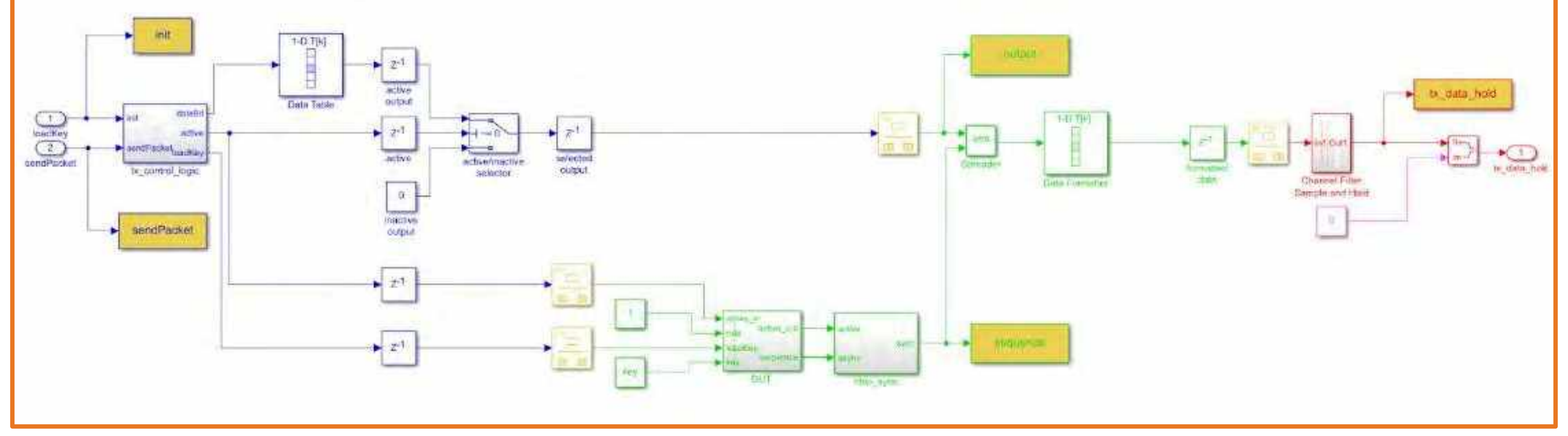
The goal of this project was to develop a Software Defined Radio system running on the Zedboard hardware. The system was to use direct sequence spread spectrum communication.

The technical specifications provided by Inmarsat Gov included the following:

- Occupied bandwidth = 2MHz
- Roll-off factor = 0.25
- Bandwidth = occupied bandwidth/(1+roll-off factor)=1.5MHz
- Spread gain = 30dB
- Data rate = bits/symbol*bandwidth/spread gain = 1.5kHz
- BPSK
- Spreading factor = chip rate/ data rate = 1000

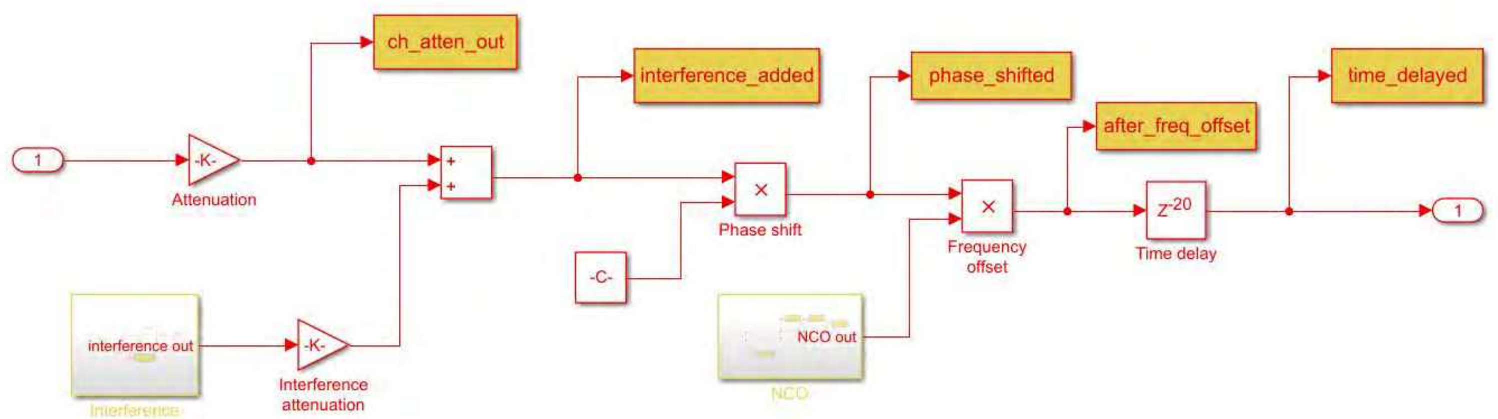
Transmitter

The Transmitter consists of a memory buffer, pseudorandom sequence generator, spreader, data formatter, and channel filter. The spreader multiplies the data signal by the much higher frequency pseudorandom sequence of "chip" bits, greatly increasing bandwidth while reducing peak of the signal's power spectral density below the noise floor. The channel filter adjusts the signal in anticipation of distortion in the channel.



Channel

This is a simulated connection between transmitter and receiver. Our model accounts for attenuation, interference, phase shift, frequency offset, and time delay arising from the transit of the signal. Real connections could be a cable or the air.

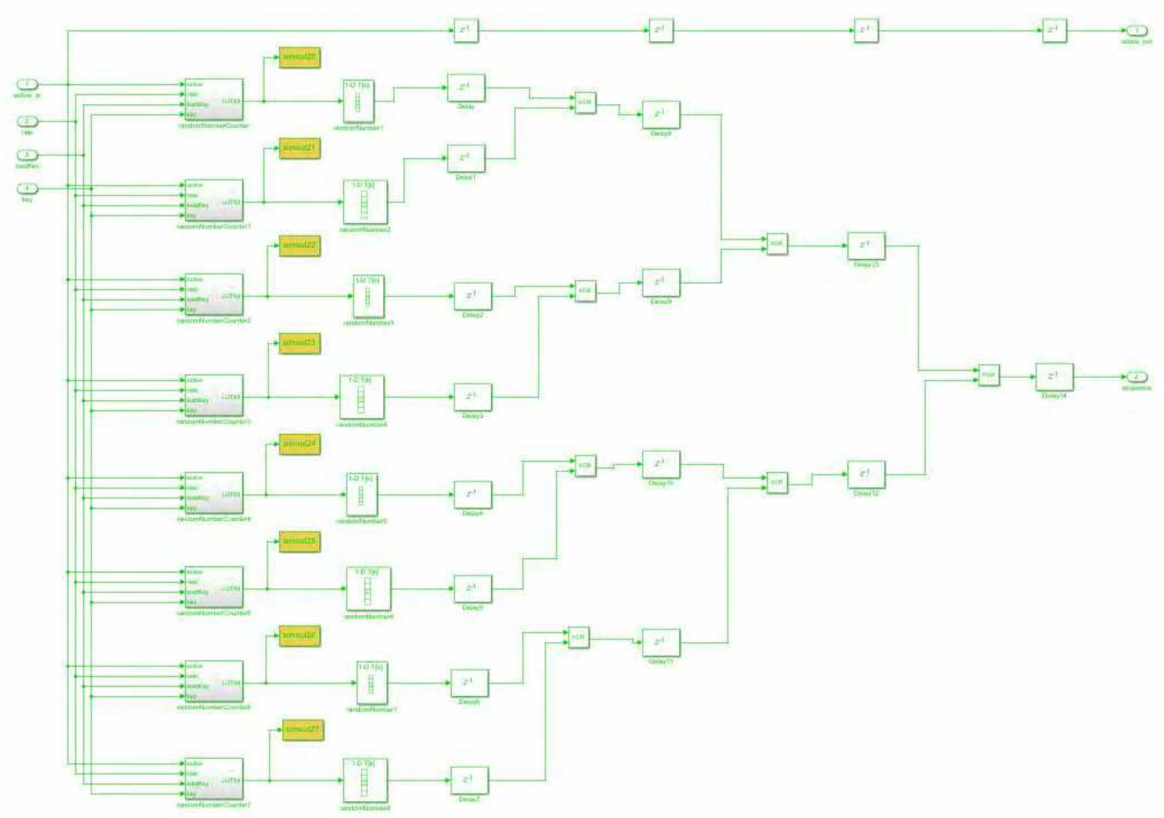


Receiver

The receiver is consisted of a sequence generator, tracking loops, a channel filter, a matched filter, and a despreader.

Sequence Generator

Eight accumulators with different periods were used to generate an endless sequence of pseudorandom bits. The output of each accumulator selected a bit from a Lookup Table (LUT) and a single pseudorandom bit was derived by sending the eight selected bits through a series of XOR gates.

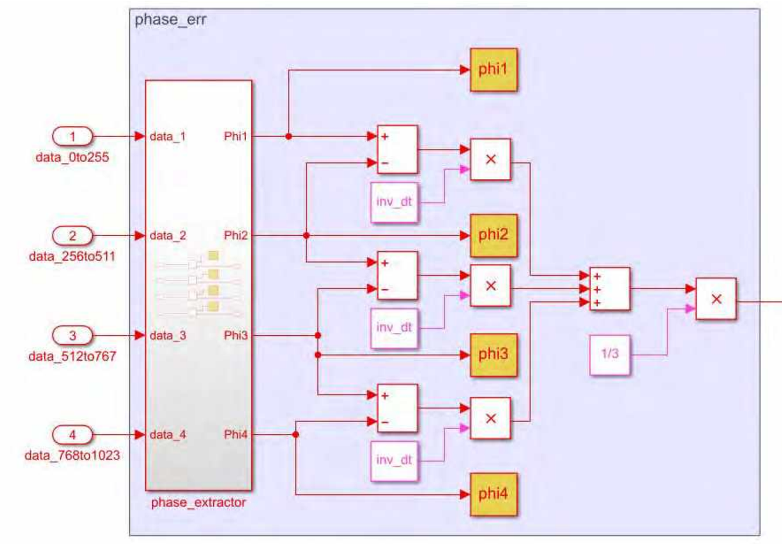


Tracking Loops

Once the signal is received it needs to be locked with the internal code.

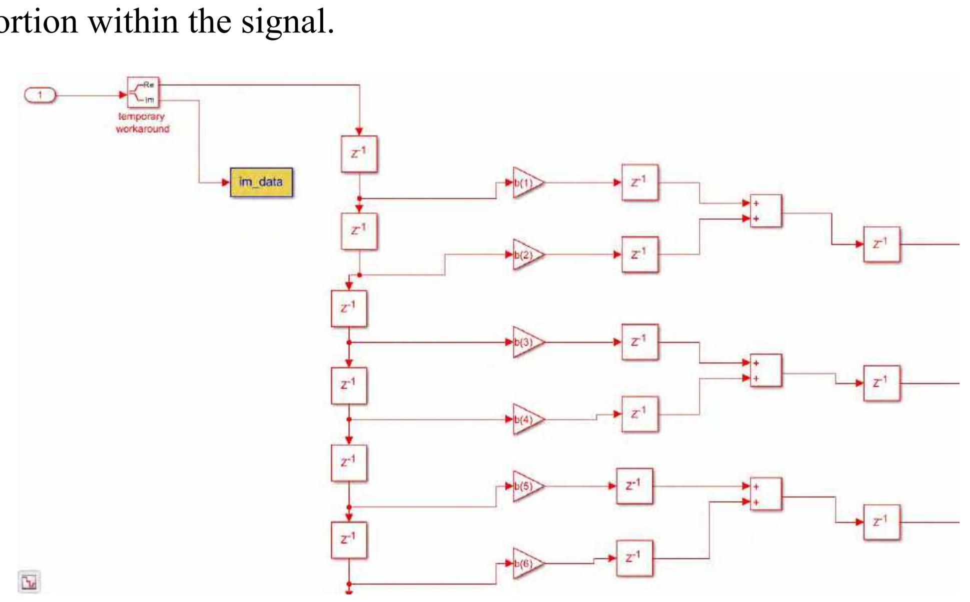
Delay locked loops correct for timing errors. Early-late detection algorithms are used.

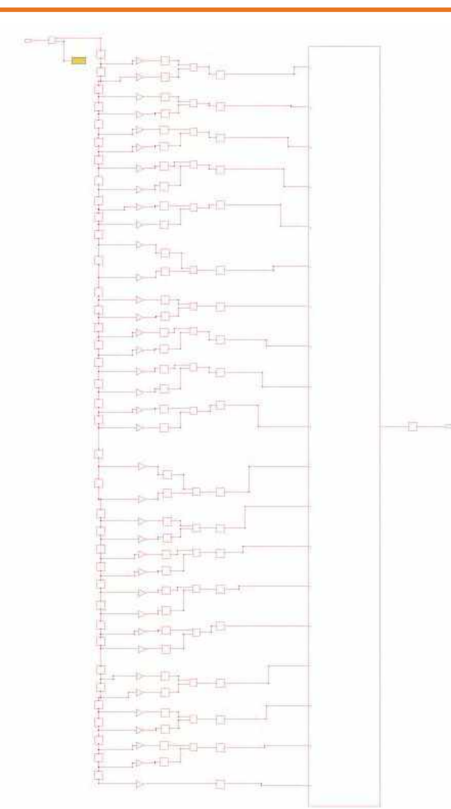
Phase locked loops correct for phase error accumulation. Costas loops are used.



Channel Filter

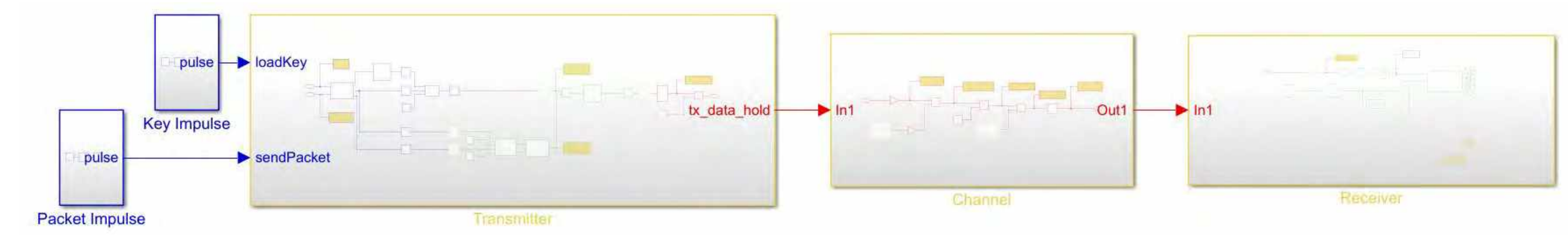
The full channel filter is on the right and a zoomed in section is below. The channel filter design is based on the Raised-Cosine FIR Filter consisting of coefficients that are upsampled to filter out noise and distortion within the signal.





High Level Block Diagram

At the highest level of the simulated design you see three blocks: the transmitter, channel, and receiver.



Results

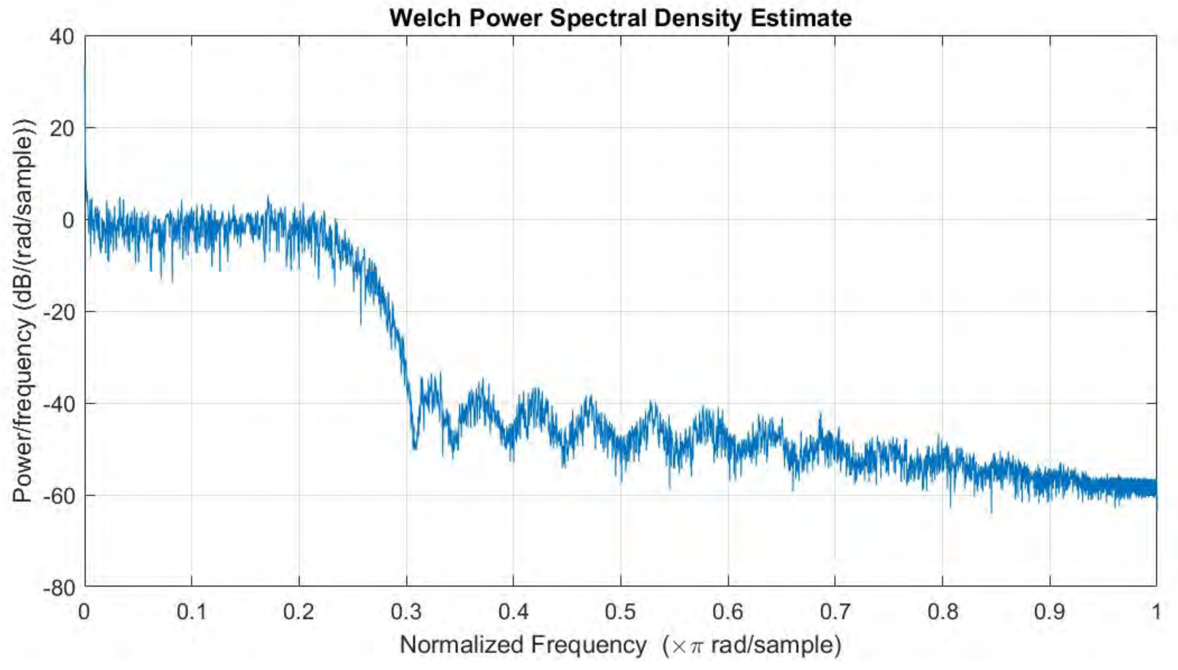
To the right are signal values at the input to the spreader in the transmitter. These both change from active to inactive at the same time, indicating proper synchronization of the sequence generator with the rest of the transmitter circuitry.

Sequence represents the randomized output from the sequence generator used to obfuscate the data signal. It is inactive when it is fixed at the first bit in the sequence and is active when it begins to change values.

Output is the data stream which is intended for the user of the receiver. In this test, the first bit of data to transmit was set to 1 to differentiate between the active and inactive states. Here it is inactive at the beginning of this sample and becomes active when it changes to 1.

out.output		out.sequence	
	1		1
9992	0	9992	1
9993	0	9993	1
9994	0	9994	1
9995	0	9995	1
9996	0	9996	1
9997	0	9997	1
9998	0	9998	1
9999	0	9999	1
10000	0	10000	1
10001	1	10001	1
10002	1	10002	1
10003	1	10003	1
10004	1	10004	1
10005	1	10005	1
10006	1	10006	0
10007	1	10007	0
10008	1	10008	1
10009	1	10009	1
10010	1	10010	0
10011	1	10011	0
10012	1	10012	1

This figure shows the power spectral density of the transmitter output.



Future Plans

Implement the design to hardware on the Zedboard platform.

Add forward error correction and framing.

Conduct over the air testing with Inmarsat's satellite.

Acknowledgements

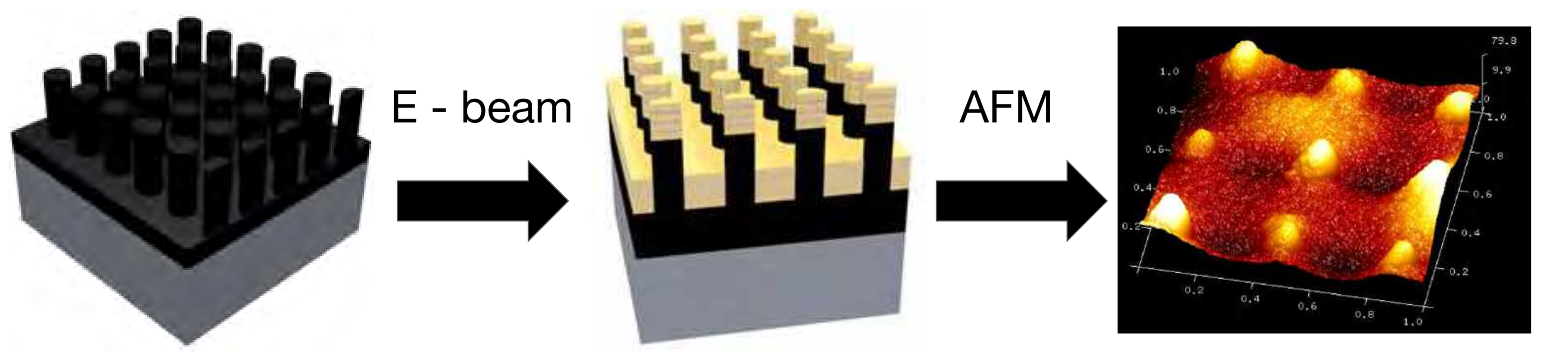
We would like to thank the following people:
Wendy Votaw and Carl Burris (Customer Points of Contact)
Alan Michaels (Subject Matter Expert)
Gino Manzo (Mentor Professor)

Nanotransducers for Simultaneous Optical-Electrical Sensing

Team Members: Will Banner, Shubham Dawda, Collin Hood, Bumsu Kim, Steven Parker
Customer: Nick Phucas, Micron **SME:** Dr. Wei Zhou **Mentor:** Prof. Gino Manzo **GTA:** Amrita Chakraborty

Motivation

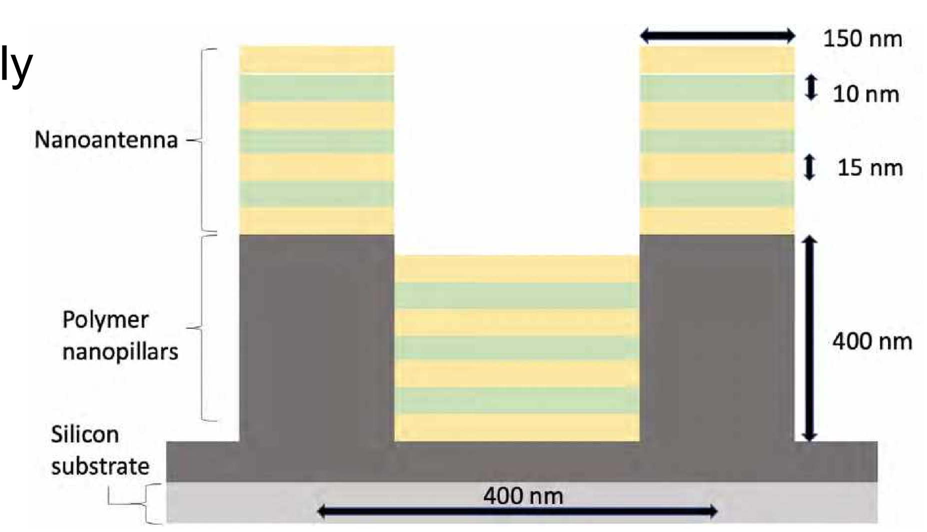
Provide Surface Enhancement of Raman scattering over a tunable broad wavelength range with a simple fabrication technique and perform simultaneous measurement of intracellular electrical potential in cells.



Objectives

1. Fabricate out of plane nanoantenna with electrically conductive and optically transparent ITO - Metal structure.

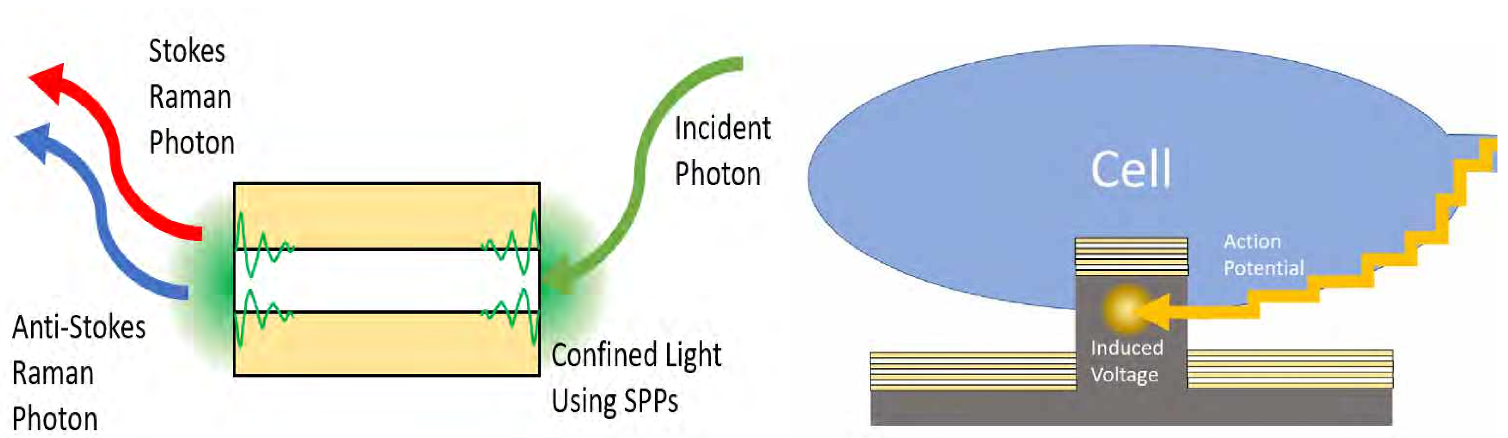
2. Determine deposition parameters to deposit optically transparent and electrically conductive ITO on a metal substrate.



Theory of Operations

Electrical Operation
The nanopillars are dimensioned such that they can be engulfed by a cell or can provide direct intracellular access. Voltage signals within cellular environments, such as action potentials, can induce voltages on a nanopillar or set of nanopillars. The signal can then be detected via electrodes connected directly to the array surface and read into a data acquisition system.

Optical Operation
Through optical techniques, the nanopillars allow for better detection and categorization of molecular species within the nanopillar environment. The method performed is known as Surface Enhanced Raman Spectroscopy (SERS). In this method, incident light is intensely confined into Surface Plasmon Polaritons at each metal-insulator interface and is then scattered by nearby molecules. The identity of the molecules can be obtained by analyzing the spectrum of the scattered light.



Fabrication Process

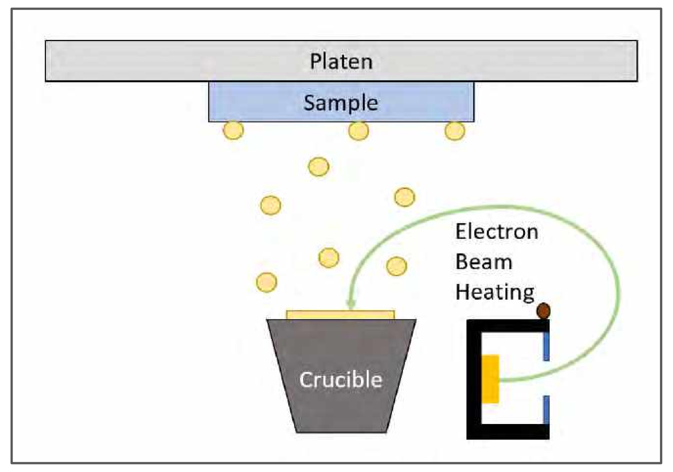


Table 1: ITO deposition parameters

Deposition Thickness	65.1nm
Deposition Rate	1.0 A/s
Current	17-18 mA/A
Substarte Temperature	200°C
Chamber Pressure	9.5x10^-5 torr
Oxygen Flow Rate	3.4 sccm

This project required the use of Electron Beam deposition, which is a form of physical vapor deposition. E-beam works by targeting a material with this beam, which then causes the material to turn into a gaseous phase. Once complete, this material then precipitates as a solid form and coats everything that is in the vacuum chamber with a thin layer of the material. By setting deposition parameters, we can then increase or decrease the rate at which this material precipitates and coats the target substrate.

Test Results

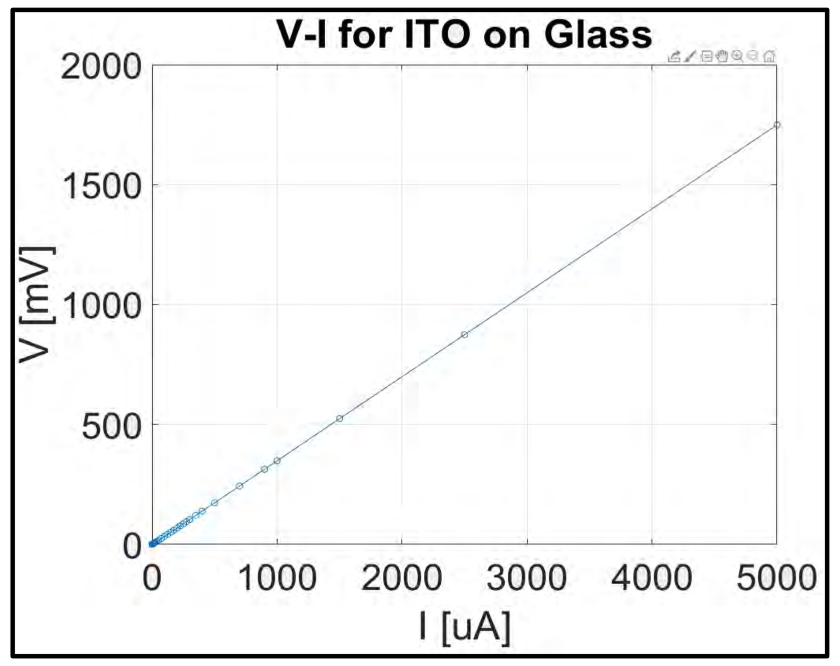


Fig 1. V-I of ITO on Glass, R' = 9.5E-5 Ω-m

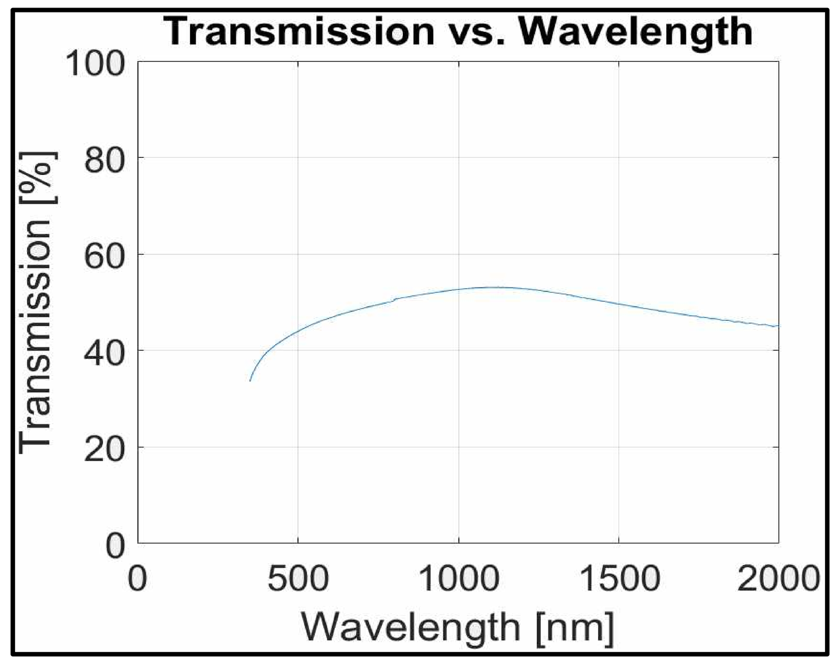
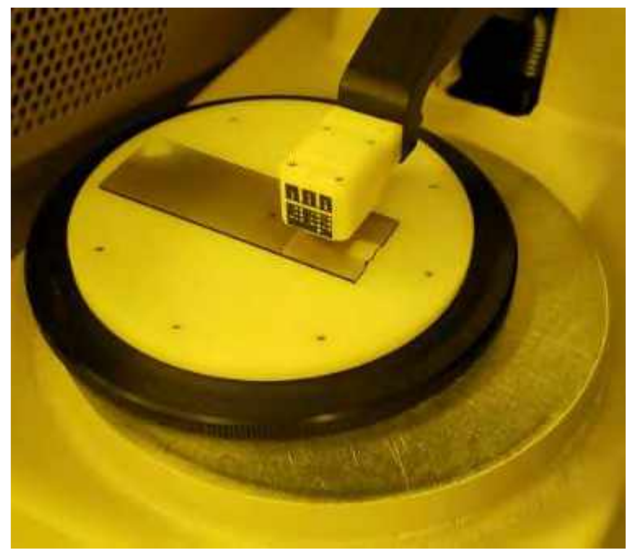


Fig 2. T(λ) for 65 nm ITO on 1mm glass slide



Agilent Cary 5000 Spectrophotometer
Source: agilent.com

FDTD simulation

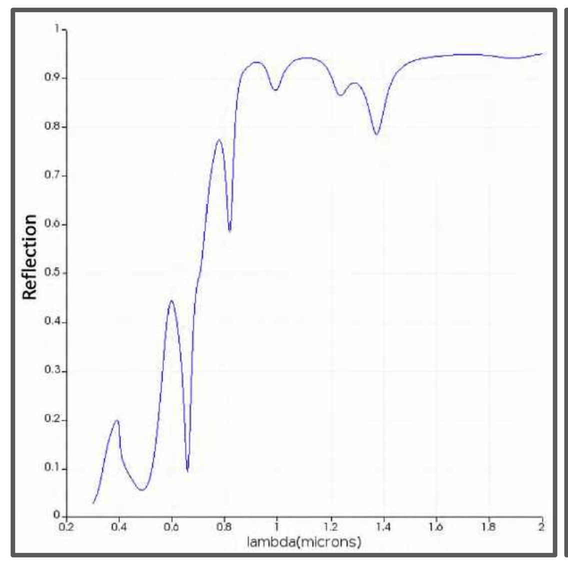


Fig 3. Au/SiO_2 Nanopillars Reflectance Spectroscopy

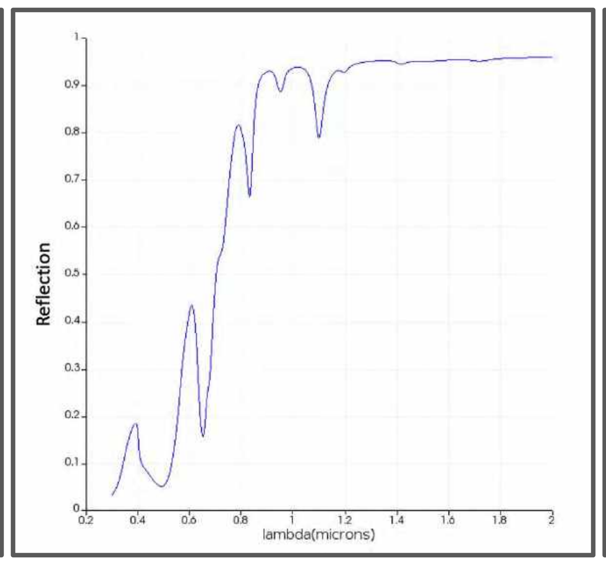


Fig 4. Au/ITO Nanopillars Reflectance Spectroscopy

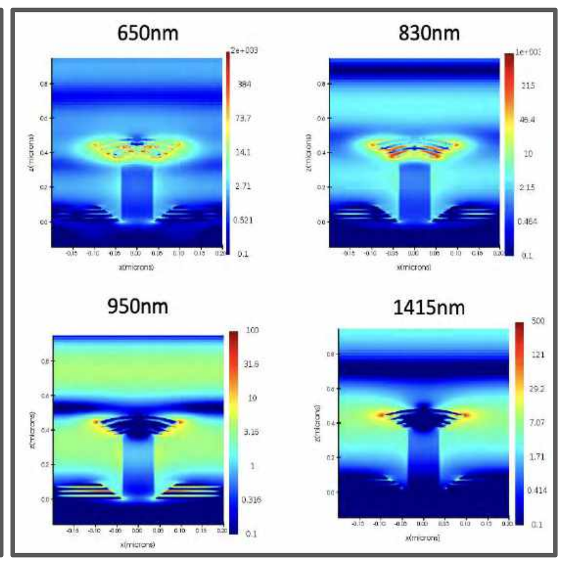


Fig 5. Au/ITO Nanopillars Spatial distribution of Enhancement Factor at resonant wavelengths

Analysis and Conclusion

1. The V-I characteristic of ITO shows the resistance of 350 Ω. Considering the location of measurements taken on the device and the probe structure, resistivity can be calculated to be of 9.6 x 10^{-5} Ω-m which is on par with reported values in literature. The spectrophotometry shows the transmission percentage of 48% over the wavelength of 600 nm - 800 nm.
2. This data suggests the feasibility of ITO as the insulator material for the nanoantenna, as it satisfies both the electrical and optical constraints; conductive in low frequency (DC) for electrical measurements and optically transparent and electrically insulating in the high frequency spectrum.
3. Fig 3 and Fig 4 show simulated reflectance spectroscopy for the Au/SiO_2 and Au/ITO nanopillars. It can be concluded that theoretically, both SiO_2 and ITO have comparable optical properties and nanoantennas made with both have multiple resonant peaks in the Visible to NIR wavelength range. Fig 5. shows the spatial distribution of intensity enhancement factor for Au/ITO nanoantennas showing multiple hotspots and enhancement factors upto 10^3, which would lead to a practical intensity enhancement of 10^{12} in the hotspots.
4. This work provides proof of the manufacturability and capability of hybrid electrical-optical nanoantennas deposited with an Electron Beam Physical Vapor Depositor.

Future Plans

In the future, Gold-ITO nanoantennas will be fabricated and their functionality will be tested by performing the characterization tests in Table 2 on them.
Furthermore, to make the device CMOS compatible, new nanoantennas will be fabricated with Copper or Aluminum as the metal and the characterization tests in Table 2 will be performed on them.

Table 2: Characterization tests

Characterization	Test
Structural	Atomic Force Microscopy
	Scanning Electron Microscopy
Optical	UV-Vis-NIR Spectrophotometry
	Spectroscopic Ellipsometry
	Surface Enhanced Raman Spectroscopy
Electrical	Four Point Probe
	Electrochemical Impedance Spectroscopy

Exploring possible applications for the technology will also be important. Growing cancer and neuron cell cultures on the devices and attempting to measure intracellular electrical potentials as well as performing Raman sensing will show the novel capabilities of this device. Additionally, biocompatibility of the CMOS compatible materials will also need to be analyzed.

Acknowledgements

We would like to thank the following people for their continued support:
- Dr. Wei Zhou (SME)
- Prof. Gino Manzo (Mentor)
- Nick Phucas (Customer Contact)
- Amrita Chakraborty
- Yuming Zhao
- Don Leber (Clean Room)

Symbol Constellation Detection Algorithm for Classifying Signals

Team Members: Ethan Goldenberg, Ben Hecker, Jade Sabourin

SME: Dr. William "Chris" Headley **Mentor:** Toby Meadows **MITRE:** Dr. G.R. Dattatreya, Dr. Dale Herdegen

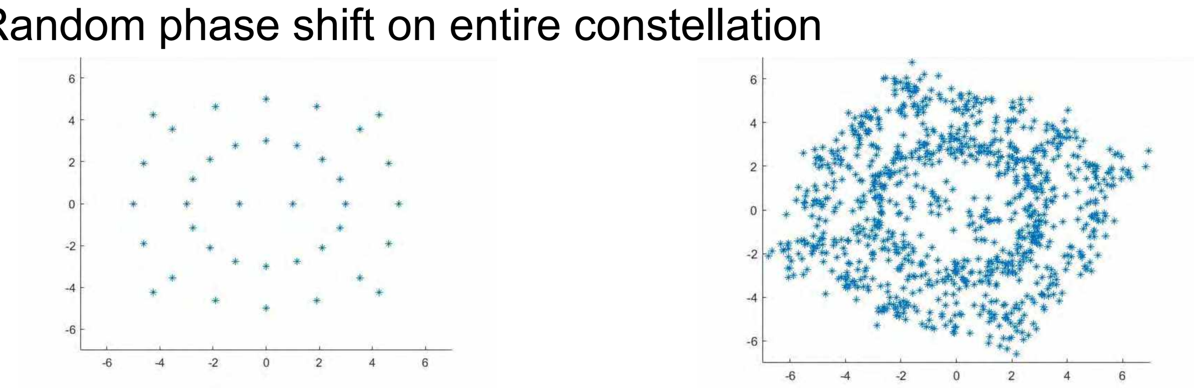
I. Motivation

Design and develop an algorithm to identify APSK modulated signals. The goal is to aid in keeping friendly signals undetected and intercept enemy signals for intelligence purposes. The digitally modulated symbols will be represented in symbol constellations which are complex scatter diagrams of the symbols.

II. Key Requirements

The symbol constellations from the signals will have:

- 1 - 4 amplitude levels
- 2-16 PSK per amplitude level
- Additive white gaussian noise to mimic channel noise
- Random phase shift on entire constellation



III. Test Cases

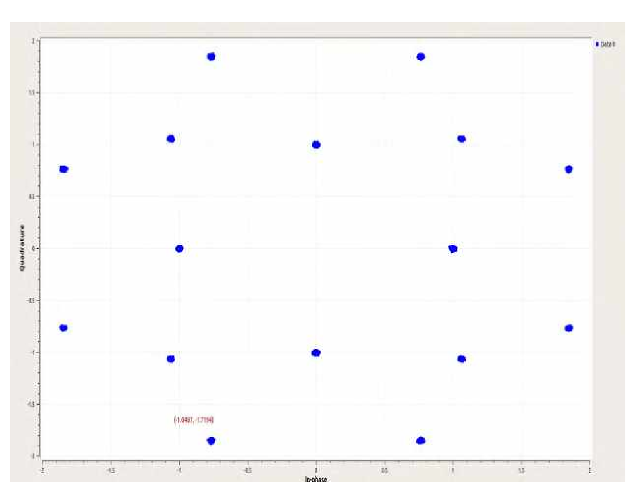
Team Orion was asked to specifically identify the following constellations.

Test Case 1

1. QPSK, no phase shift
2. QPSK, 45° phase shift
3. 8-PSK, 22.5° phase shift

Test Case 2

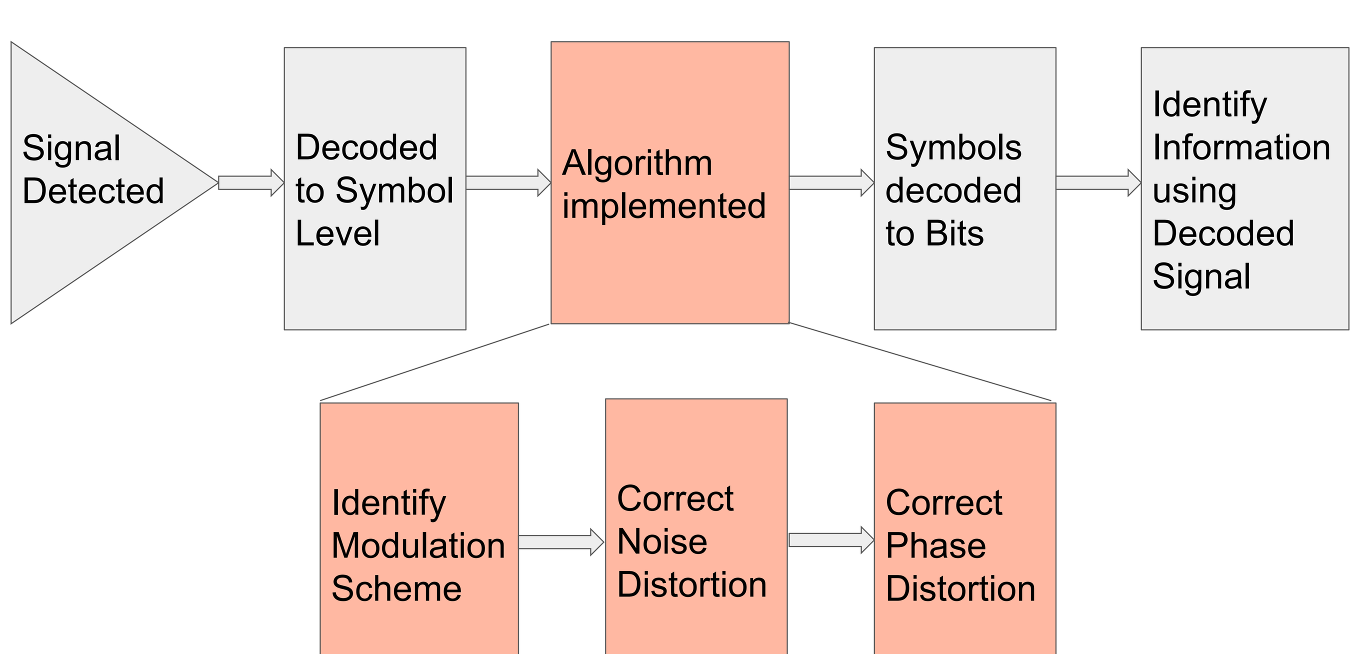
PSK order of 2,3,4,5 if the constellation is one amplitude



Test Case 1

IV. System Block Diagram

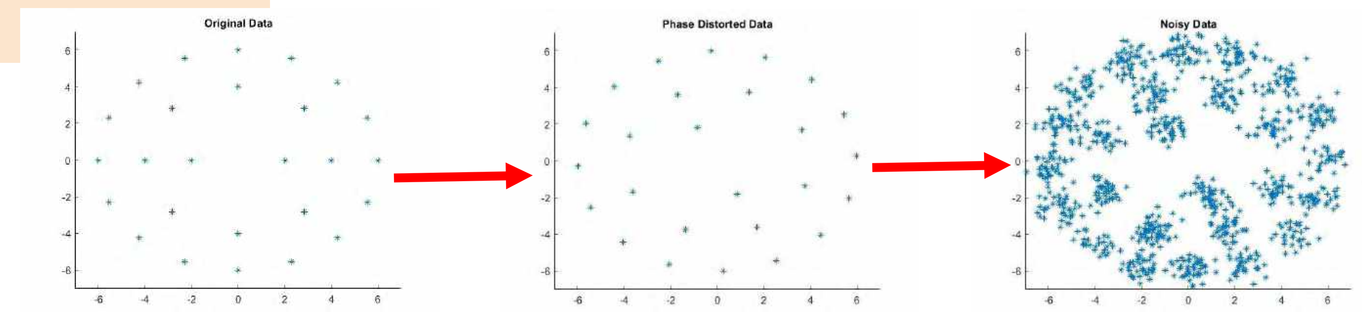
The algorithm will be used after the signal has been detected and frequency locked but before the symbols have been decoded to bits and the information has been retrieved.



V. Algorithm Process

Step 0: Signal Generation

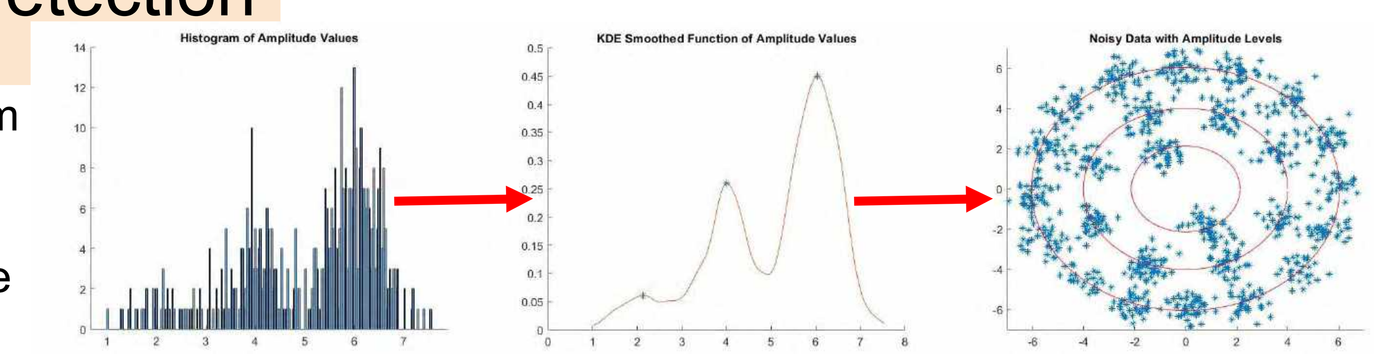
The test signals have a randomly generated modulation scheme with an added random phase shift and AWGN.



Modulated Symbols — Shift Applied — Noise Added

Step 1: Amplitude Detection

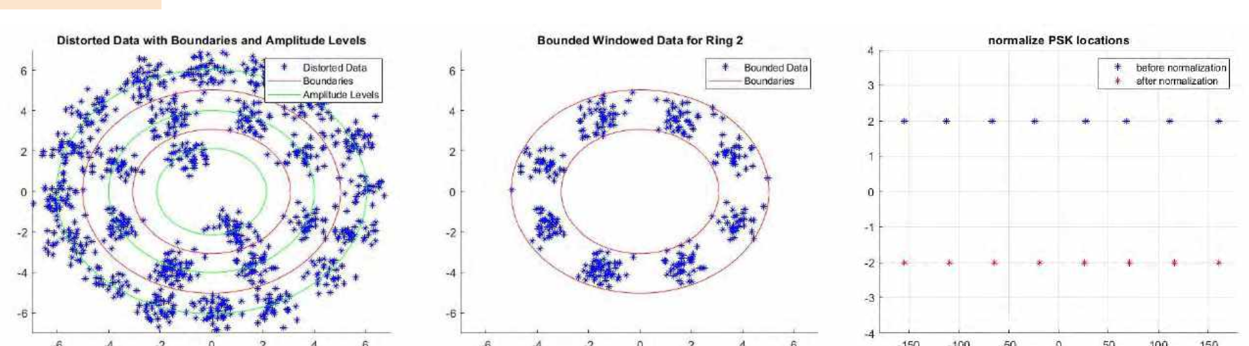
The algorithm takes a histogram and uses a KDE function to smooth the data. It then finds the local peaks which designate the amplitude levels.



Histogram — KDE Curve — Levels in Red

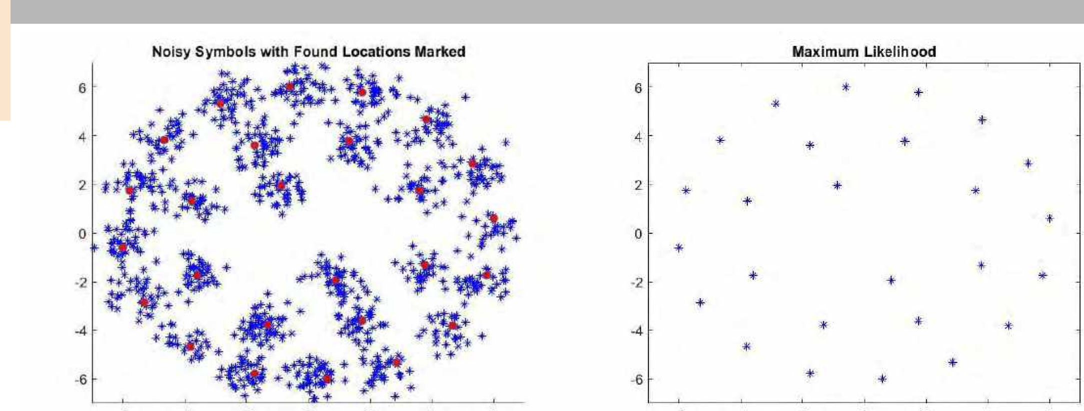
Step 2: PSK Detection

The found amplitude levels then determine the boundary conditions. With the data split, the algorithm creates similar histograms and KDE curves to determine the phase locations. The locations are then normalized for even spacing.



Step 3: Correct Distortion

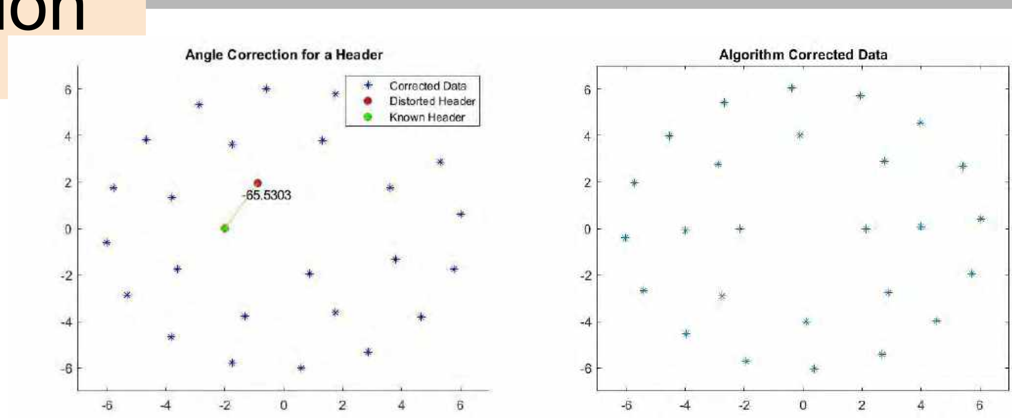
With the phases and amplitudes determined, the algorithm can determine the intended locations for the data. Then, each noisy data symbol is "snapped" to those locations, removing the noise. Phase distortion is also corrected, using a header if one is present.



Found Locations in Red — Data with Noise Removed

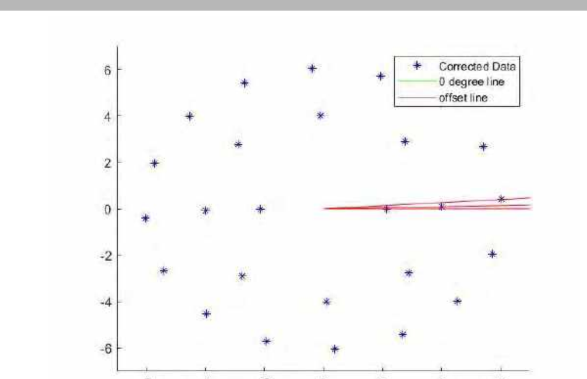
Step 4: Correct Phase Distortion

In this example, the phase distortion is identified by the angle offset of a header. However, this phase distortion may still be corrected without the use of a header.

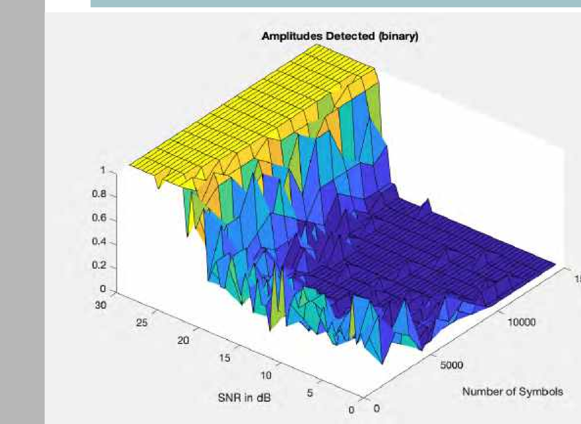


Step 5: Determine Ring Offsets

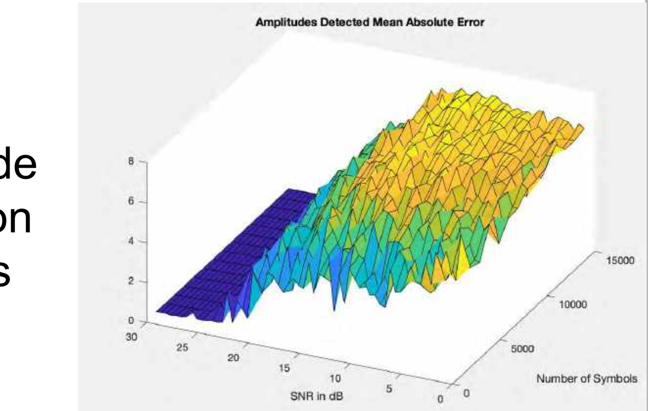
The last step in the algorithm is to determine if there is a phase offset between rings in the original modulation scheme. This is done by finding the location closest to 0 degrees for each of the rings and taking its angle value as the offset value.

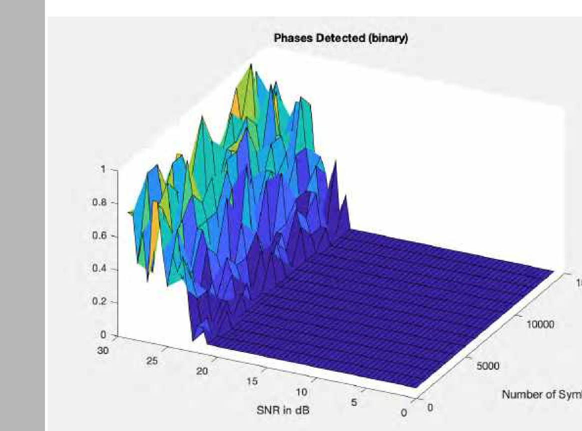


VI. Performance and Analysis

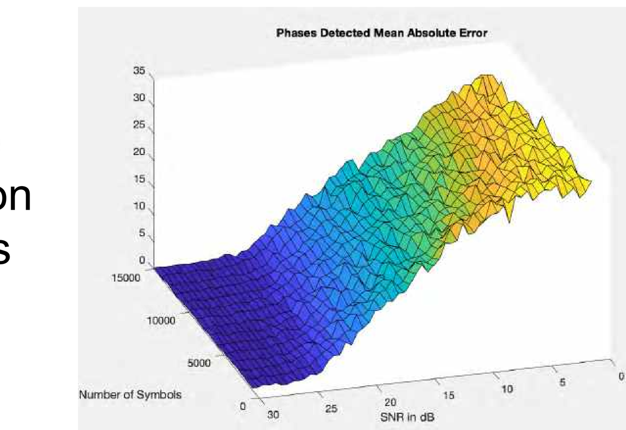


Amplitude Detection Graphs

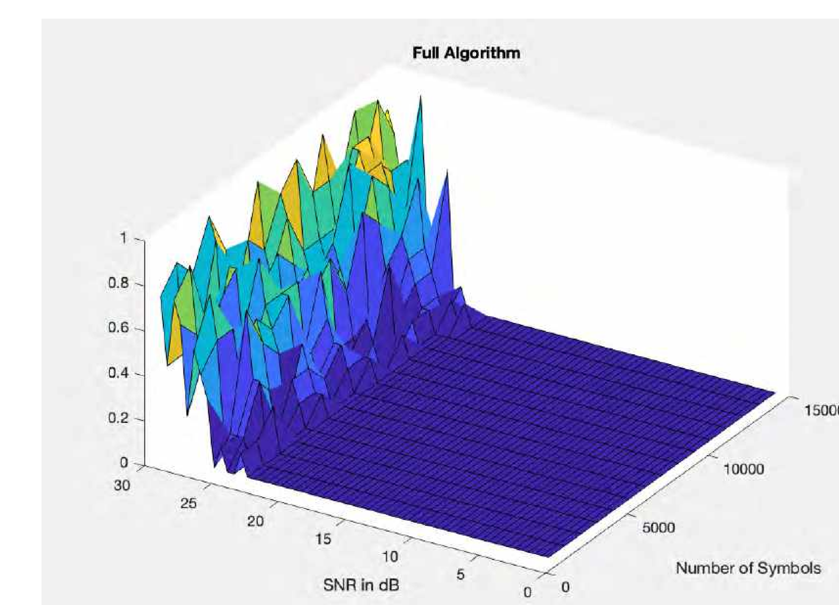




Phase Detection Graphs



- Tested at a range of 0-30 dB for SNR and 150-15,000 symbols.
- Phase and Amplitude detections tested independently
- Determined to be a function of SNR
- Minimal effect with increasing number of symbols



This graph shows the total algorithm's accuracy in identification of the modulation scheme. Meaning, all amplitudes were found within 5% of their true values, the correct number of phases were detected for each ring, the locations were within 5 degrees of their true locations, and any phase shift was identified.

VII. Conclusion

The algorithm correctly identifies the modulation scheme at or above 90% of the time at an SNR around 24 dB with a minimum of a few hundred symbols. More research is needed to understand the effect of the number of symbols on the algorithm's effectiveness.

VIII. Future Work

Future opportunities to improve the algorithm and the scope:

- Test performance over open-air channel with USRP and GNU
- Reduce computational intensity to reduce run time
- Implement the Mackenthun Algorithm for PSK detection
- Reduce the number of assumptions (such as Tx/Rx synchronization)

IX. Acknowledgement

Special thanks to Dr. Headley, Dr. Dattatreya, and Dr. Herdegen for their guidance and assistance throughout the year.

Drone Reconnaissance - Object Detection

Team Members: Austin Fuller, Xukai Hu, Jonah Orevillo, Srinidhi Rao
Customer: Michael Sparr **SME:** Dr. Daniel Stilwell **Mentor:** Prof. Toby Meadows

Introduction

Drone reconnaissance missions frequently use military target identification. This project simulates drone to drone communication - one drone performing object detection and the other drone performing object retrieval - to accomplish reconnaissance missions. While doing so, the drones are to communicate with each other for the position data of the desired target to ultimately retrieve said object quickly and efficiently.

Key Requirements

- System shall transmit flight and target data to ground station (GS) and to sister drone
- System shall automatically detect and evade obstacles in flight path
- System shall report (ie. GPS, lat, lon, alt, heading, battery %, mission etc.) at a rate of 1 Hz
- Operator shall be able to deviate drone from original mission path in mid-flight
- System shall resume mission from where it last left off after deviation
- Drone shall be able to fly for a minimum of 15 minutes at an altitude of 6 feet or more
- System shall contain:
  - kill switch, manual override, geofencing, return to home when battery is depleted
- System shall provide target recognition of these shapes:
  - circle, square, triangle
- System shall automatically provide info of target movement data to sister drone

System Architecture

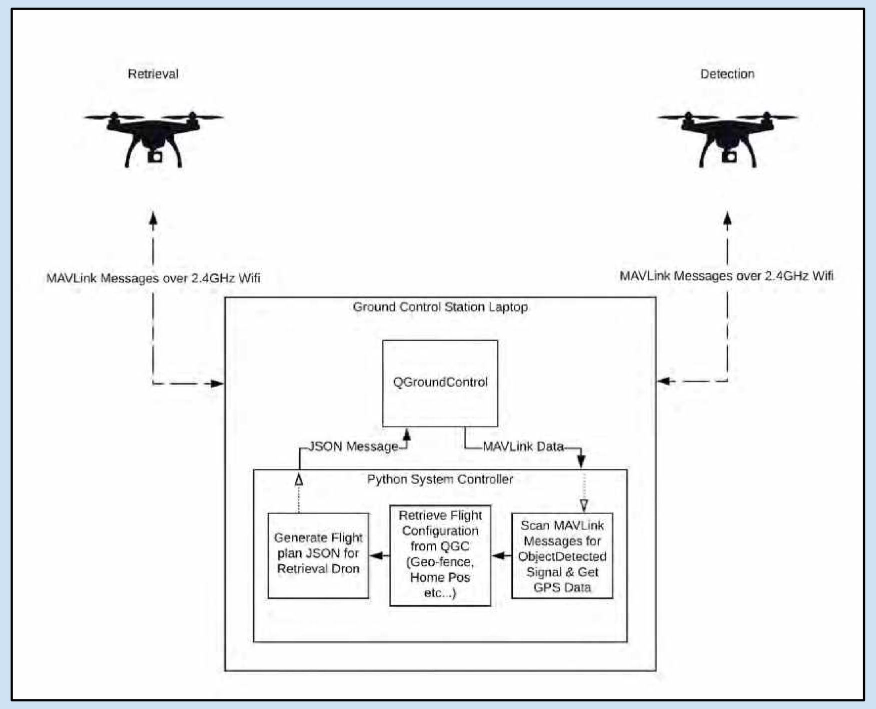


Figure 1: System Architecture Block Diagram

Sample Flight Procedure

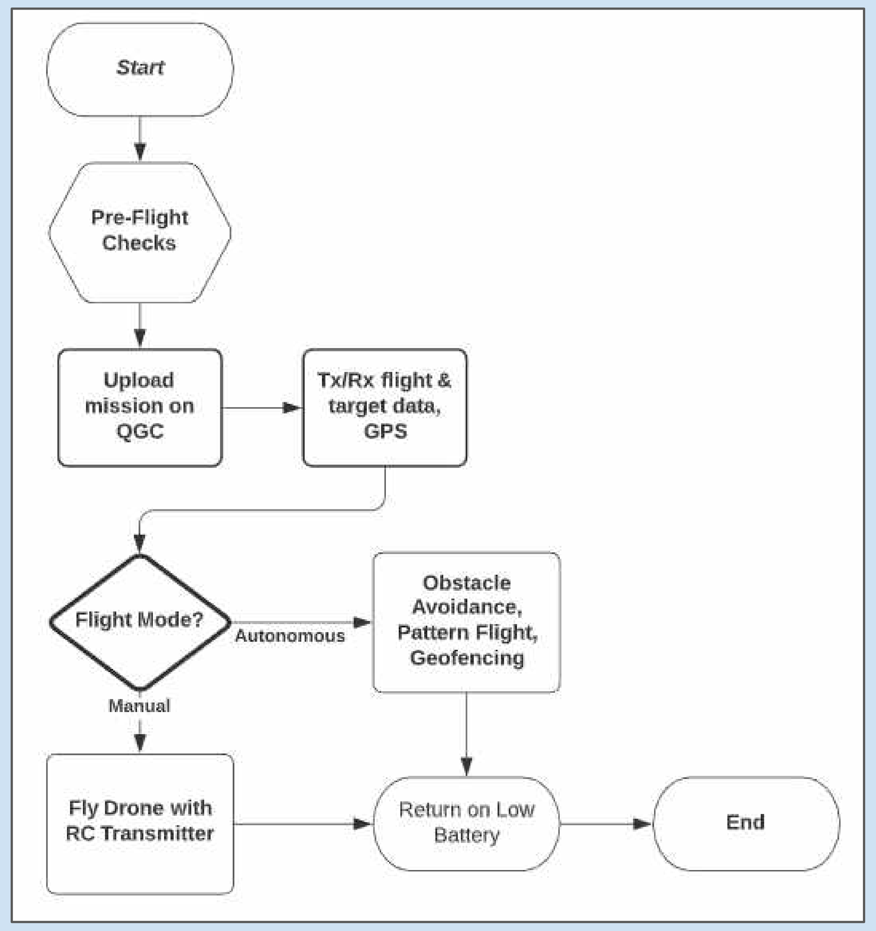


Figure 2: Sample Drone Flight Procedure Flowchart

Sub-System Designs & Results

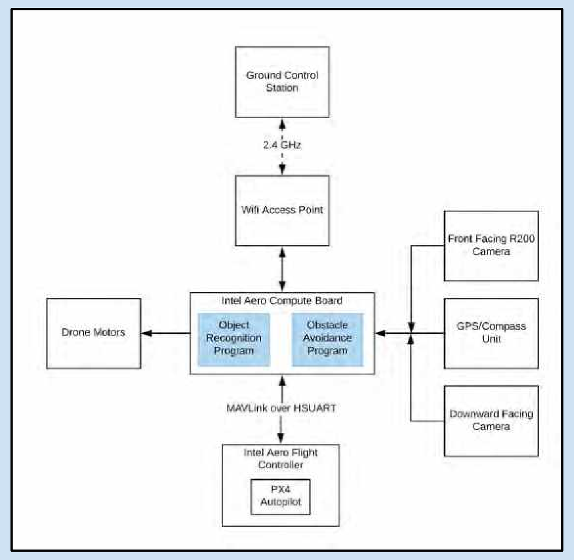


Figure 3: Sub-system Block Diagram

System divided into multiple sub-systems:
- Telemetry
- Flight Control
- Object Detection

Experimental Setup
- Drone
- GS - computer with QGroundControl (QGC)
- Python Script running object detection program
- QGC running obstacle avoidance software

Ground Control Station

Figure 4: QGC Main View

Figure 5: Drone-GCS Setup

Optimizing QGroundControl enhanced the system design. QGC provided user friendly capabilities to communicate with the drone and sister drone to provide key information regarding GPS and Telemetry for the drone reconnaissance mission.

Obstacle Avoidance

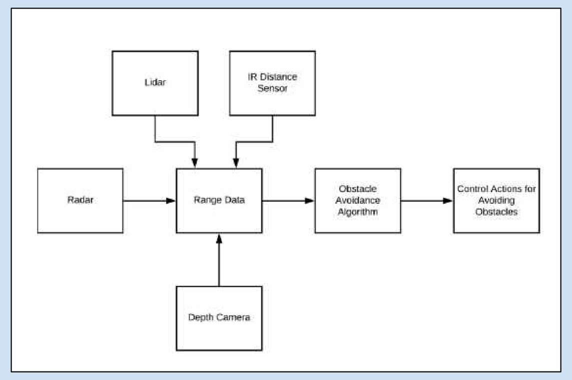


Figure 6: Obstacle Avoidance Block Diagram

Figure 7: Obstacle Avoidance Simulation:

The obstacle avoidance system is shown through a simulation running on Gazebo with ROS in Ubuntu. The red line is the estimated route calculated by PX4, and the green line is the actual flight path of the drone.

Object Detection

Running the Python script with OpenCV library included, red images (shapes) were shown to the camera at a 5 ft. distance and the black and white images are contours of said detected image.

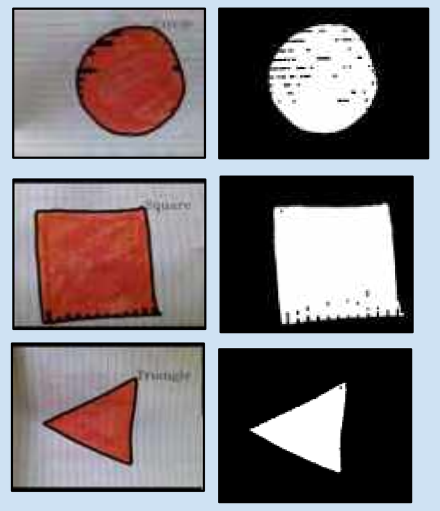


Figure 8: Object Detection Results from Webcam

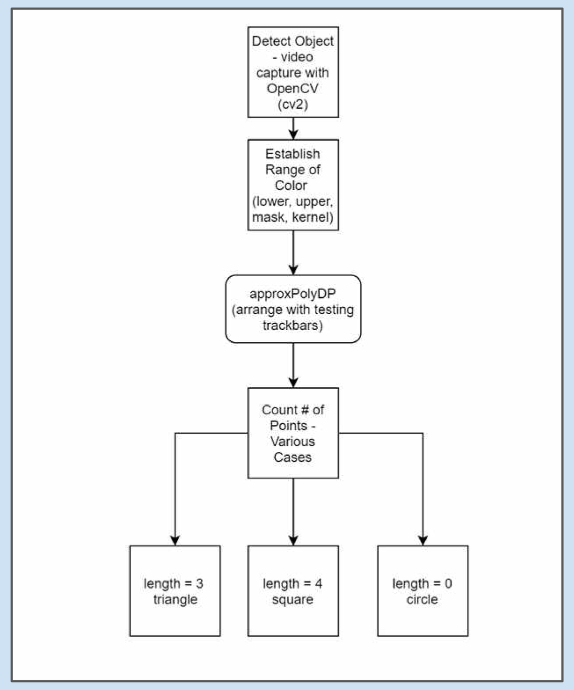


Figure 9: Edge Detection Block Diagram

Challenges

Major Challenge: Drone mission cannot be uploaded from GCS to drone. Faulty communication protocol

Initial Problem Sources:
- Faulty Version of PX4 does not allow mission upload
- High loss rates between drone and GCS prevent messages from sending properly

Initial Solutions:
- Reinstall PX4: Various attempts at reinstalling PX4 made, none worked. Bug may be more prevalent than expected.
- Use stronger antenna on drone and GCS to reduce loss rate: Unsuccessful, loss rate remained high. Other team drone had same issue

Results: None of our fixes solved the problem and we were left with an inoperable drone. The provided software from the manufacturer is plagued with bugs, and the documentation is incomplete

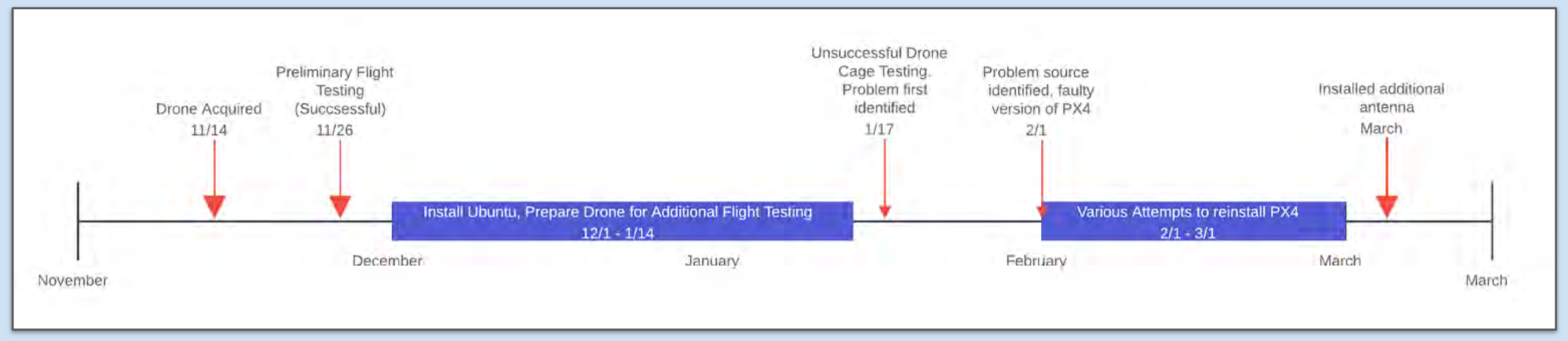


Figure 10: Project Event Timeline

Future Plans

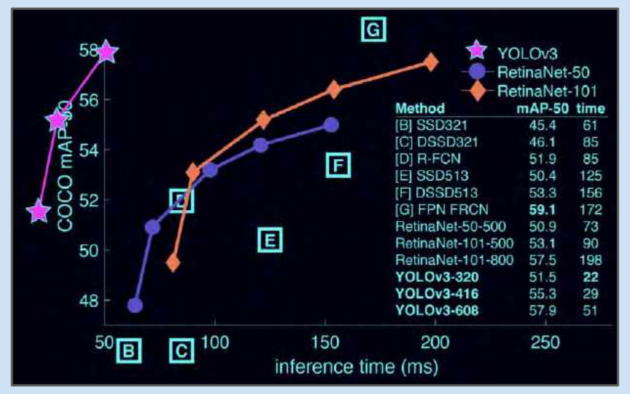


Figure 11: YOLO CNN Image Detection Time Comparisons
https://pjreddie.com/darknet/yolo/

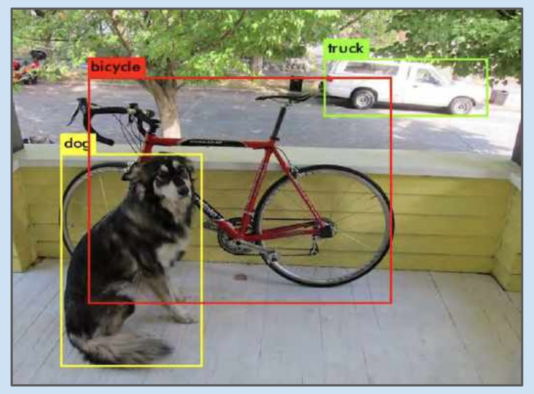


Figure 12: Example Image Detection using YOLOV3

- YOLO Convolution Neural Network for for more complex image detection
- Sister Drone could be set up as mesh network to increase overall system radio range
- Have camera hardware compatible for certain weather circumstances (ie. rain)
- Replace the original microprocessor with a higher performance microprocessor so that the actual flight path could be more accurate

Acknowledgements

We would like to thank the following people for their support throughout the project:
- Dr. Daniel Stilwell (Subject Matter Expert)
- Michael Sparr (Customer Contact)

NAVAIR Drone Retrieval

Team Members: Mary Benden, Ethan Brooks, Brett Pollman, Nick Sileu **Customer:** Mr. Thomas Newhart
SME: Dr. Daniel Stilwell **Mentor:** Prof. Toby Meadows **GTAs:** Amrita Chakraborty and Jiayu Li

Motivation

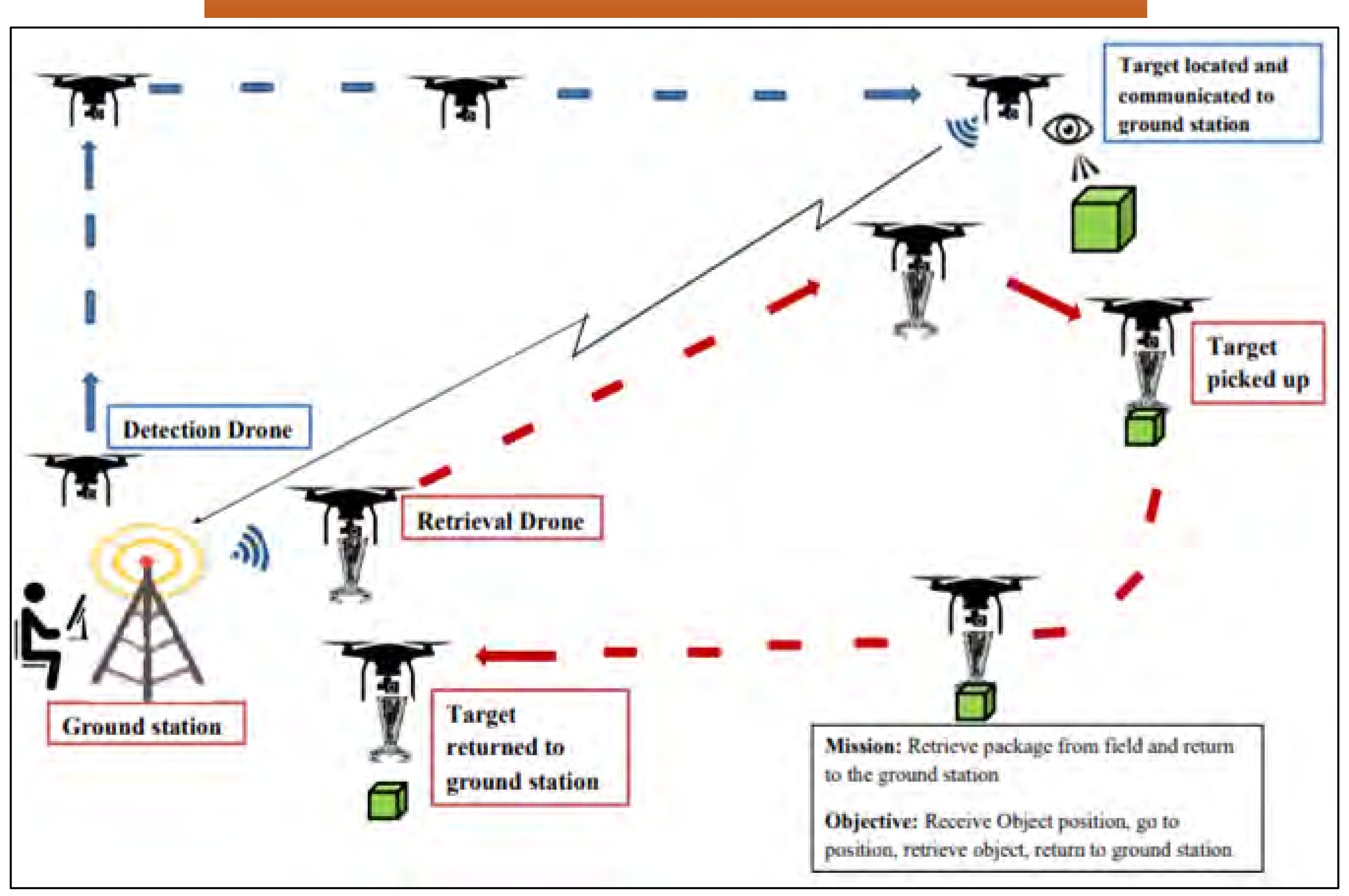
In civil scenarios, there are many times where objects, such as food or medical supplies, need to be retrieved or delivered to secure or dangerous environments. To help deliver these supplies, NAVAIR is developing a dual drone system that relies on a surveillance and retrieval drone that communicates through a centralized ground server system.

Objective

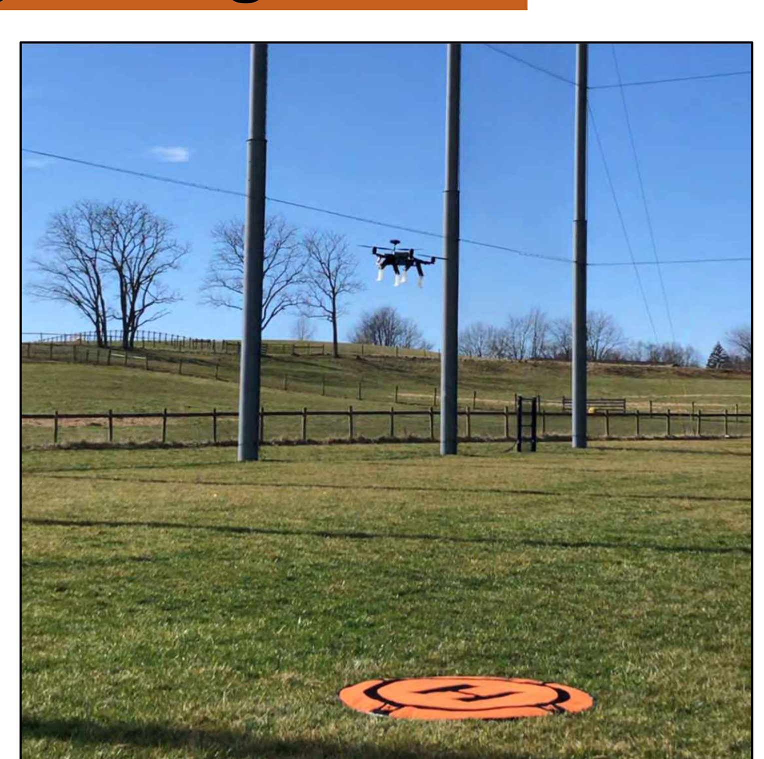
Our objectives were to develop a mechanism capable of the following:

- Autonomously retrieving an object in any terrain
- Carrying the target at a height of at least six feet for up to 15 minutes
- Transmitting and receiving flight and target data throughout the mission
- Automatically detecting and avoiding obstacles in the flight path
- Terminating the current mission upon utilization of a kill switch
- Returning the object to the home-base location

CONOPS



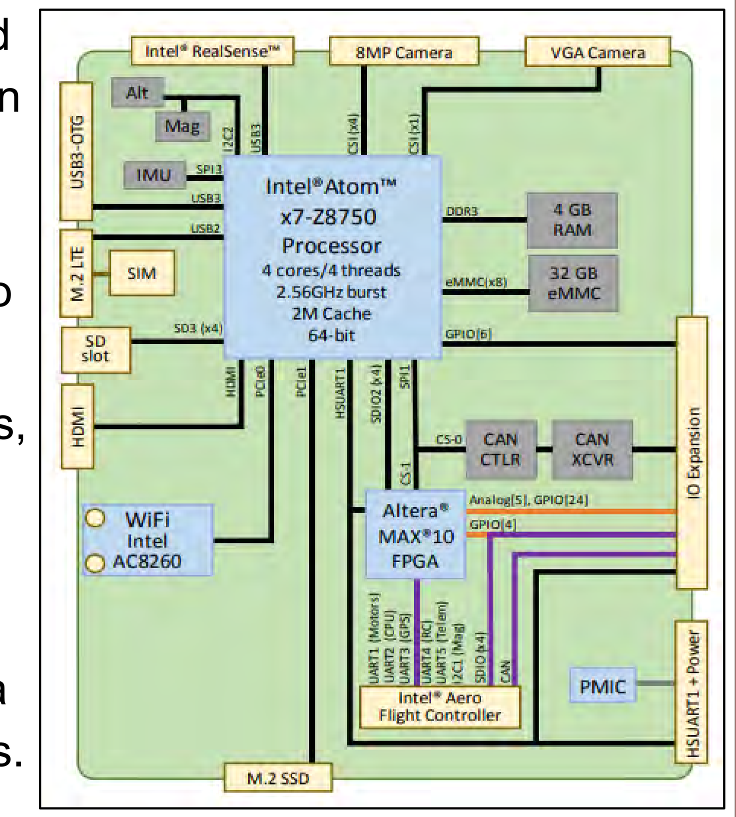
Drone Flight Images



Drone and QGroundControl

The Intel Aero Drone, which uses software called QGroundControl (QGC) to communicate between the drone and computer, was used:

- The Intel Aero Drone comes with an autopilot function that can be accessed through QGC to support autonomous missions.
- The drone has an accessible internal compass, gyroscope, accelerometer, and speed sensor.
- QGC has geofencing capabilities that limit the active flying area.
- QGC also gave the ability to get real time data as the drone recorded different measurements.



Claw/Arm Design Alternatives

Three alternatives were designed for retrieving the target and returning it to the ground base. Figure 1 shows the velcro stamper which attached to the target via a velcro strip. The claw shown in Figure 2 attached to the drone through an electromagnet and would be released at the drop location. Figure 3 is a pincer that uses Pulse Width Modulation (PWM) to open and close the servo.

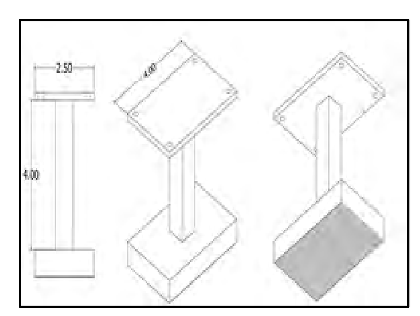


Figure 1: Velcro Arm Stamper

Figure 2: Electromagnetic Claw

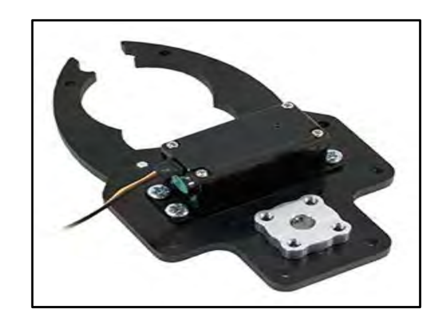
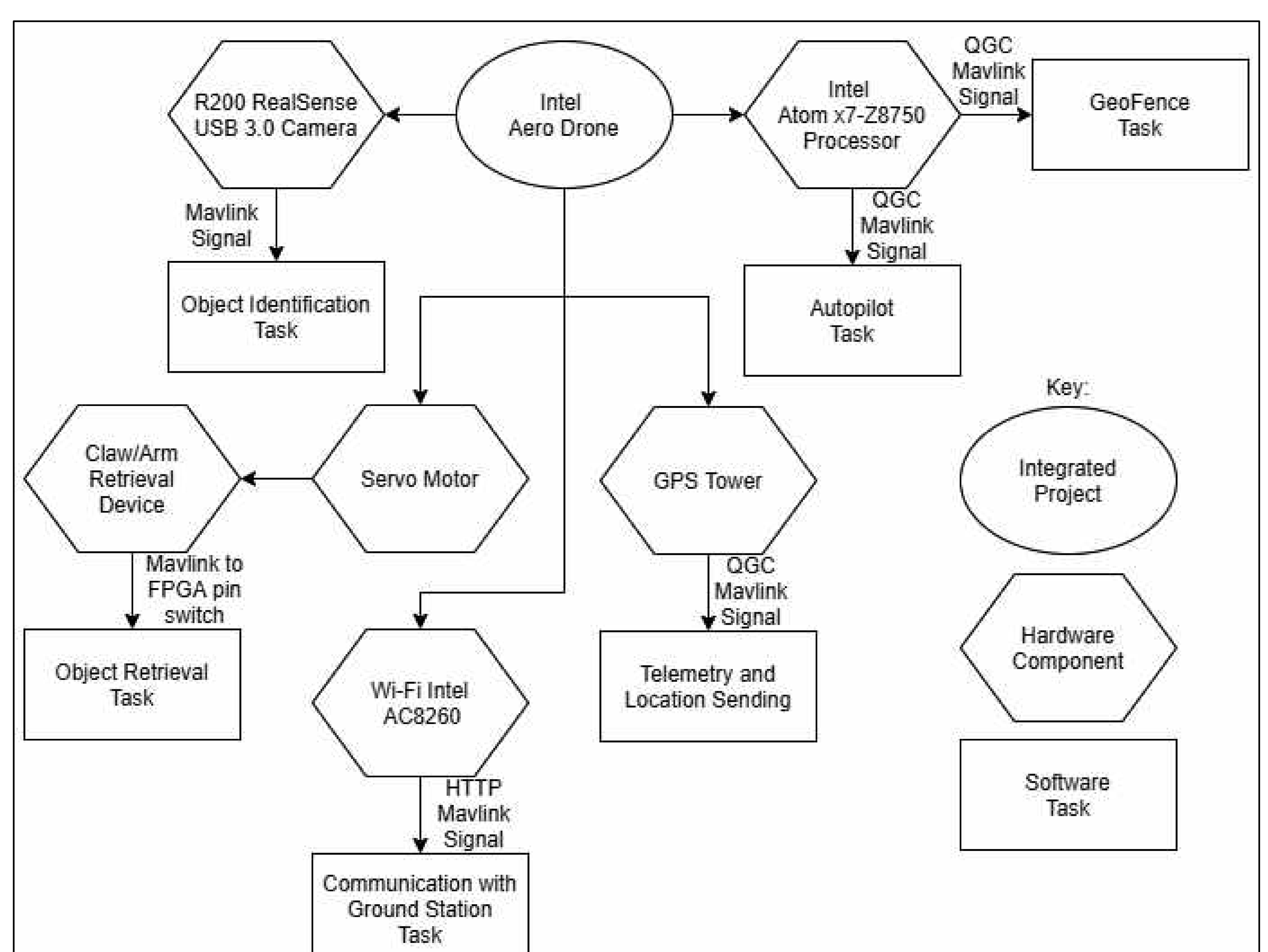


Figure 3: Horizontal Pincer

System Architecture



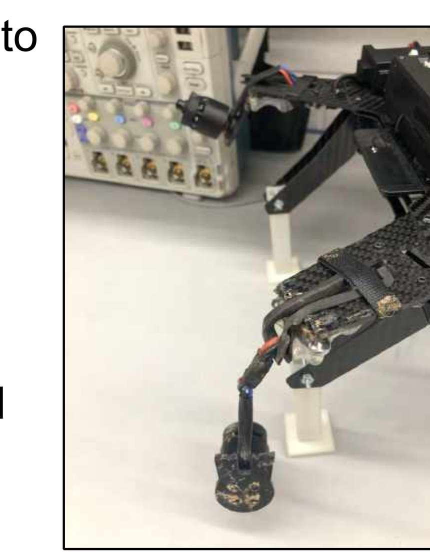
COVID-19 Mitigation

Due to the unfortunate timing of COVID-19, the Drone Retrieval team could not make any further progress on the project. Our last flight test in late February was our most recent progress point, where we successfully uploaded a mission to the drone using QGroundControl. We have kept our customer up to date and forwarded any deliverables possible given that the flight testing of the drone was ceased.

Challenges

The Intel Aero Drone is outdated and is no longer supported by Intel. No software updates have been posted since discontinuation in February 2019. This caused multiple challenges for our team including:

- Mission packet losses of 25%-30%, meaning a large portion of instructions sent to the drone were not received. External drone antennas were bought to mitigate this challenge, but lab closure stopped testing from occurring.
- The Drone Detection team's drone had outdated firmware, so they could not upload missions. Without their drone, ours would not be able to retrieve the object. The updated firmware was not available due to the discontinuation.
- An old unmaintained Ubuntu .iso was required for the drone OS, but the flight software had updated and clashed with the drone synthesis.
- Our team experienced a drone crash on February 19th, 2020. Instead of executing a full mission, the drone skyrocketed into the drone cage roof (80m high) while out of communication range. Two carbon fiber arms snapped, but the motors still worked. Parts were ordered and delivered, but lab closure due to COVID-19 caused repairs to remain incomplete. To the right is a picture of the damages sustained by the drone after the crash.



Project Continuation

- Drone parts have been delivered but the drone still requires repairs
- External antennas need to be attached, synchronized, and tested to decrease packet loss
- Internal log scripts need to be created for system data logging
- Flight Safety Procedures have been created and must be followed to ensure crashes do not occur again
- Arms need to be attached and the camera identification script integrated to the onboard FPGA

Acknowledgements

We gratefully acknowledge the contributions of Professor Meadows, the Drone Retrieval team mentor, for his guidance and assistance throughout the semester. We also thank our customer point of contact, Mr. Newhart, for working with us throughout the year and with many RFP changes.

Teledyne Vacuum Gauge Bluetooth Module

Team Members: Brady Ingham, Joshua Hall **Customer: Teledyne Hastings, POC: Dr. Douglas Baker**

SME: Dr. Tim Talty **Mentor: Prof. Gino Manzo**

Background

Figure 1: HVG2020 (Right)

Teledyne Hastings Instruments is a leading provider of vacuum gauges and gas mass flow instruments

Vacuum gauges are sometimes installed in places where wired communication and manual readings are often difficult

Direct competitors to Teledyne Hastings Instruments currently provide wireless functionality for their gauges via external modules

Consumers are requesting that wireless communication options be made available to query vacuum instruments

A lack of Bluetooth connectivity for the newly released HVG-2020 could result in a loss of market share

Objectives and Requirements

Design a converter module that mounts directly to the serial port of an HVG-2020A gauge that can convert serial data into a Bluetooth signal and vice-versa, such that a user can remotely send and receive data to and from the instrument.

<u>Major Tasks to Meet Objective</u>

Evaluate Bluetooth converter chip sets

Develop "proof-of-concept level" Bluetooth converter

Analysis of limitations such as distance and RF interference

Evaluation of Bluetooth serial communication apps (iOS and Android)

Demonstration of final Bluetooth converter module

<u>Key Requirements</u>

Input: 9-pin male D-Sub that can connect to an input serial cable

Output: 9-pin D-Sub that connects to HVG-2020A gauge

Signal Flow: Module acts a passthrough for the 7 non-communication signals on the input and output connectors, and adds RX/TX TTL signals for the output from the Bluetooth interface on the module

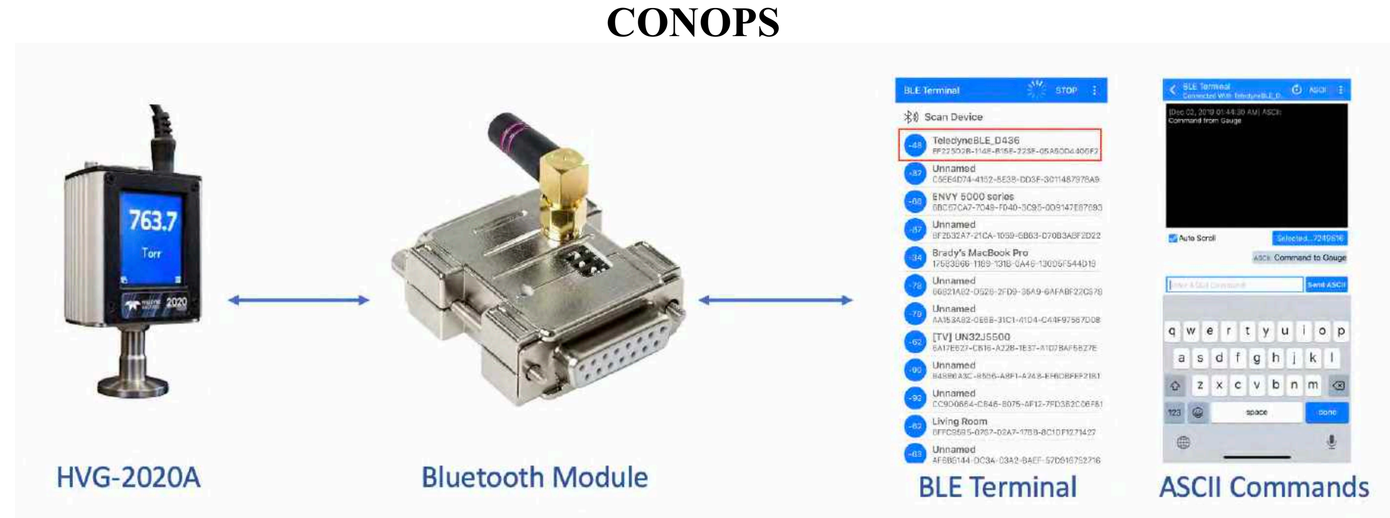
Power: Module must be powered by voltage source from input or output connectors with a voltage between 24-36V

Connectivity: Bluetooth connectivity via a mobile device (both iOS and Android)

Final Product: Proof of concept level circuit demonstrating full capabilities

Design Process

CONOPS



From the customer requirements and derived concept of operations, we were able to develop a block diagram, and from that generate a schematic capture and PCB layout. Through multiple design, build, and test iterations , we ended up with a final prototype

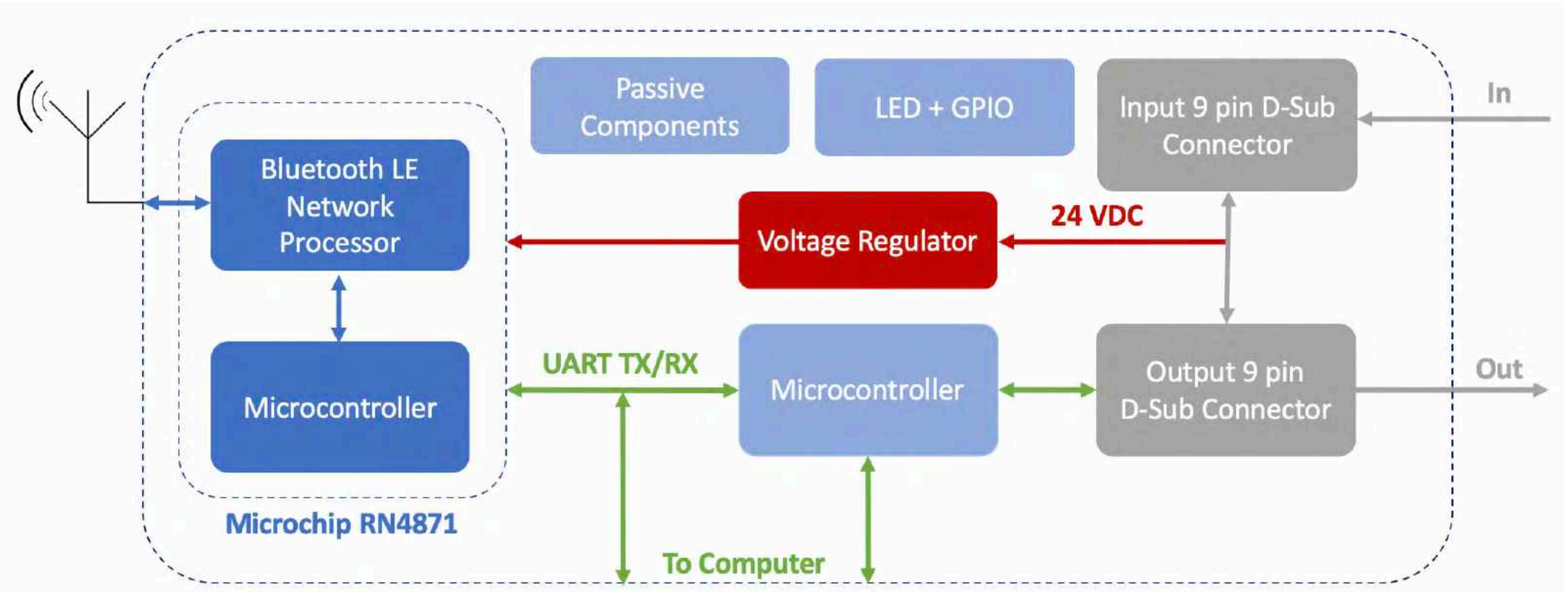


Figure 2: Block Diagram of Final Prototype

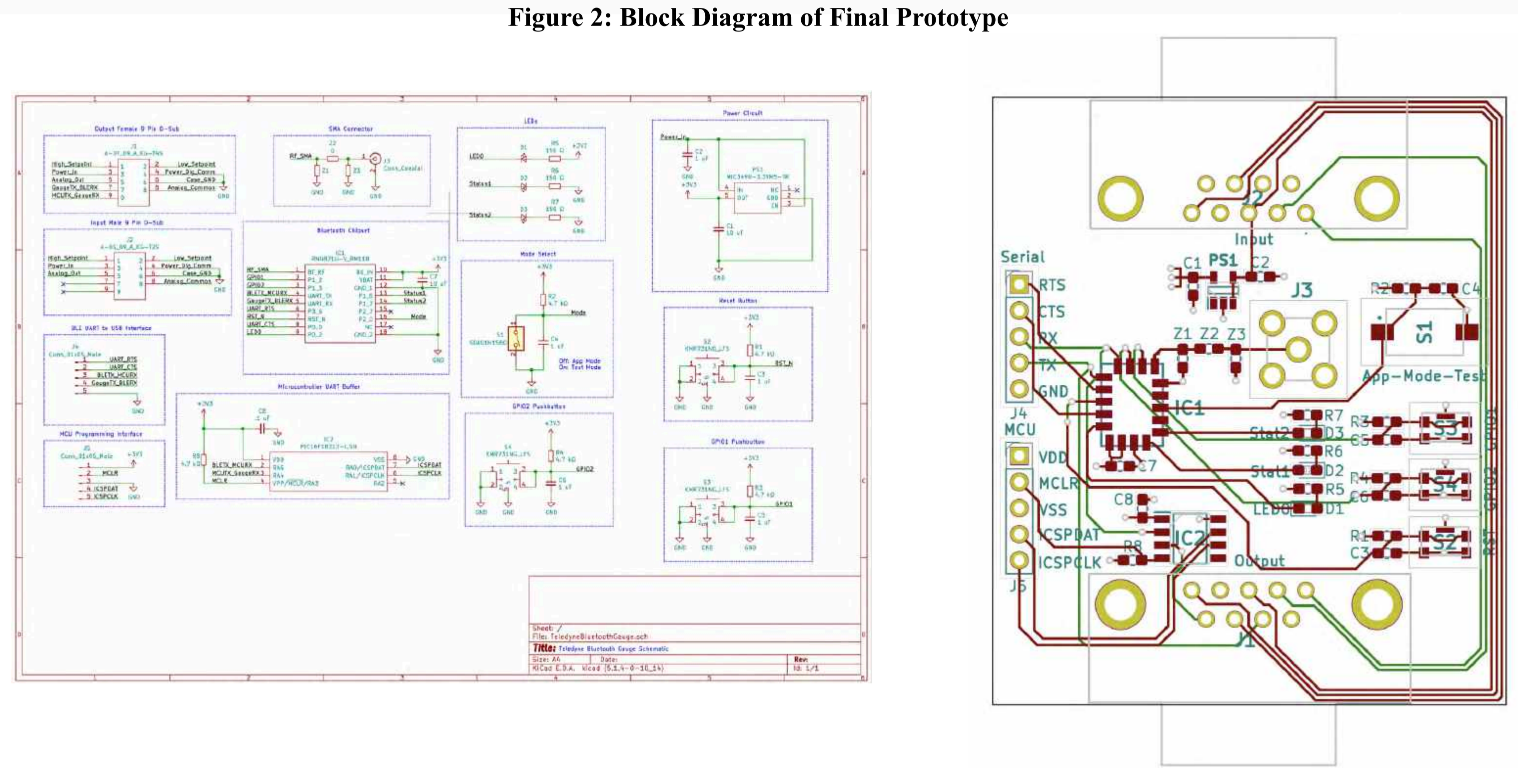


Figure 3: Schematic Capture (Left) and Built PCB (Right)

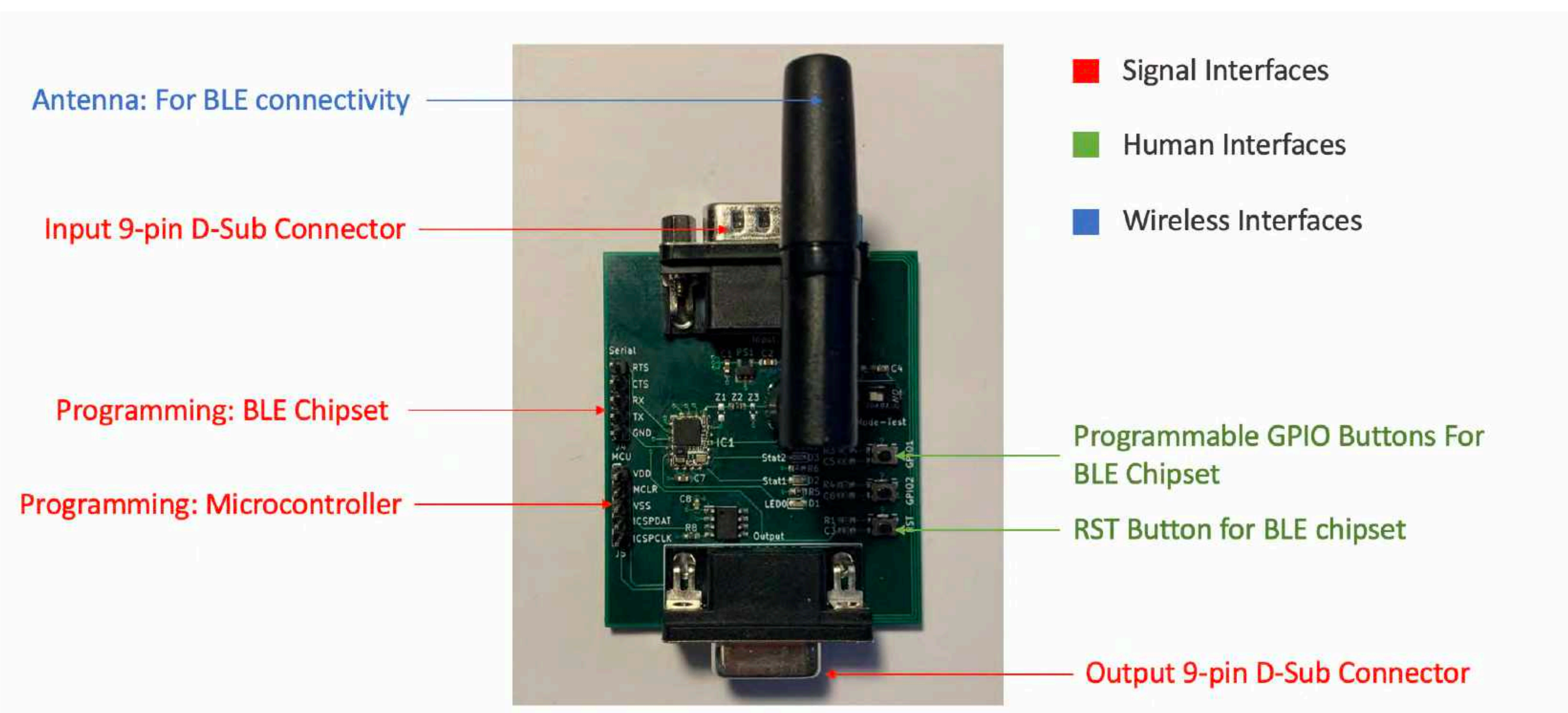


Figure 4: Final Prototype

Final Product Testing

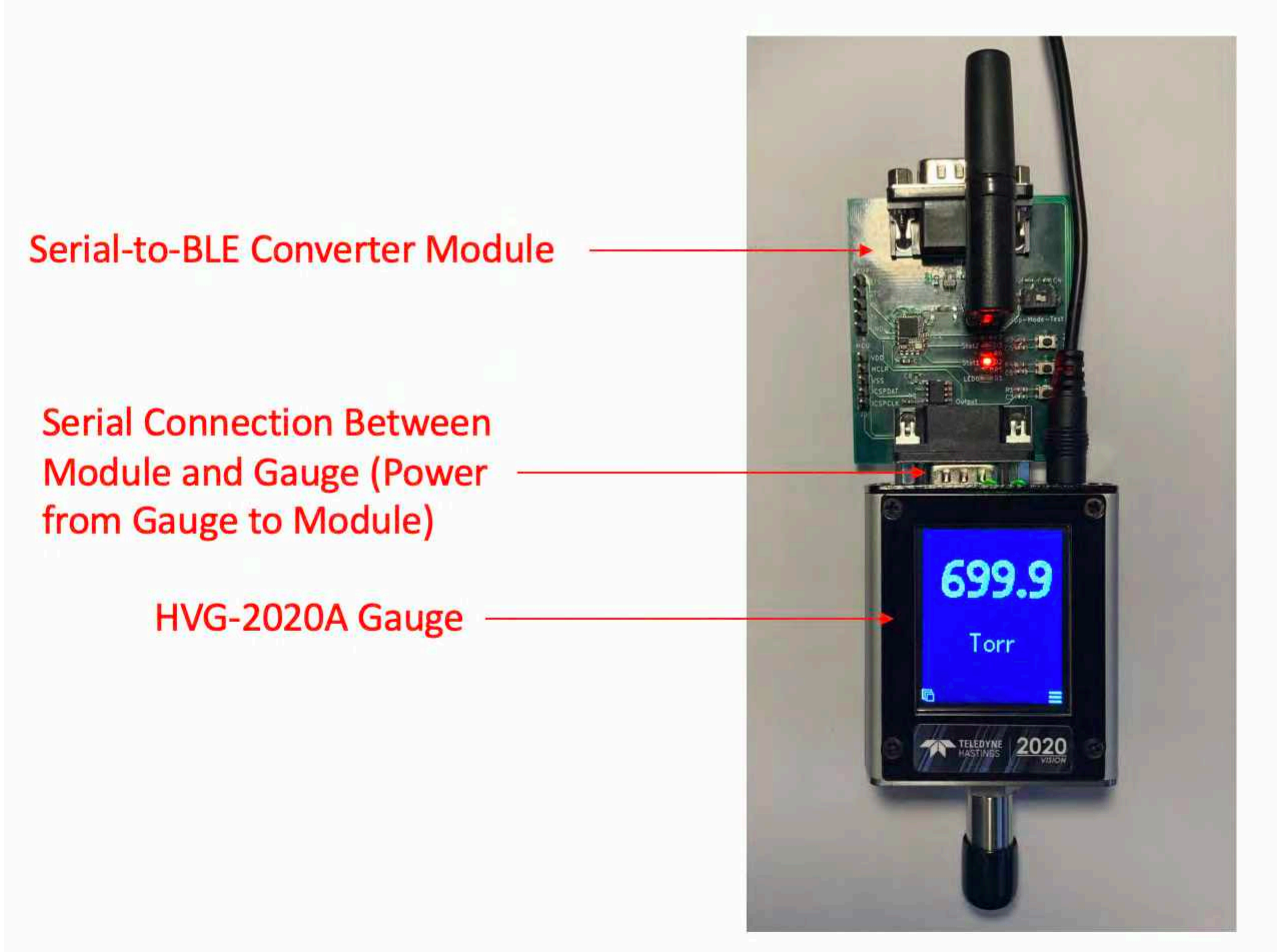


Figure 5: Final design attached to the HVG-2020A Vacuum Gauge

The module connected to and interfaced with the vacuum gauge successfully. The module allowed the user to send commands to the vacuum gauge and receive accurate responses as desired.

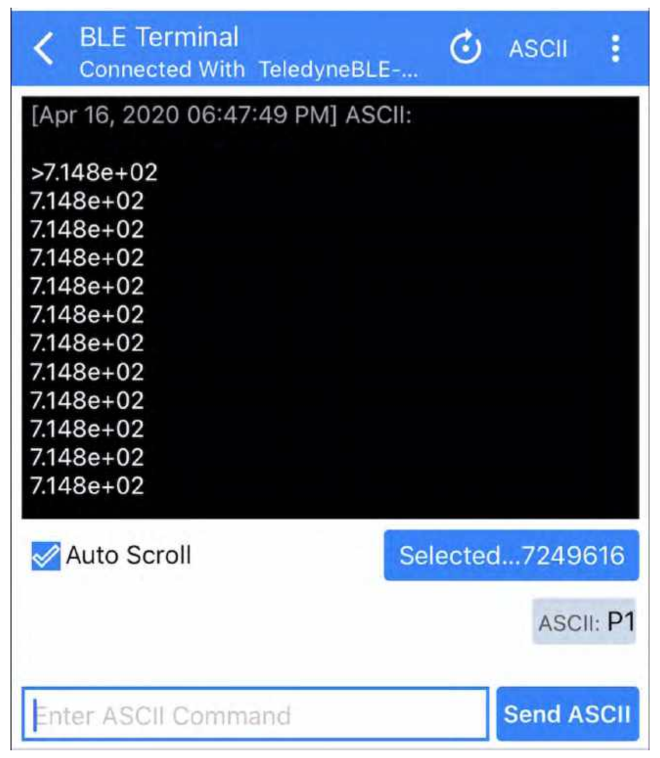


Figure 6: iPhone BLE Terminal App Communication with Gauge

Future Plans

The next steps to bring the product to market are:

- Add programming hardware to the PCB
- Optimize the PCB layout to minimize product size
- Add a metal enclosure to add durability

Acknowledgements

We would like to thank the following people for their support throughout the project

- Dr. Douglas Baker (Customer Point of Contact)
- Dr. Tim Talty (Subject Matter Expert)
- Professor Gino Manzo (Project Mentor)

TI Robotics Kit

Team members: Ashley Barclift, Qingshuai Mao, Zach Kaplan and Zhuqing Zhao
Customer: Mark Easley   SME: Peter Han   Mentor: Gino Manzo

Background

Texas Instruments (TI) has a wide variety of products and kits that allow students and aspiring engineers to learn the basics of hardware and software design. TI has reached out to Virginia Tech and asked our team to upgrade and modernize one of their existing robotics kits. This improved kit will include additional capabilities to enhance user's engineering skills with a cost effective robotics experience.

Purpose

The main purpose of this project is to improve the TI-RSLK robot kit by adding capabilities to existing hardware to meet current market trends. These capabilities include:

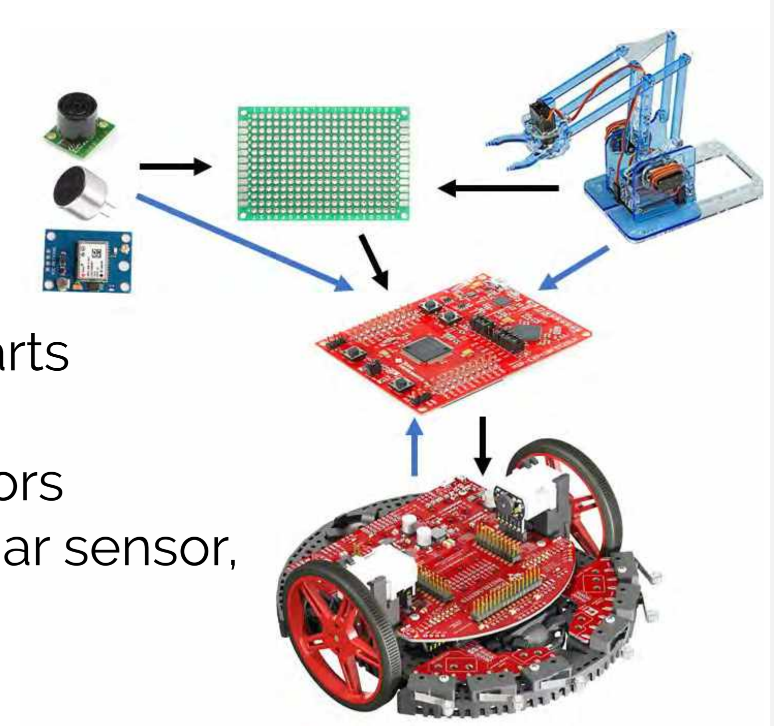
- GPS and IMU for location and movement detection
- Collision Prevention using sonar distance sensor
- Speaker and microphone for communication
- Modular Connector to utilize additional hardware
- Robotic arm

In addition to the added hardware, we must provide deliverables required by our customer.

- Fully operable PCB for added components
- PCB drawing in open source CAD tool
- Example code
- Bill of materials
- User manual

Approach

Our team started with a budget of $150 and a schedule that detailed the design process for the first semester and building and testing process for the second semester. We split into hardware and software teams.



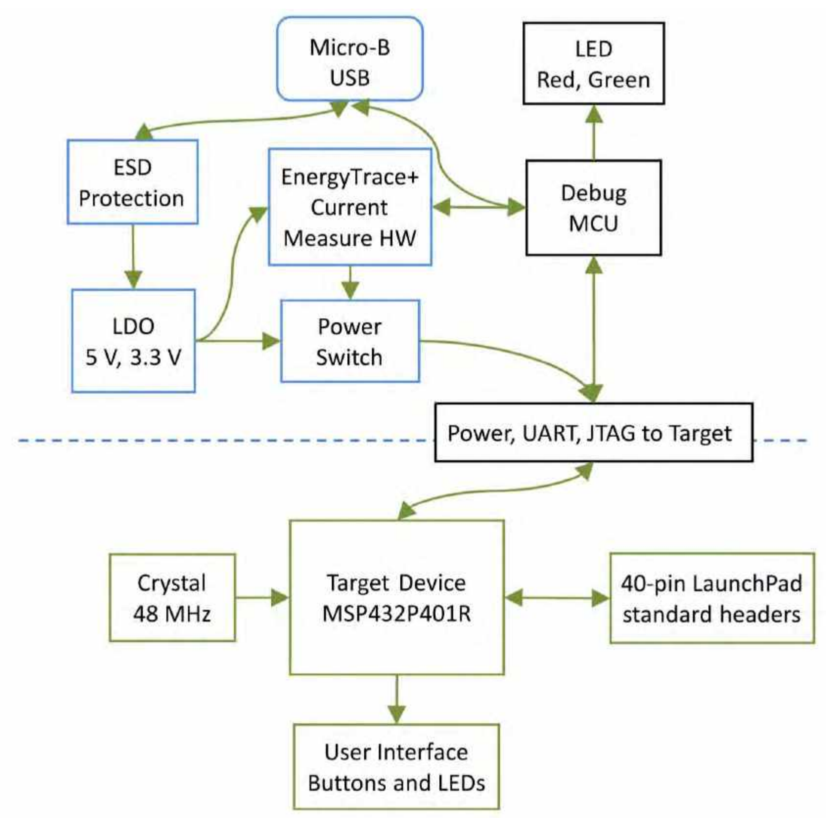
Phase 1

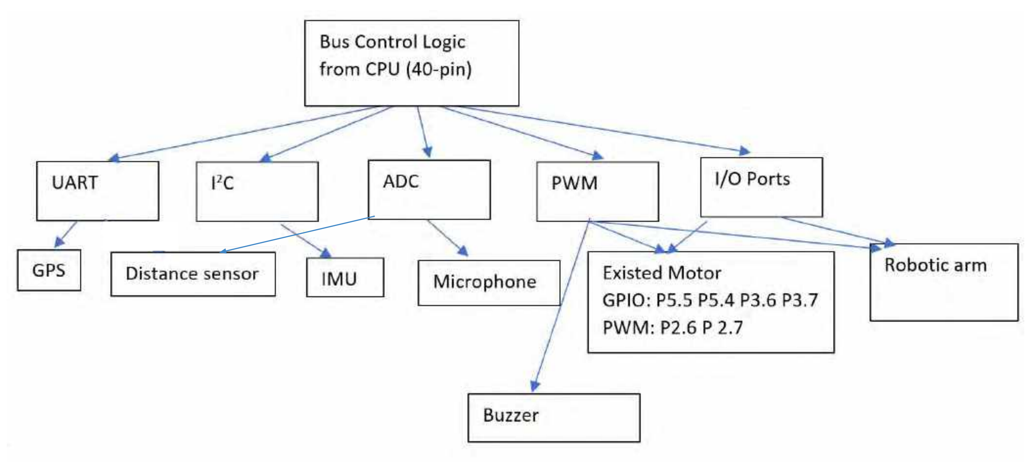
- Hardware
  - Code robotic arm
  - Design PCB
  - Draw PCB in CAD tool
  - Design BOM/purchase parts
- Software
  - Code and prototype sensors including the GPS, IMU, sonar sensor, microphone, and buzzer

Phase 2

- Hardware
  - Mechanical design for robotic arm
  - Solder PCB components
- Software
  - Finalize sensor code
  - Integrate and consolidate example code

Technical Design





Technical Design

- GPS
  - Using I2C for interfacing
- IMU
  - Using I2C for interfacing
- Distance sensor
  - Using ADC sampling and active filter
- Buzzer and microphone
  - Using PWM to generate certain frequency,
  - Using ADC for data sampling
- Robotic Arm
  - FSM describes movements for the execution of PWM when arm receives starting signal from distance sensor
  - ADC uses 5V source from Launchpad and converts to digital signal using potentiometers to move servos
- PCB
  - Schematic written in KiCAD
  - Component footprints determined and Gerber file sent to manufacturer
  - All sensors soldered to PCB and PCB connected to Launchpad with headers

Conclusion

Texas Instruments wants our team to provide additional hardware and software capabilities on TI-RSLK robotics kit and enhance its performance and educational scope. We designed new capabilities to improve existing TI-RSLK and designed a PCB for the new features to embed on.

We assembled and programed the components available onto the robotic kit. Due to the COVID-19 pandemic, our team was unable to solder and test the designed parts with the PCB. We successfully interfaced the GPS, distance sensor, buzzer, microphone and IMU with the MSP432, but there is still further assembly needed to fully demonstrate the kits functionality.

We have written technical documentation, user instruction and example code for the user to learn. This documentation has been uploaded to the open source engineering project website hackster.io to show our customer the progress of our project.

Future Study

Future study will include finishing each part of the project. This includes mounting and testing the breakout board in its current design, and writing code for the I2C devices. The GPS and distance sensors need to be tested on the mobile vehicle as well. Code for the buzzer and microphone needs to be written and tested and the Robotic Arms mounting system needs to be optimized. The PCB may require additional development should it not work in its current configuration.

Acknowledgments

The team would like to thank Professor Peter Han of the Virginia Tech ECE Department, Mark Easley of Texas Instruments and Professor Gino Manzo of the Virginia Tech ECE department for their guidance, mentorship, and contribution to the success of this project.

Inertial Measurement Unit

Team Members: Cody Bright, Kevin Jacobson and Yichun Huang
Subject Matter Expert: Ryan Gerdes
Customers: Matt Mandros and Chuck Saunders, TMEIC

Introduction

In this project, we aimed to design and build an inertial measurement unit (hereafter often referred to as an IMU) to be implemented on cranes in order to estimate the position of the crane based on measurements of acceleration and angular velocity.

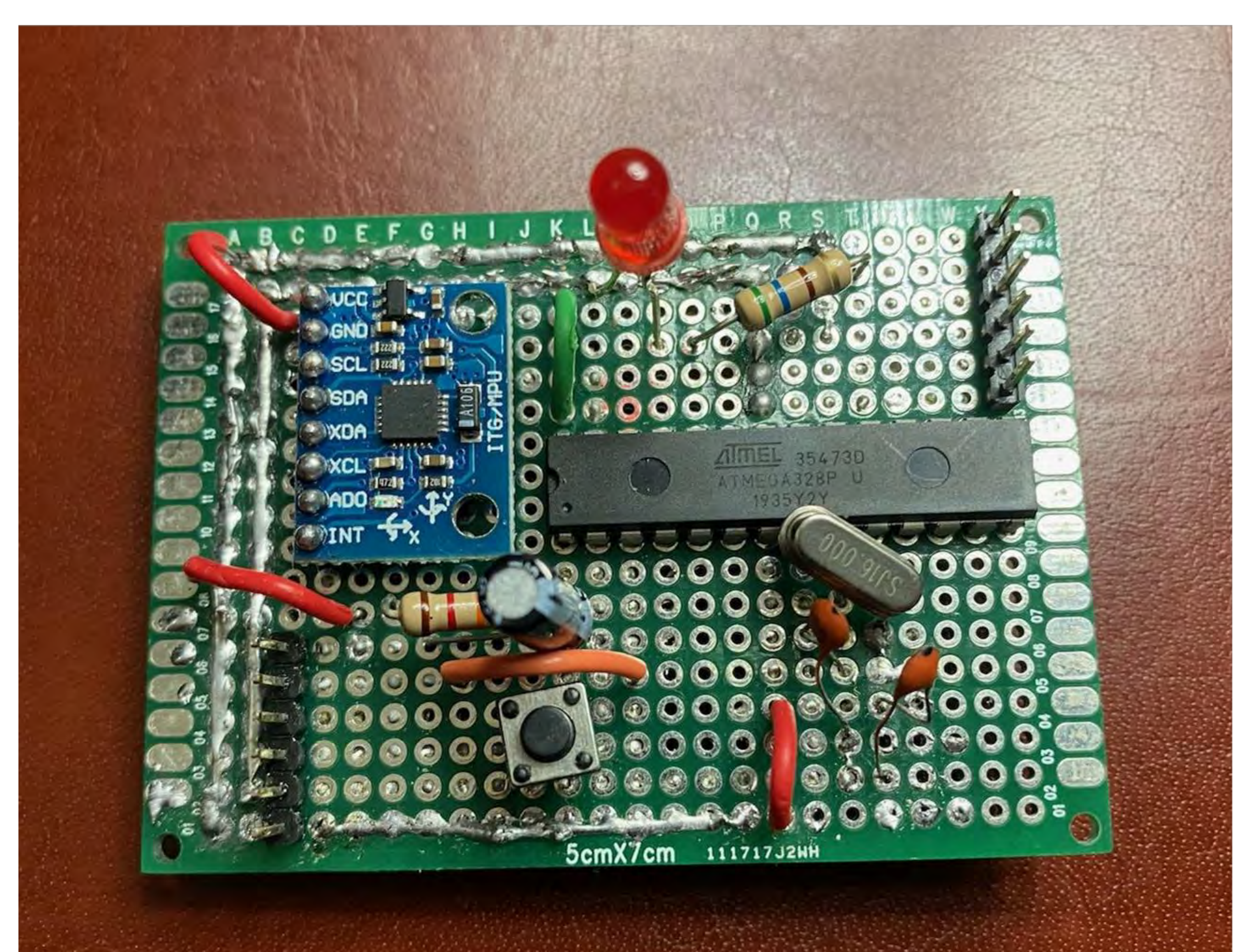
Requirements

TMEIC has provided specific requirements for the IMU devices as follows:

- The IMU is required to have a 3-axis gyroscope and a 3-axis accelerometer.
- The accelerometer must be capable of measuring at least 6g with final integrated drift no more than 50mm per minute
- The gyroscope must be capable of measuring at least 250 deg/s with final integrated drift no more than 1 degree per minute.
- The IMU must have a powered-on shock rating of at least 30g.
- The IMU must be powered by a 24V power supply.
- The IMU must operate in temperatures ranging from -40C to +60C.
- The IMU must be concealed in an IP65 rated sealed case.
- The IMU must operate on an ethernet-based protocol

Approach

Initial research went towards developing a prototype to help understand how accelerometer and gyroscope readings are used to calculate a position estimate. Error due to each sensor is compounded exponentially as the position estimate is made. Testing and analysis of the prototype would identify how the accuracy of the sensors correspond to the performance of a position tracking unit. Further efforts went towards developing a filter that would reduce unwanted noise within the sensor and eliminate drift. This filter would help improve upon the raw data coming from the sensors. After finishing the software design and analyzing the performance of the prototype, a finalized product could be constructed. The preliminary analysis would ensure that the sensors included in the final product would be accurate enough to meet the project specifications. The finalized product would be packaged into a water resistant device where it would output the position estimates over ethernet.



Results

- Built a prototype IMU device with limited capabilities
- Determined a strong correlation between data sheet parameters and actual results for IMU zero-input bias drift
- Developed kalman filtering software which improved the quality of data from the prototype
- Developed software to estimate the position of the device based on IMU measurements.

Conclusion

Though much progress was made on this project, there is further work to be done to completely satisfy requirements. A team could build on the research and prototyping we completed to select an IMU sensor. They could use and improve the software we have written to carry out pose estimation and communication with the device, combining everything together to complete a functioning unit. This

Acknowledgements

We would like to thank the following people for supporting this project:

- TMEIC: Matt Mandros, Chuck Saunders
- Subject Matter Expert, Ryan Gerdes
- Mentor professor: Gino Manzo

Digital Stethoscope and ECG for Heartbeat Sound Capture and Analysis

Team Members: Matthew Gill, Bruno Saldana, Li Song, Ryan Golshahi, Luyi Wang

SME & Customer: Jaime De La Ree Mentor: Prof. Toby Meadows

VIRGINIA TECH

Objective

To design and develop a portable medical device that can measure and analyze cardiac health in areas with limited healthcare access This project was motivated by the need for an inexpensive and portable heartbeat analysis device for areas that cannot afford expensive medical equipment or do not have the infrastructure to operate them

Requirements

- We shall build a heartbeat recording device with a noise output magnitude of -20dB compared to dB magnitude on desired frequency range.
- We shall create an extension to the ECG circuit that can record and store electrical signal data.
- We shall design a method which will allow the contents of the stored data to be viewed and analyzed in our own database

System Architecture

The device consists of three stages: Circuits, ADC Conversion and Website Design. Below is a block diagram outlining this architecture:

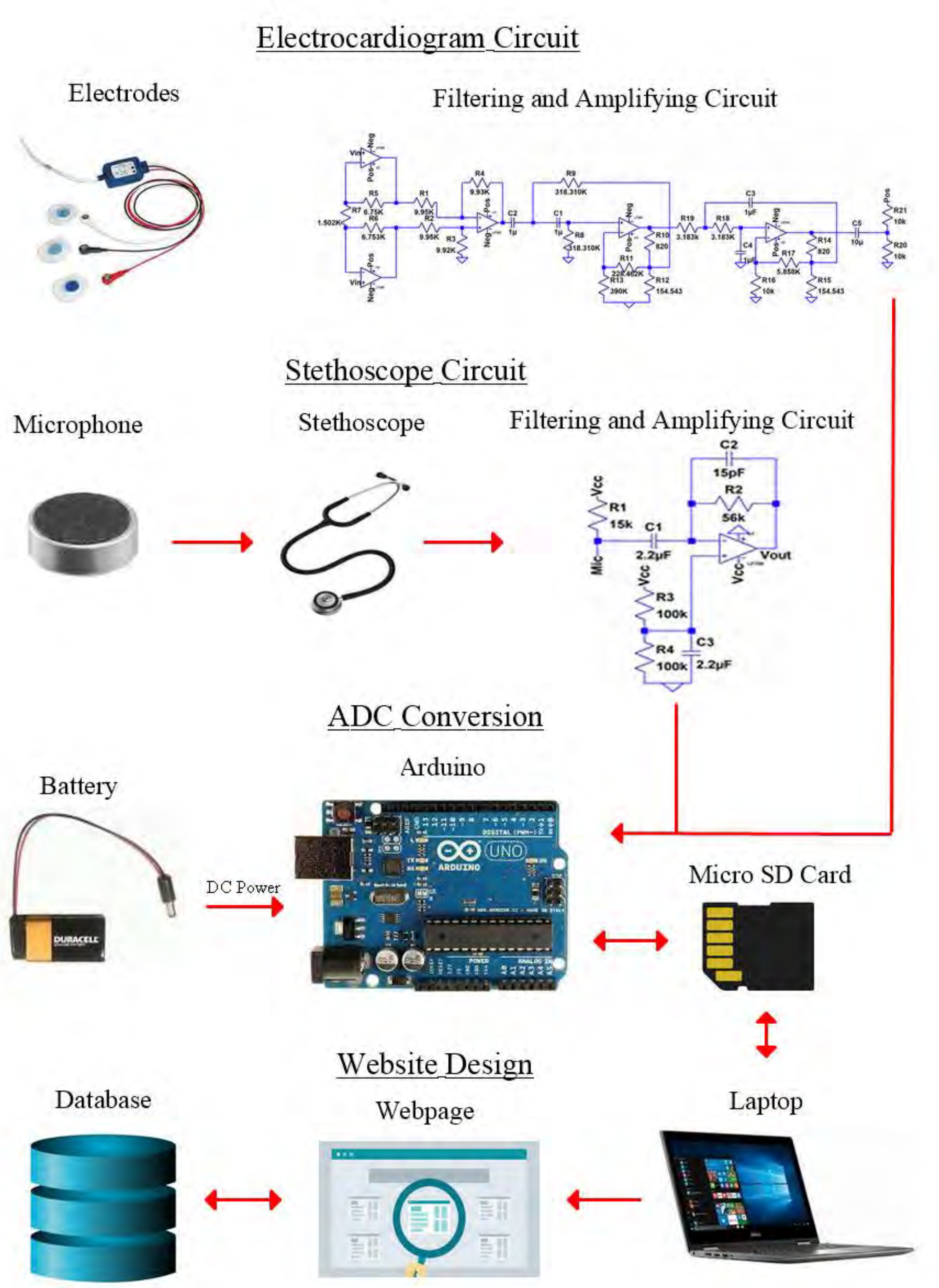


Figure 1: Block diagram representing the system hierarchy and process

Design Approach: Circuitry

Our design consisted of two different circuits: A Digital Stethoscope and ECG circuit that record the heart beat signal simultaneously.

- The Digital Stethoscope (Figure 2) used an Electret Condenser Microphone to record and amplify important heart sounds. It consists bandpass filter centered at 100Hz with gain>40dB from 20Hz-5KHz.
- The purpose of the circuit is to amplify heart signals from 20-150Hz and reject muscle noise from 1-5Hz.
- 0dB gain @ 5Hz
  40dB gain @ 20Hz
  71dB gain @ 100Hz
  70dB gain @ 150Hz

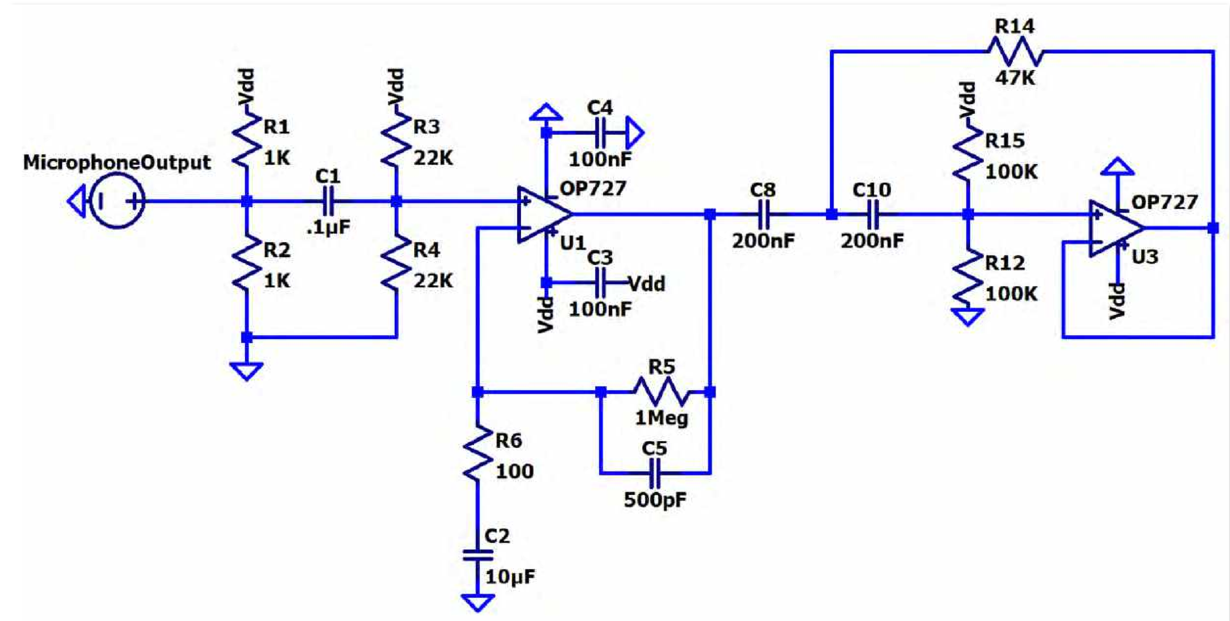


Figure 2: Digital Stethoscope final circuit design. Schematic was created in LTspice.

- The purpose of the ECG circuit (Figure 3) is to record and amplify electrical heart pulses.
- This circuit uses a differential amplifier in series with a bandpass circuit with an overall gain of 60dB
- Bandpass has -3dB points @

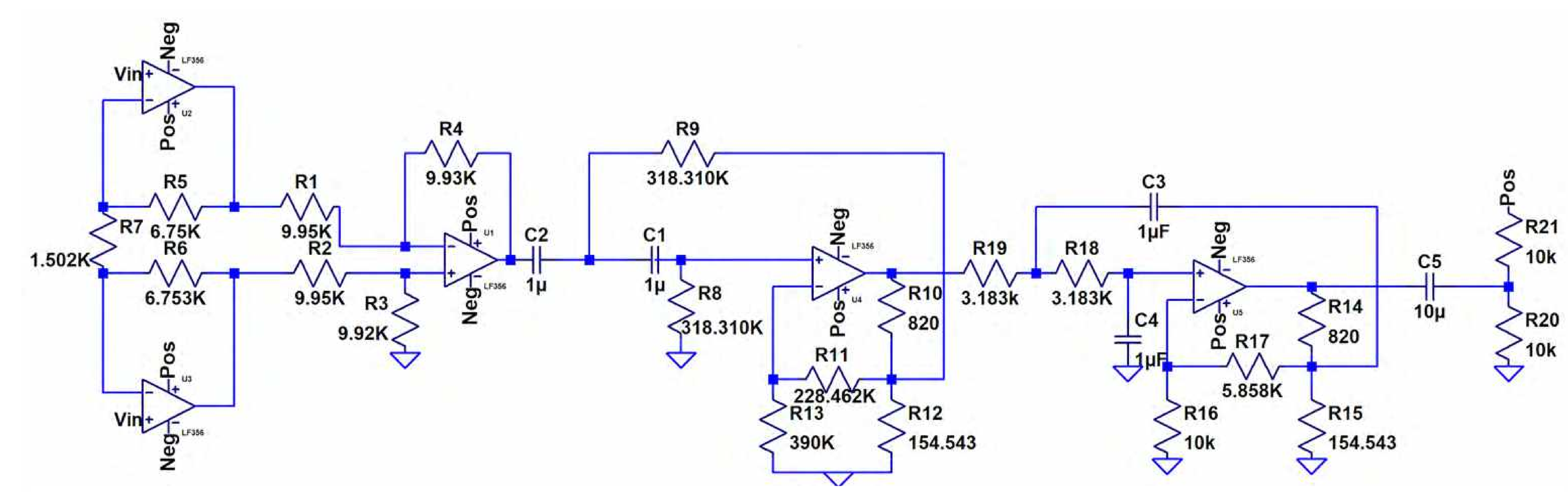


Figure 3: Final ECG circuit design. Schematic was created in LTspice.

Design Approach: Signal Digitization

To digitize the results retrieved from the circuits shown above, we used an Arduino Uno. This microcontroller was used both as an ADC and to create the data file which would be used for later heartbeat analysis. We then used MATLAB to implement some digital filtering methods and further clean up the signal. Figure 4 tis a recording from our digital stethoscope using the circuit in Figure 2, and Figure 5 is the same recording after digital filtering methods in MATLAB were impemented.

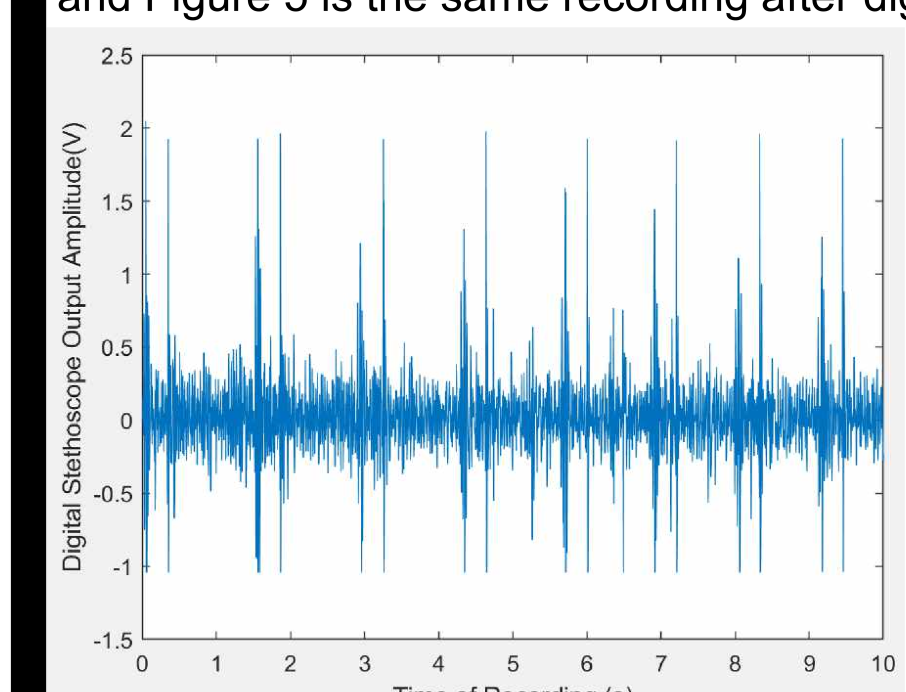


Figure 4: Digital Stethoscope recording before filtering.

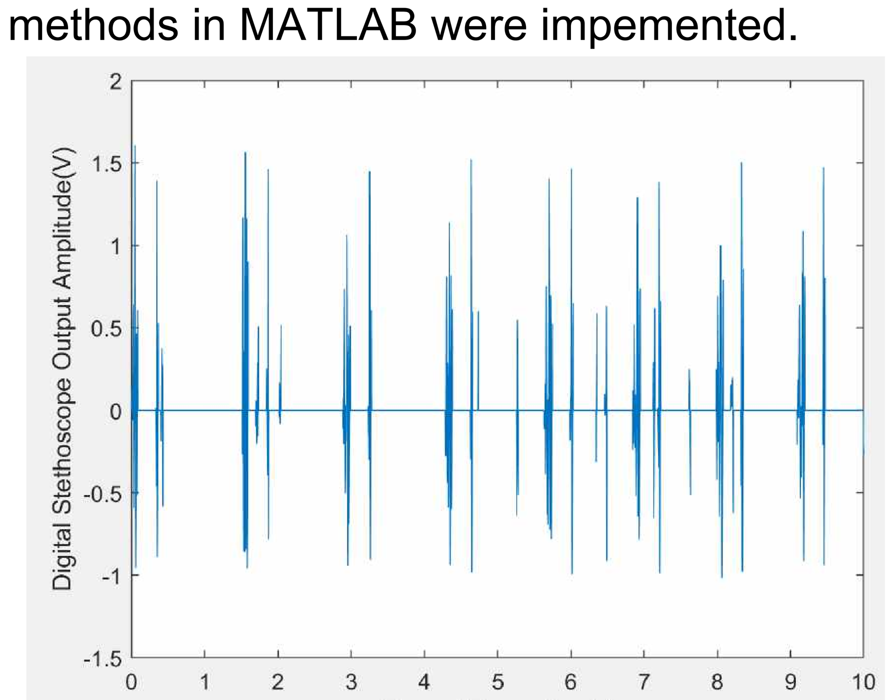


Figure 5: Digital Stethoscope recording after filtering

Design Approach: Analysis and Databasing

In order to detect irregularities in heartbeat signals, the team used MATLAB as a tool for analysis and databasing of heartbeat waveforms. This process requires extensive knowledge of the shapes, location, and timing of valvular murmurs in a phonocardiogram signal. Figure 6 depicts a template that classifies heartbeat murmurs based on their characteristics. We are using a MATLAB heartbeat classifier to determine whether the signal is abnormal and normal, then segmenting the irregularities by timing then determining the specific issue. The approach for detection anaysis is exhibited in Figure 7.

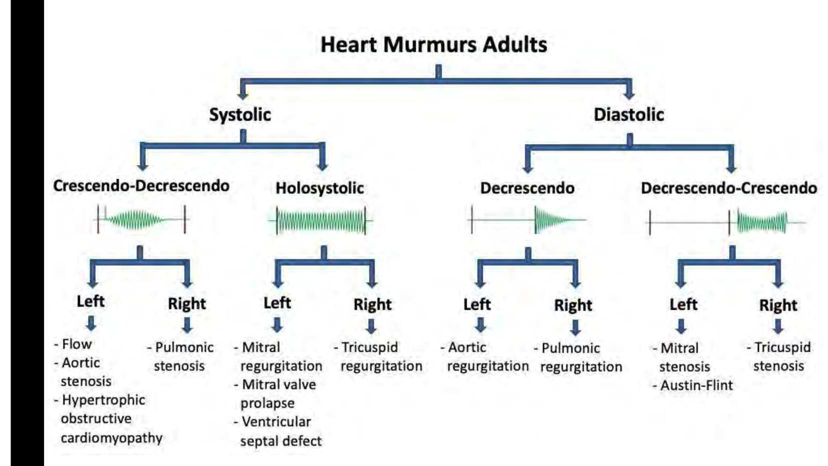


Figure 6:Template for heart murmurs in adults.

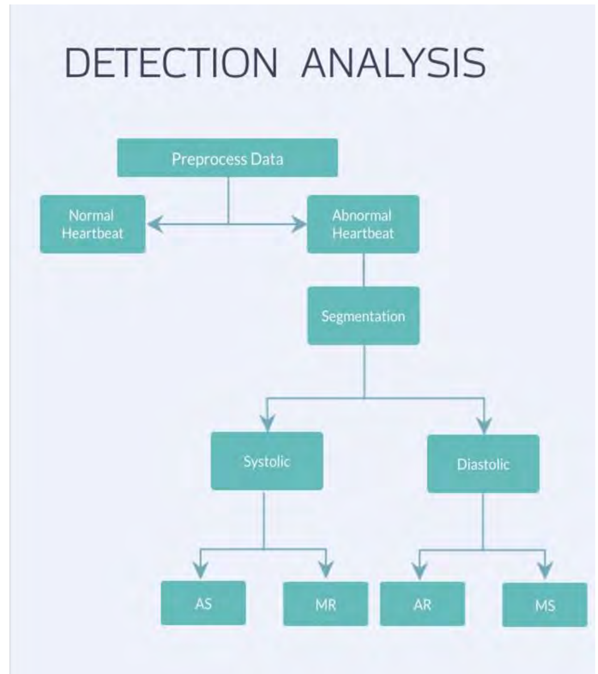


Figure 7:.Design Approach for Detection Analysis

Project Continuation

Our project is going to be continued in the Fall 2020 semester. Future plans include:

- Website design and porting code from MATLAB
- Final product encapsulation by Aileen De La Ree Valencia, and final product packaging
- Complete detection algorithms for heartbeat analysis and comparison

Challenges Encountered

- Difficult placing and stabilizing microphone in stethoscope
- Arduino for sampling could only accept positive voltages up to 5V therefore circuits were adjusted for voltage offset
- Due to piezoelectric having high sensitivity, undesired noise was present in the output
- Covid-19 has greatly altered project schedules and plans, as well completely halt some project aspects.
- Arduino cannot power circuits without large power supply noise

Acknowledgements

The Heartbeat team would to thank the following people for their outstanding support throughout the project:

- Dr. Jaime De La Ree
- Toby Meadows
- Dr. William Baumann

Power Supply for Nanosatellite

Team Members: Mian Liao, Jinrui Zhang, Ryan Nickerson, Thomas Muglia, and Linxuan Zhou
SME: Dr. Jih-Sheng Lai
Virginia Polytechnic Institute and State University

1. Objective

Our team's goal is to build a power supply for Nanosatellite for the IEEE International Future Energy Challenge (IFEC). The power supply includes power sources from multiple solar PV panels (two) mounted on the surfaces of the nanosatellites. Batteries are used as the energy storage system, which are charged through the solar PV panels and discharged to supply loads when necessary. Different types of loads are considered. Thus, the power converters include unidirectional DC-DC converters and a bidirectional DC-DC converter for the batteries. The designed power supplies should perform the basic functions – extract the maximum power from solar PV modules; charge and discharge the batteries.

2. Preliminary Specifications:

- 2x DC inputs: Max power < 60 W, Max current < 3 A, voltage 20 V
- 3x DC outputs: 3.3 V @ 5 A, 5 V @ 4 A, and 8 V @ 2600 mAh
- Functionalities: MPPT control
- Functionalities: Battery charging and discharging

3. Circuit Topology

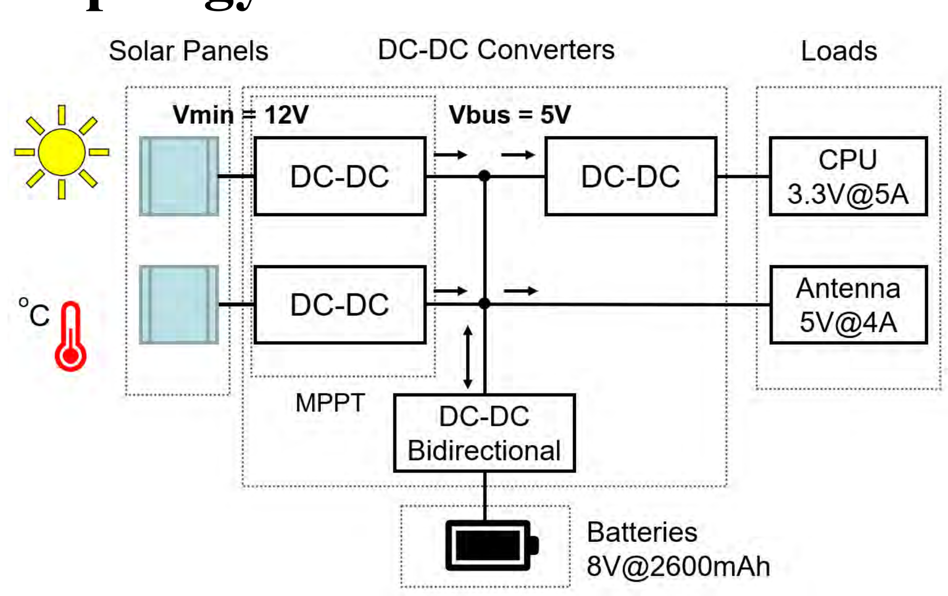
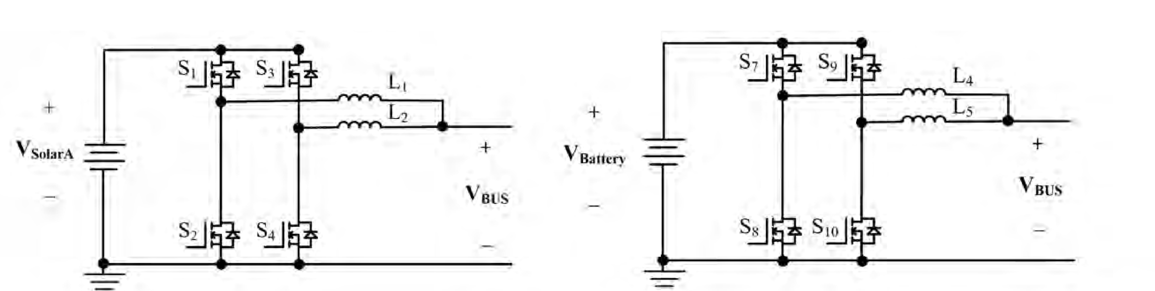


Figure 1. Block Diagram

Mode	PV panels	Battery	Loads
I	Active	Inactive	Active
II	Active	Active	Active
III	Inactive	Active	Active



Solar A Two-phase Interleaving Buck (BCM Control)

Battery Two-phase Interleaving Bidirectional (BCM Control)

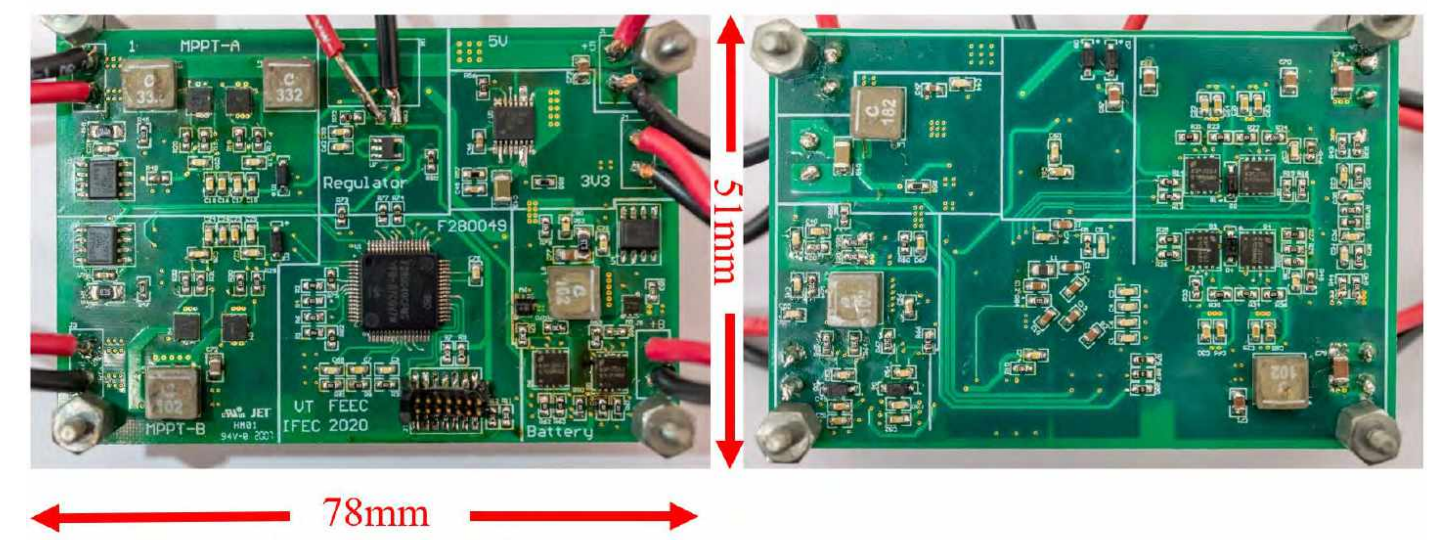
Solar B Two-phase Interleaving Buck (BCM Control)

3.3V Load Single-phase Buck (CCM Control)

Figure 2. Circuit Topology

4. Hardware Design

Dimension: 78mm × 51mm × 10mm



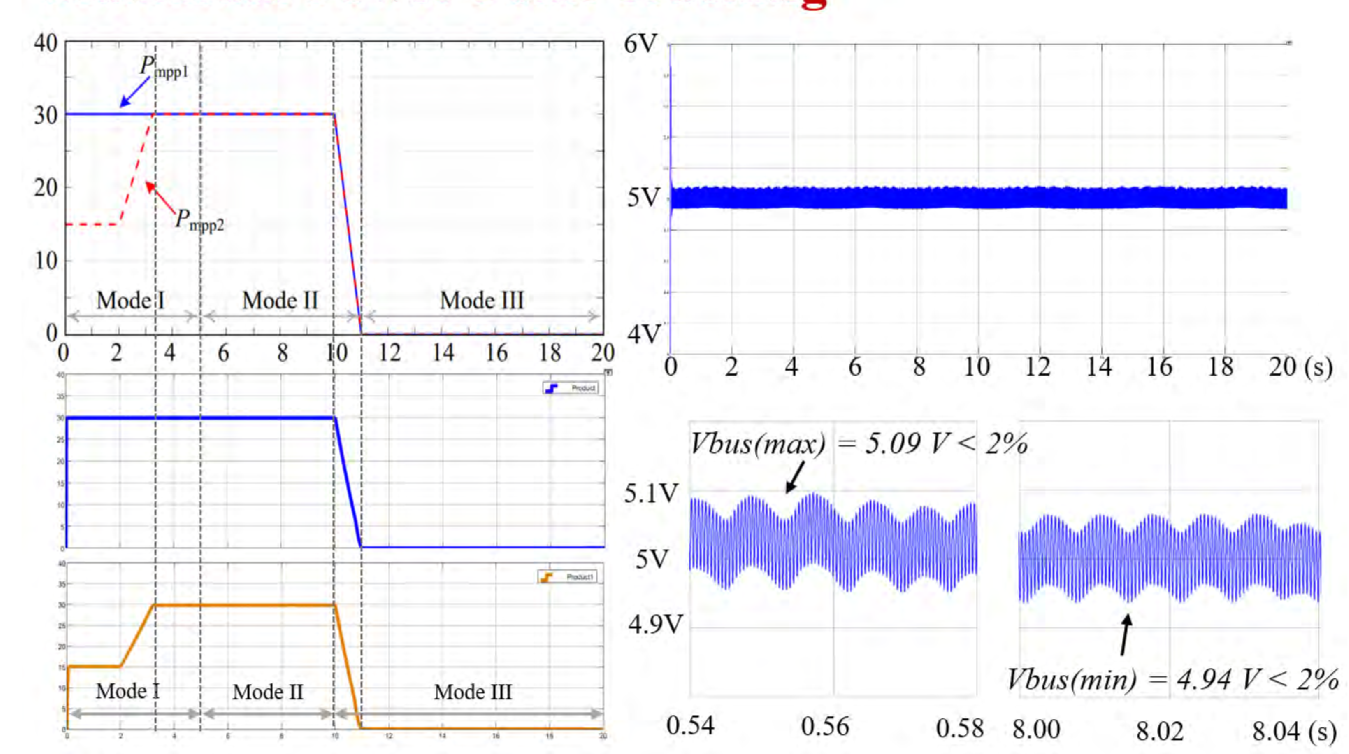
Top View of the PCB Board

Bottom View of the PCB Board

Figure 3. PCB final design dimensions and overview

5. Software Design

Maximum Power Point Tracking



MPPT Simulation in Simulink

Vbus in Simulink

Figure 4. MPPT Control Simulation by Simulink

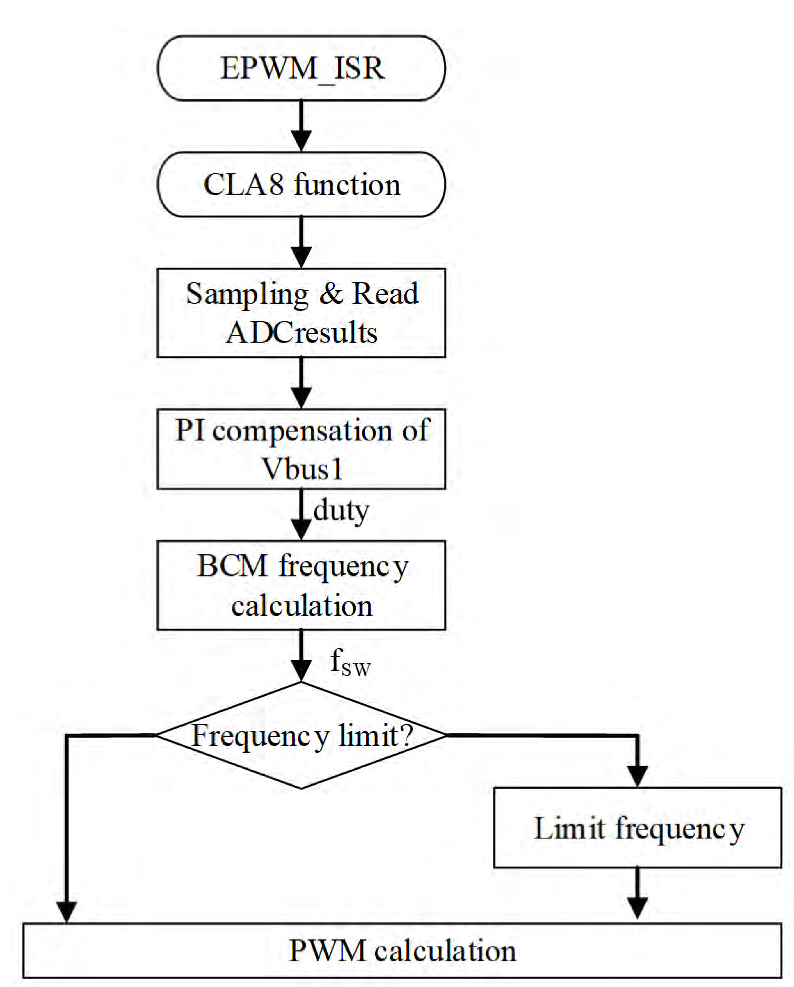
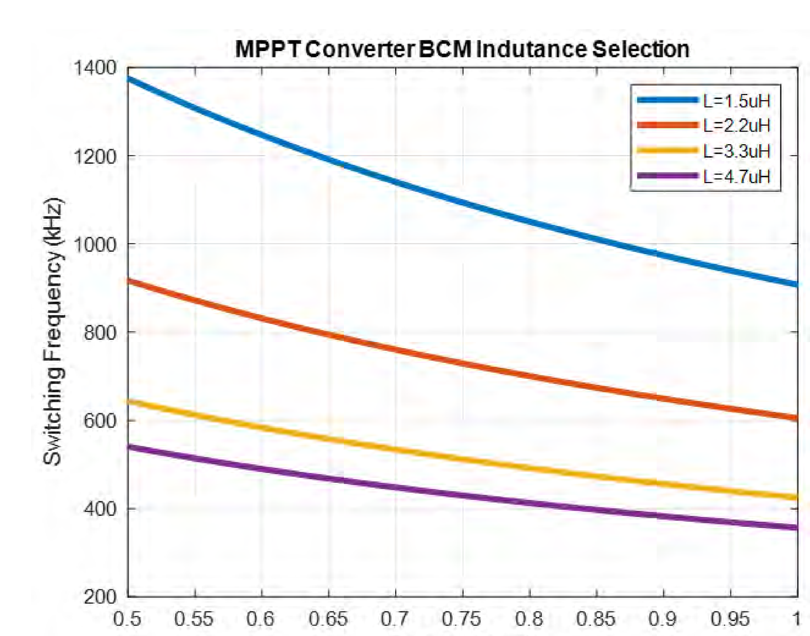


Figure 5. Control Block Diagram for BCM



When L = 3.3uH, frequency range is 600 kHz (full load) to 640 kHz (half load)

Figure 6. BCM Inductance Selection

6. Experiment Setup

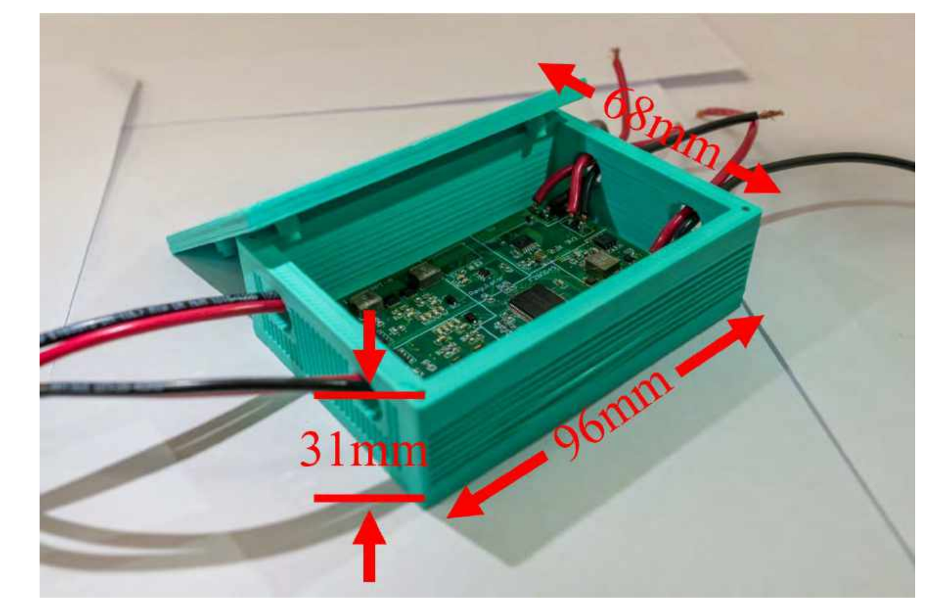


Figure 7. Case for PCB by 3D Printing

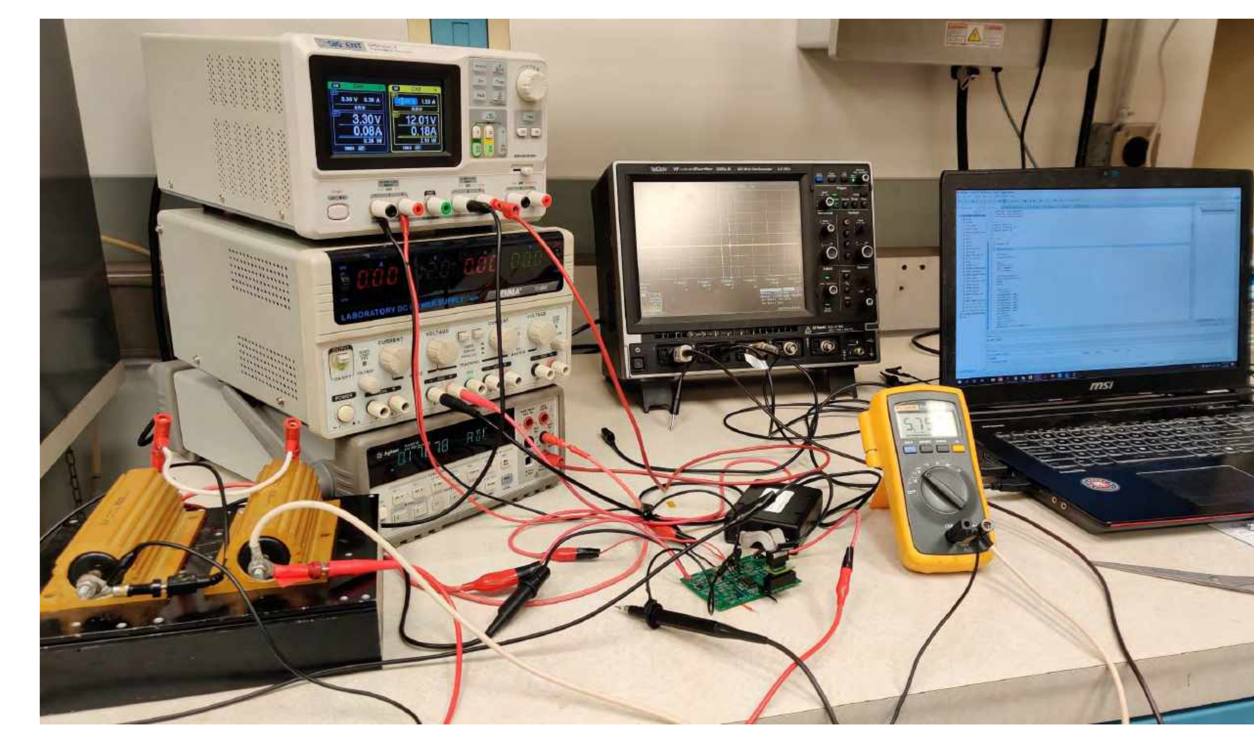


Figure 8. Test System with load

7. Experiment Results

	MPPT	Bidirectional	5V-3.3V Power Stage	System Total
Mode I	95.49%	-	95%	93.26%
Mode II	95.88%	97.39%	95%	93.62%
Mode III	-	97.56%	95%	95.29%

Figure 9. Efficiency of Power Stage for Mode I, II and III

8. Summary

- BCM and soft-switching design to increase system efficiency
- BCM is implemented under high variable switching frequency significantly reduces the switching loss and the inductor size
- 2-phase interleaving design of converter reduces current and voltage ripple
- Thermal paste is directly applied to power switching devices for better heat dissipation

Identifying and Grading Lincoln Head Wheat Pennies for the Purpose of Finding Valuable Coins

Presented by the Change Makers MDE Team

Jack Hawes, Ramzy Hudson, Mika Murphy, Sumved Ravi

Virginia Polytechnic Institute and State University, 302 Whittemore Hall, Blacksburg VA 24061, USA

College of Engineering
Bradley Department of Electrical and Computer Engineering
Virginia Tech

Motivation

To automate and objectify the currently subjective and human-centered process of identifying and grading of valuable coins

Objectives

- Design an imaging system that can capture high-quality images of a large set of coins in a quick manner.
- Develop an algorithm to identify which coins belong to a set of desired coins.
- Grade the coins based on color on a red to brown scale.

Approach

Step 1: Capturing Images

- Build a controlled lighting environment to image the coins using a Raspberry Pi Camera and White LEDs (7 on top face)
- Use a white matte finish for the case and a black matte finish for the base (see Fig.1 and Fig.2)

Step 2: Re-orientate and Crop the Coins

- Create generalized method to crop coin from full background and remove defects from surrounding area
- Rotate coin to be consistent with a up right right facing lincoln cent (See Fig.3)

Step 3: Date Recognition

- Use a Hough Transform to identify the coin in the image.
- Compare a Sobel Transform of the coin to an upright template to orient the coin.
- Zoom in on the last two digits. (see Fig. 4)
- Compare a Sobel Transform of the digits to templates of the desired coin, and determine if correlation passes threshold.
- Effectiveness of the date recognition classifier is determined using the Area under the Curve (AUC) of the Receiver Operating Characteristic Curve, using the equation, where TPR is true positive rate and FPR is false positive rate.

$$AUC = \int_0^1 TPR(FPR)$$

Step 4: Color Grading

- Separates the coins into either Bronze or Steel categories based on their Median Saturation (see Fig. 5 and Fig. 6)
- Uses Median values of Saturation and Luminosity to determine the Percentage Red of a coin using the equation:

$$\%Red = 100 * \frac{(CoinSat + CoinLum) - (MinSat + MinLum)}{(MaxSat + MaxLum) - (MinSat + MinLum)}$$

Sample Imaging and Analysis

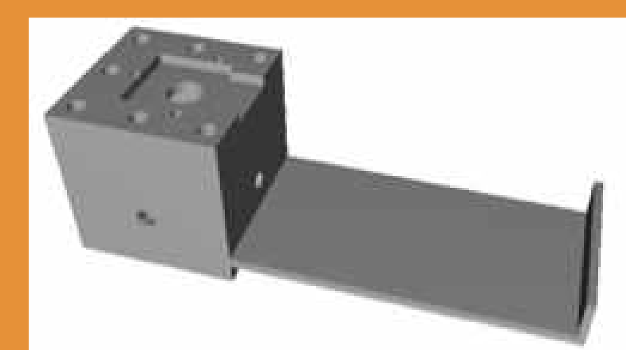


Figure 1: Imaging Light Case with up to 11 LEDs and Raspberry Pi Holder Used to create ideal imaging conditions

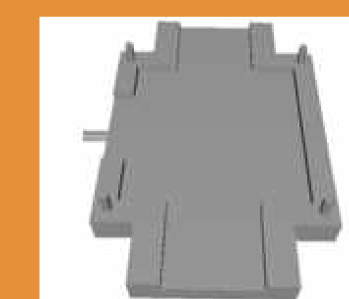


Figure 2: Modular Imaging Base for the Light Case and various backgrounds for imaging

Figure 3: Properly Oriented Coin with accuracy within 2 degrees

Figure 4: Sobel Transform of the Digits '56', yielding a correlation of 0.87 against the template, passing the threshold of 0.81

Figure 5: Color Grading Coin (Left) 35% Red Coin (Right) 75% Red Coin

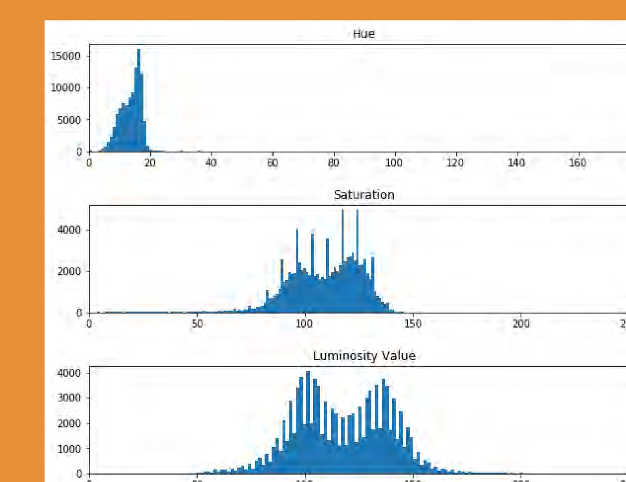


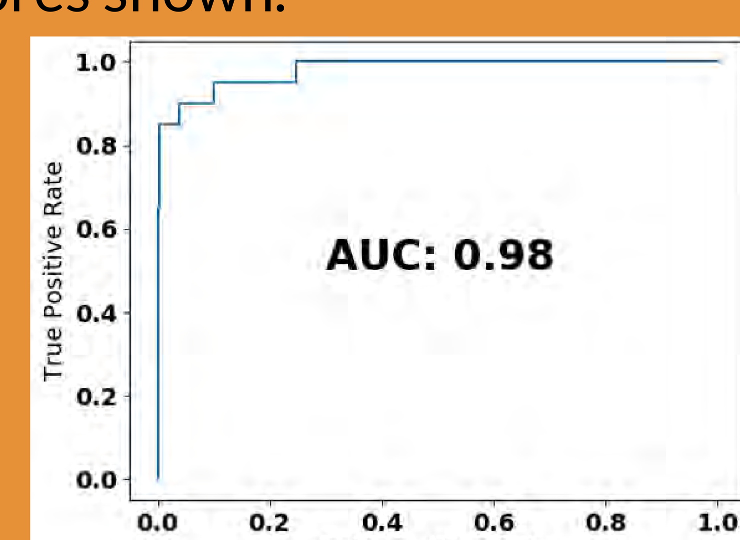
Figure 6: HSI Evaluation of Figure 5a which is used to find the average hue and saturation for various graded coins

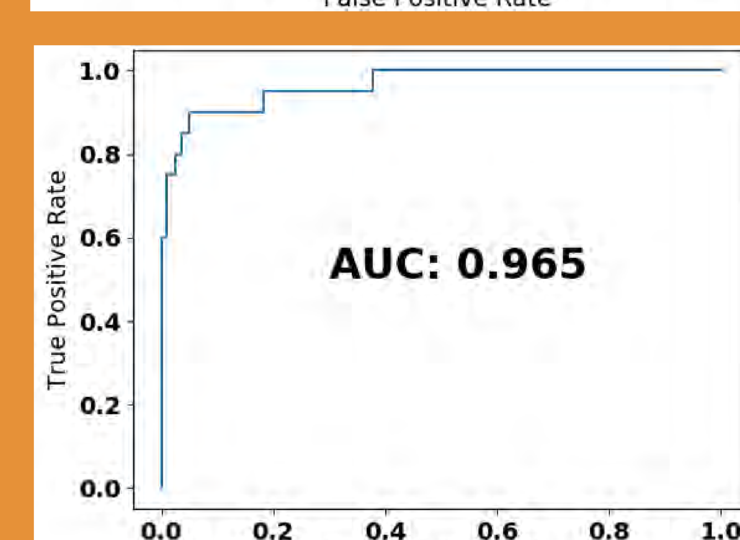
Experimental Setup

Out of a set of 300 coins, there were 20 coins with dates 1937 and 20 coins with dates 1956 coins that needed to be identified. These coins covered a variety of colors and quality to ensure the reliability of our system.

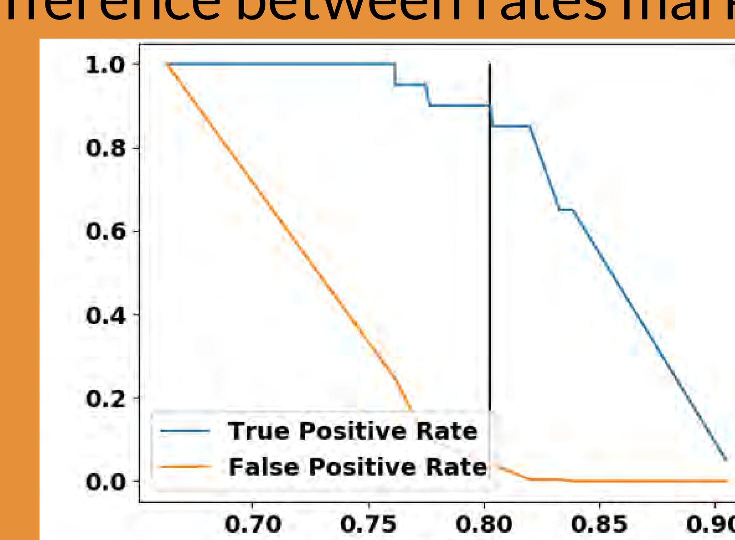
Results

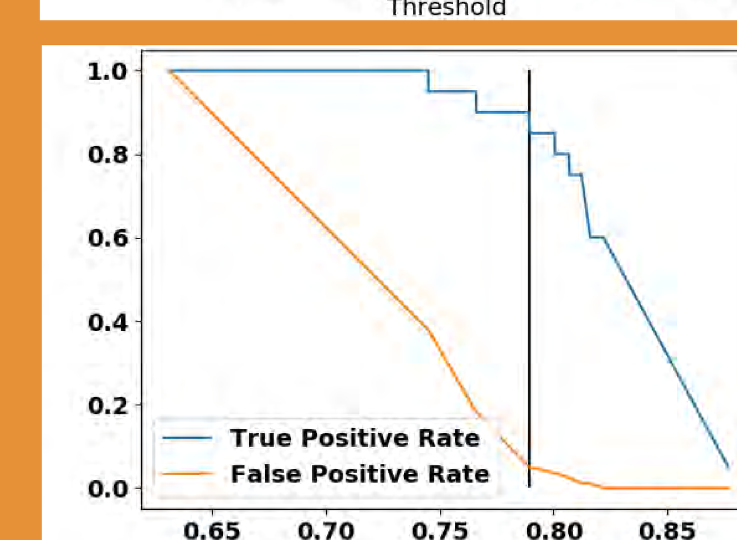
The Receiver Operating Characteristics for 1937 and 1956 coins, respectively, with the AUC scores shown.





The TPR and FPR compared to the thresholds for 1937 and 1956 coins respectively, with the maximum difference between rates marked.





False Positive/ False Negative

1937: 3.93% false positive, 10% false negative

1956: 5% false positive, 10% false negative

Conclusion

- An imaging system was developed to reliably capture high-quality images of coins in a consistent manner.
- These images could be processed to orient the coins to an upright position, identify the unknown digits, and compare these digits to a template of a desired coin. The resulting classification had an AUC score of 0.98 and 0.965 for 1937 and 1956 coins, respectively, making this an excellent binary classifier.
- At the best possible threshold, the false negative and false positive rates did not meet the 2.5% rate required by the customer. This challenge could not be quite met with our approach because coins that have a significant amount of grime receive much lower correlation scores through template matching. Thus, to have a low false negative rate, we would need to have a very high false positive rate.
- A grading system was developed that can objectively determine the color of the coin with respect to the current standard of the red-to-brown scale.

Future Plans

- Generalize the date recognition to identify all dates as opposed to binary classification.
- Expand the grading system to account for wear, corrosion, and scratches.
- Develop a mechanical imaging and sorting system to automate the entire process.

Acknowledgements

The Change Makers would like to personally thank the following people for their contributions and help towards this project:

- Dr. Luke Lester (Customer/Sponsor)
- Dr. Creed Jones (Subject Matter Expert)
- Prof. Kenneth Schulz (MDE 4806 Mentor)

Power Device Tester for Robustness and Reliability of Power Semiconductor Devices

Team Members: Keyue Shan, Haoshen Yang, Zhengrui Wang, Taehyeong Kim
SME, Customer: Dr. Yuhao Zhang **Mentor:** Prof. Toby Meadows

Background

Gallium Nitride (GaN) high electron mobility transistors(HEMTs) are being integrated to power electronic systems. They offer many benefits to make commercial products smaller, and more efficient. In order to further the commercialization of GaN devices into industrial applications, the devices' reliability and robustness needs to be fully characterized; these events include abnormal events, both within and outside of the safe-operating-area.

Figure.1 Infineon IGLD60R190D1 GaN

Objective

- Design a test setup that is able to test the reliability and robustness of GaN power semiconductor device
- Test the GaN power device through:
  - Double Pulse Test (DPT)
  - Unclamped Inductive Switching (UIS)
  - Short-circuit withstand Capability (SC)
- Analysis of test result data

Requirements

- The tester shall be a unified circuit
- The tester shall be capable of running the following tests:
  - Double Pulse Test
  - Unclamped Inductive Switching
  - Short-circuit withstand Capability
- The tester shall be automated
  - Be capable of being controlled remotely by operators
  - Be capable of collecting and saving data automatically
- Three functions of the tester shall be able to switched by user through remote controller for safety consideration

System Deposition

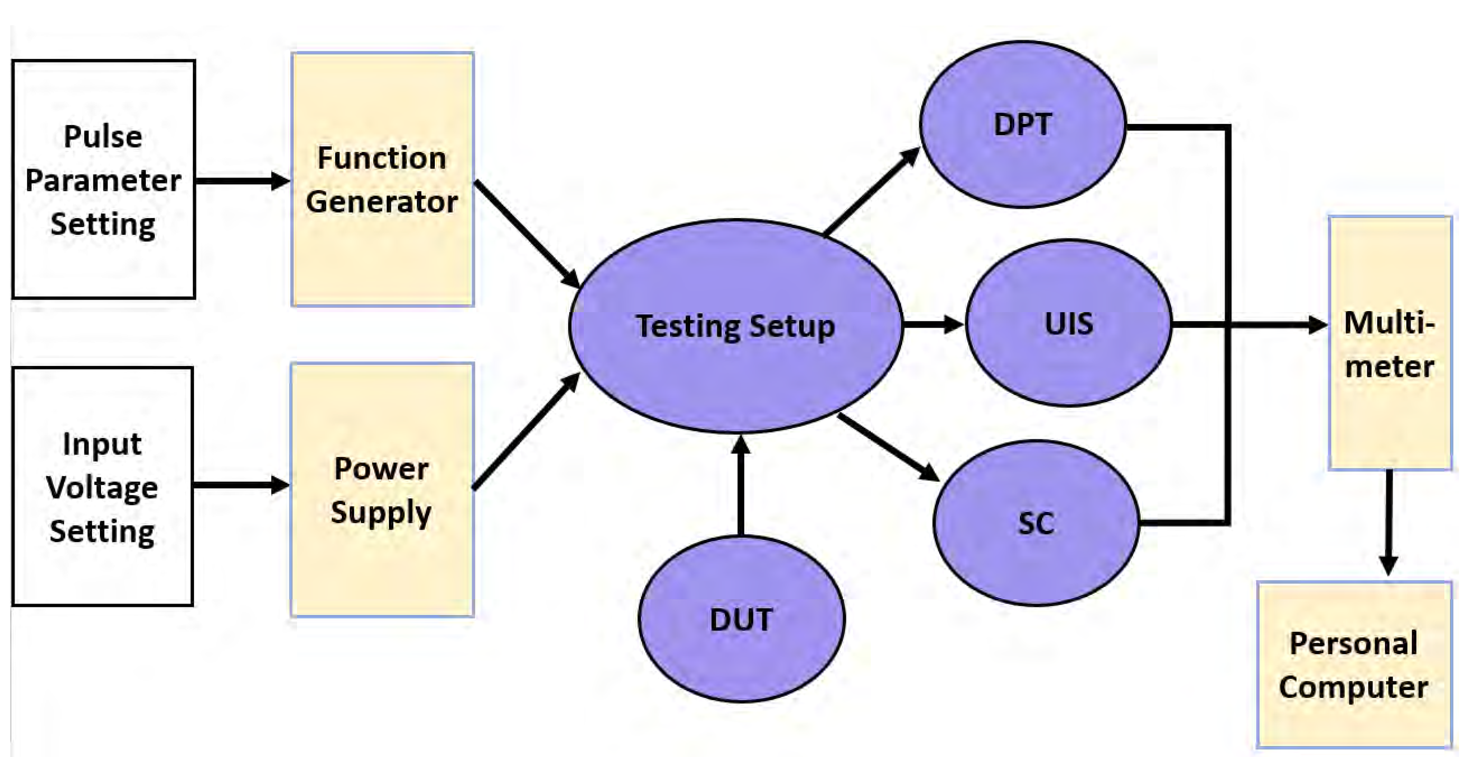


Figure. 2 Testing System Operation Procedure

As shown in Figure. 2, white rectangles indicates the user setup parameters, yellow rounded rectangles indicate equipments can be found in labs, and purple circles indicate PCB designed by the team

PCB Design

- MotherBoard Schematics and Layout, including:
  - All three test circuits (DPT, UIS, SC)
  - Connector pins with DaughterBoard
  - Measurement pins

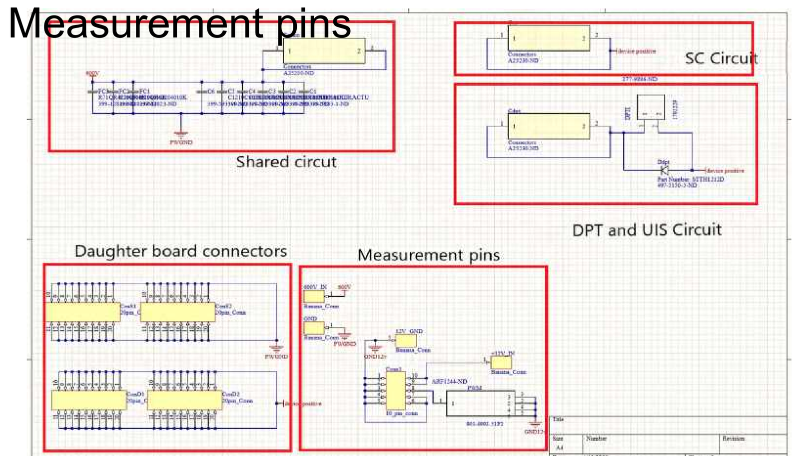


Figure. 4 MotherBoard Layout

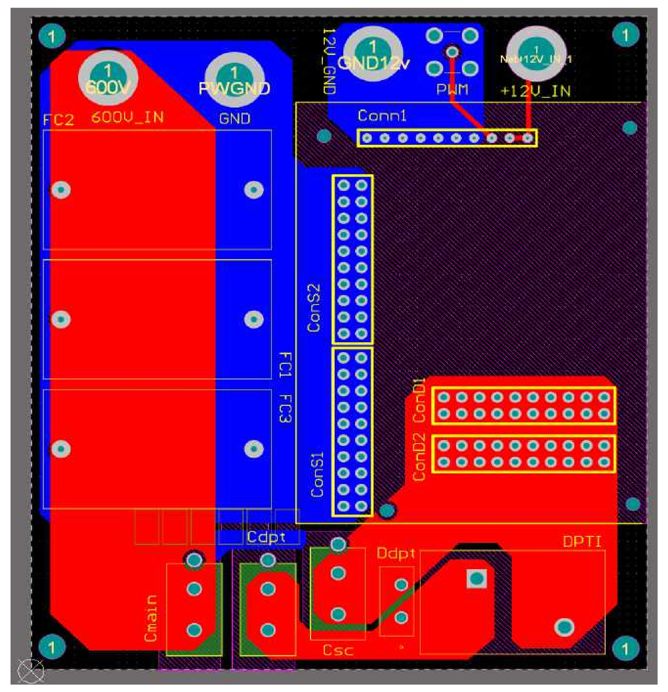


Figure. 3 MotherBoard Schematics

- DaughterBoard Schematics and Layout, including:
  - Gate driver circuits
  - Power circuits
  - Connector Pins
  - Measurement Pins

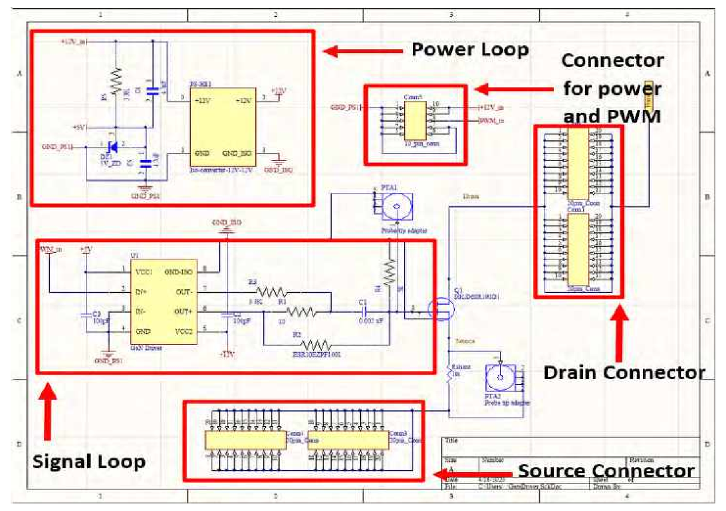


Figure. 5 DaughterBoard Schematics

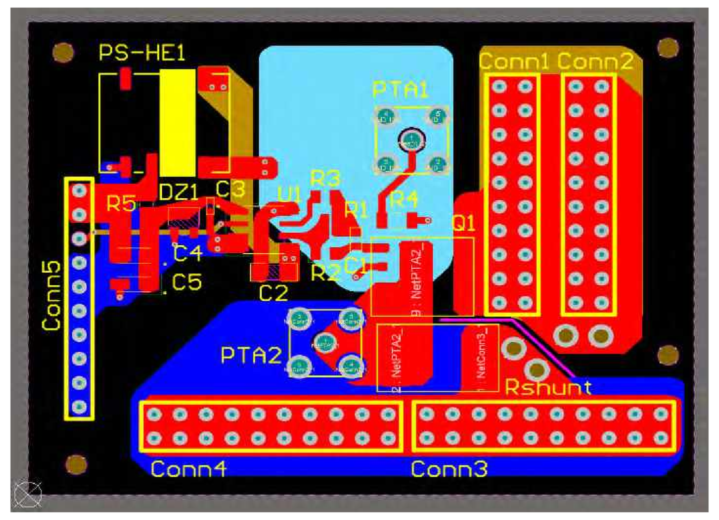


Figure. 6 DaughterBoard Layout

Printed Boards

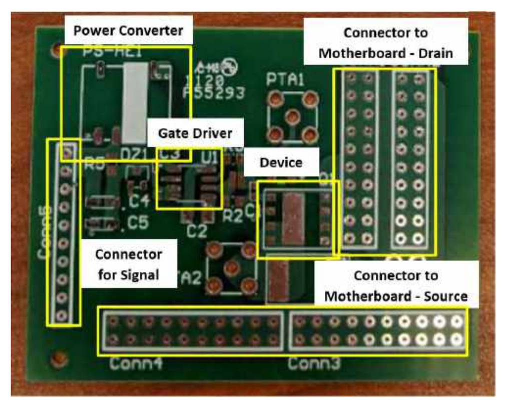


Figure. 7 Manufactured PCB-Daughterboard without Assembling

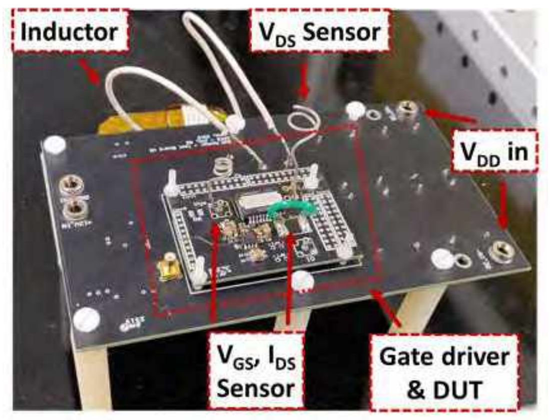


Figure. 9 Example of fully populated GaN based PCB (DaughterBorad) by Ruizhe Zhang

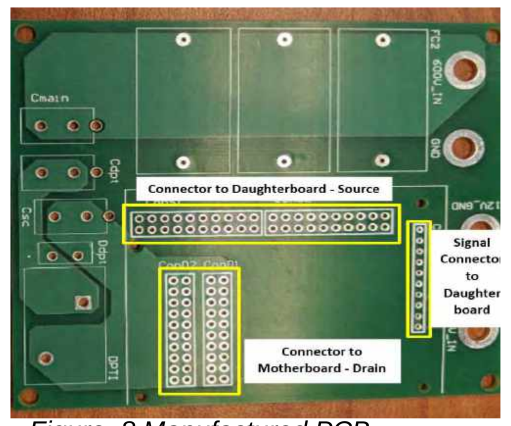


Figure. 8 Manufactured PCB--Motherboard without Assembling

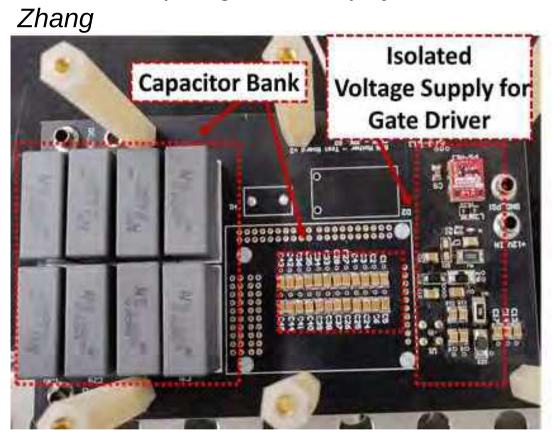


Figure. 10 Example of fully populated GaN based PCB (MotherBoard) by Ruizhe Zhang

- DaughterBoard(Top Left) and MotherBoard(Bottom Left) have been Manufactured and will be assembled After COVID-19.
- The daughterboard(Top Left) Installed directly on top of the Motherboard(Bottom Left) through spring connectors.
- Prototyped PCBs(Top Right and Bottom Right) by Ruizhe Zhang & Joseph P. Kozak which were used to characterize the ruggedness of another type of GaN device - IGO60R070D1
- Two boards would also have same way of connecting to our boards

Simulation Results

UIS Test Conditions:
V_{DS}: 920 V
V_{GS_Off}: 0 V
V_{GS_On}: 10 V
T_{On} : 6 us

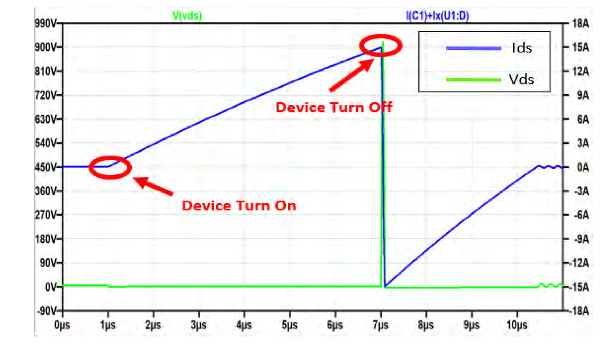


Figure. 11 UIS Simulation Results

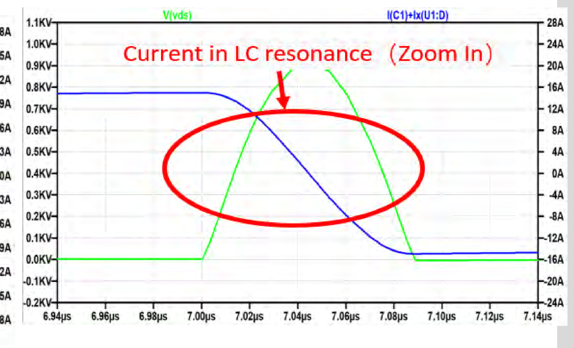


Figure. 12 UIS Simulation Results(Zoom In)

DPT Test Conditions:
V_{DS}: 650 V
V_{GS_off}: -5 V
V_{GS_On}: 5 V
T_{On} : 1.85 us (1st pulse)
$T_{Off\_Between\ Pulses}$: 0.4 us

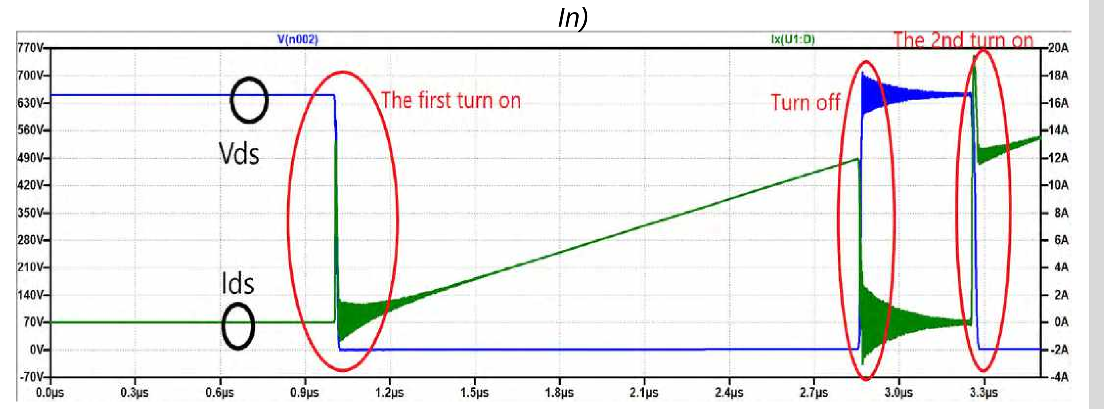


Figure. 13 DPT Simulation Results

SC Test Conditions:
V_{DS}: 300V
V_{GS_Off}: 0 V
V_{GS_On}: 7 V
T_{On} : 5 us

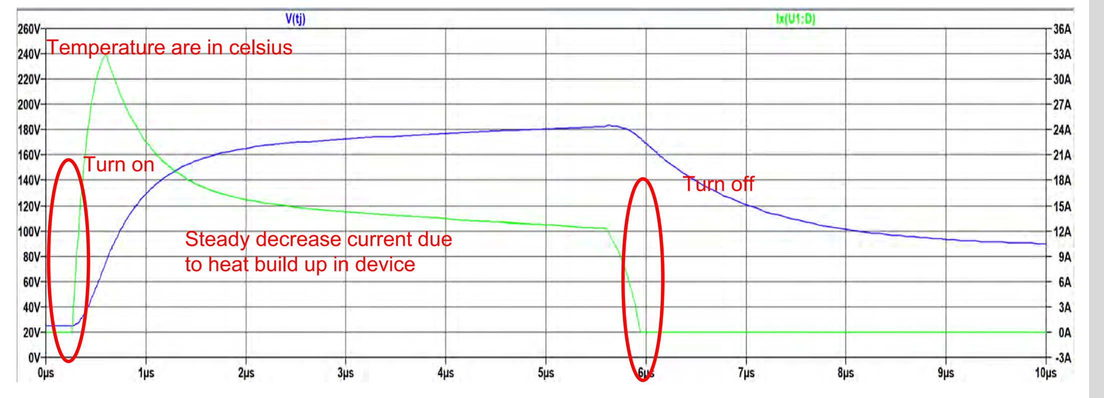


Figure. 14 SC Simulation Results

Result Analysis

- UIS
  - Device was turned off when current reached 15A and inductor continue supplying energy
  - Vds reaches about 900V and current decreases in the LC resonance pattern
  - 2DEG structure gives the device the ability to conduct in the reverse direction.
- DPT
  - The current Ids is zero and voltage Vds is 650V when the device is off
  - Ids increases gradually and Vds drops to zero when the device is on during the first pulse.
  - Ids drops to 0A when the device is off and picks up to almost where it dropped when the device turns on at the second pulse
  - Test is used to characterize device's switching energy.
- SC
  - Extreme current passes through the device causing the temperature to drastically rise.
  - As temperature rises, R_{on} increases and causes the reduction of current and power on the device
  - By energy conservation law, heat generated equals to heat dissipated

Learnings

Throughout one-year senior design project, Firstly, we have gained lots of experience in PCB design in Altium Designer. Secondly, we have a deep understanding on semiconductor reliability test for DPT, UIS and SC tests. We are now awaring of failure mechanism after GaN device failed. Last but not least, we have gotten familiar with process of completing the industrial standards based project.

Acknowledgement

We would like to thank following people for their supports:

Dr. Yuhao Zhang(Subject Matter Expert)
Prof. Toby Meadows (Mentor)
Joseph Kozak (GRA)
Ruizhe Zhang (GRA)

REDD, Set, Go

Team Members: Tyler Krochmalny, Havy Pham, Riya Sareen, Kristofer Stone, Nicholas Stamps

Customer and SME: Dr. Gregory Earle **Mentor:** Prof. Toby Meadows

Motivation

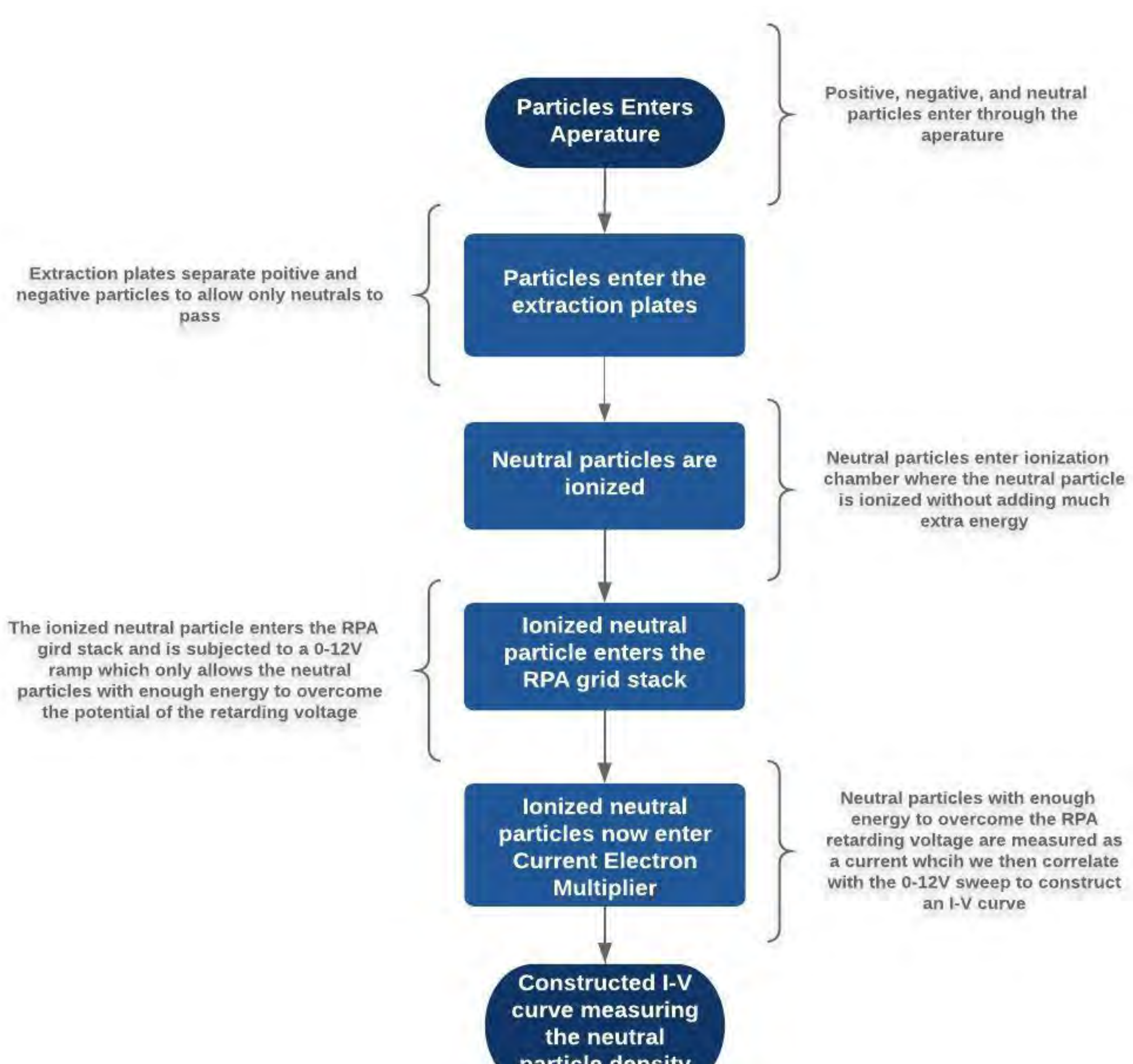
The neutral gas at the Low Earth Orbit (LEO) altitude is an important factor in predicting the onset of plasma instabilities that are known to distort and/or disrupt high frequency radio communication [1].

The goal is to design and develop the electrical subsystems for an instrument to characterize the neutral particle energy that strike the ram side of a CubeSat in LEO using an I-V curve model. The instrument would create an electron current corresponding to a certain number of neutrals at or above a particular energy. Through the measured electron current using an logarithmic electrometer, the customer would be able to determine the neutral velocity of the ionosphere [2].

Key Requirements

- Apply bias voltages to various mechanical and electrical subsystems internal to the REDD sensor
- Regulate emission from a thoriated tungsten filament
- Use a logarithmic electrometer to measure current samples from a CEM and emitted from a filament
- Format all data for communication to the spacecraft computer
- Package all electronics to fit in a 1U CubeSat along with the instrument

Concept of Operations



Printed Circuit Boards

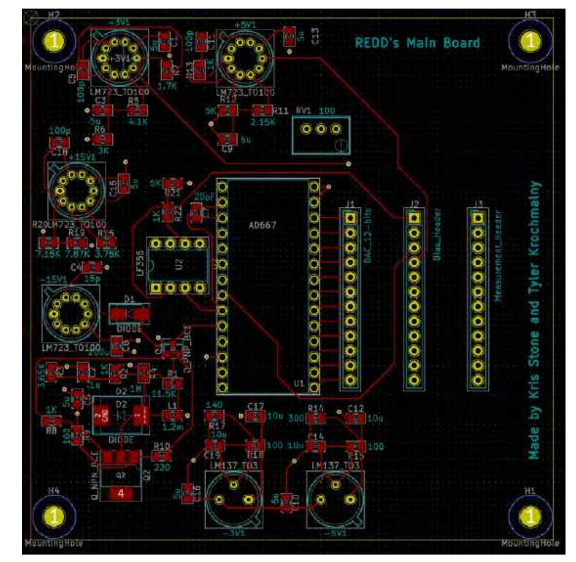


Figure 1. The mainboard contains voltage regulators to supply the needed bias voltages and the interface with the microcontroller, including the digital to analog converters (DACs)

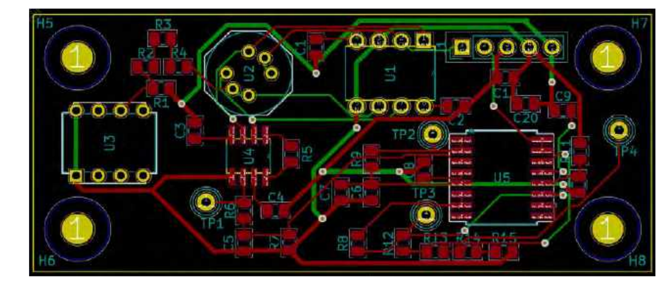


Figure 2a. CEM electrometer measures the neutral particles' current after it has gone through the CEM

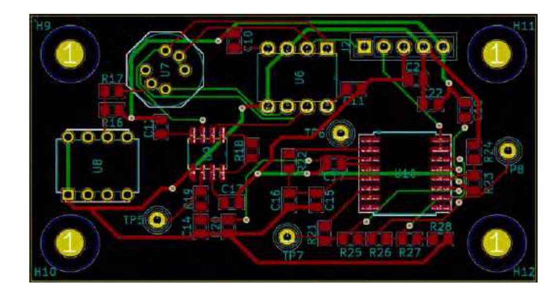


Figure 2b. Filament electrometer measures the filament's current

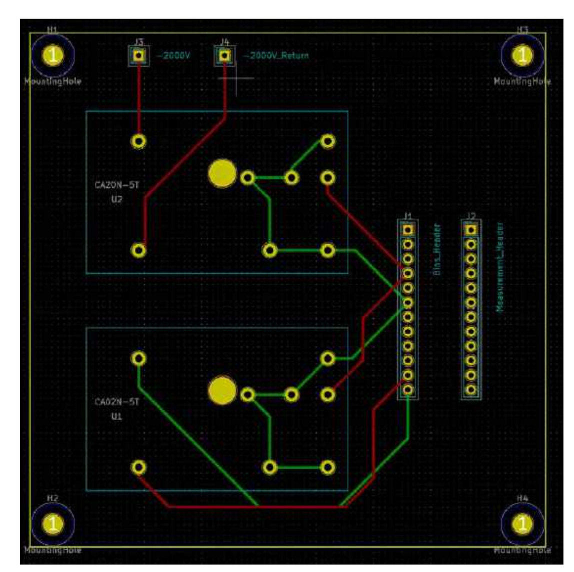


Figure 3. High voltage board layout

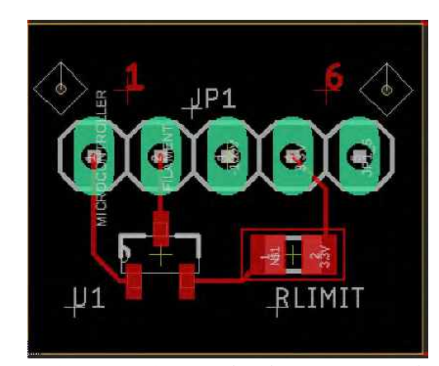


Figure 4. Emission control is responsible for the ejection of the electrons from the filament

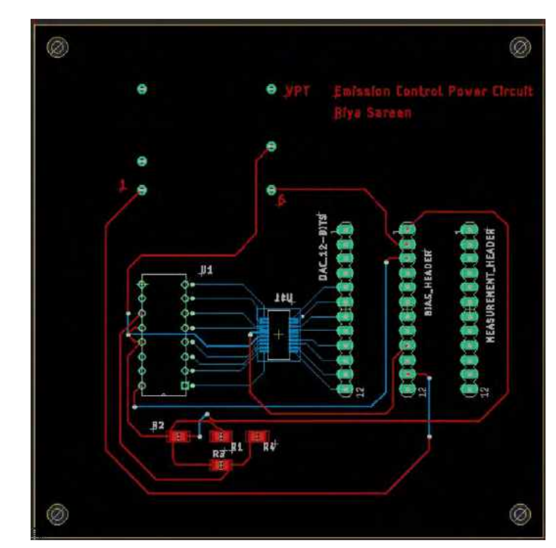


Figure 5. Emission control power provides power to the emission control board

Overall PCB Configuration

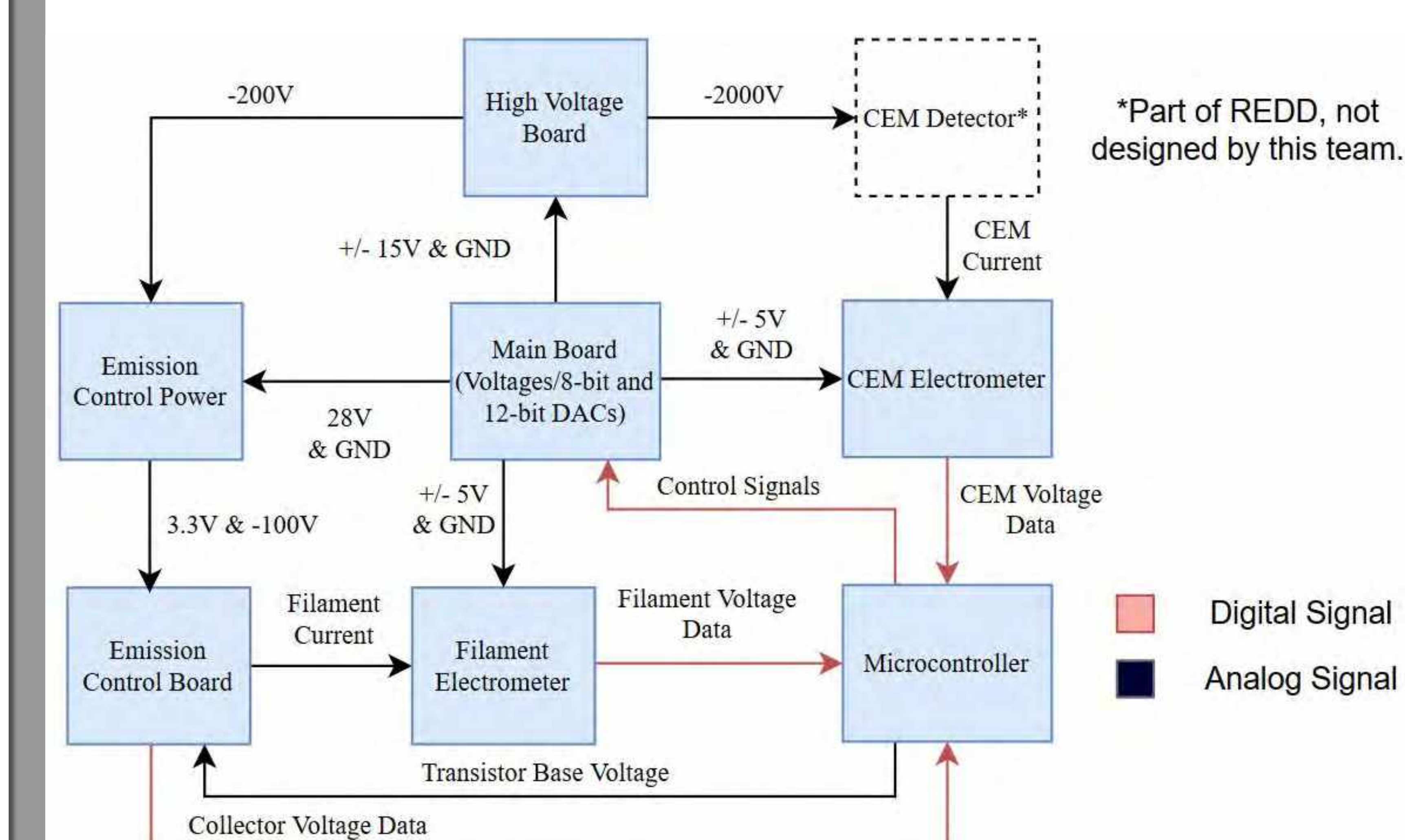


Figure 6. General diagram of how the PCBs interact with each other based on the interface control document. Each of the signals are distinguished between analog and digital signals and labeled to show what the signal is.

Analysis and Conclusion

The system is designed to analyze and compute the velocity of the neutral gas colliding with the ram side of the spacecraft and hence a ground-based result is not possible until the launch.

Only a few subsystems have been individually tested and work as expected. Those subsystems was the emission control and emission control power PCB. The mainboard, high voltage board, and electrometers still need to be tested and verified that they meet requirements.

Challenges

- Vacuum and thermal testing to simulate near-space environments
- All of the materials must be space grade and fulfill military specifications
- COVID-19 caused for the project to end at the preliminary design stage so there was little to no testing of the PCBs

Future Plans

Future plans for the project will include:

- Ordering the capacitors, resistors, and other chips for all of the PCBs
- Test the components in the design on breadboards and make any necessary corrections to the design and PCBs
- Order and populate the PCBs with the correct components
- Conduct individual tests for each of the PCBs, a compatibility test by connecting all of the PCBs together, and various environmental tests on all the PCBs
- Make changes to the PCBs based on the test results and repeat the fabrication and test process
- Update the mainboard to incorporate the stand-alone microcontroller
- Finalize development of the microcontroller's software for the Grid Stack, processing of electrometer data, and communication with the spacecraft flight computer
- Integration of PCBs into 1U CubeSat

References

[1] A. Venkatramanan, "Design of control electronics for the Ram Energy Distribution Detector," p. 69.
[2] T. Rohrer, "An Electrometer Design and Characterization for a CubeSat Neutral Pressure Instrument," p. 83.

VTES - Advanced Metering Infrastructure (AMI) Recommendations

Jose Alicea, Abdulrahman Almulhem, Ryan Edwards, Austin Morris, Daniel Webb

Customer: Mr. Rob Glenn

SME: Dr. Virgilio Centeno

Mentor: Gino Manzo

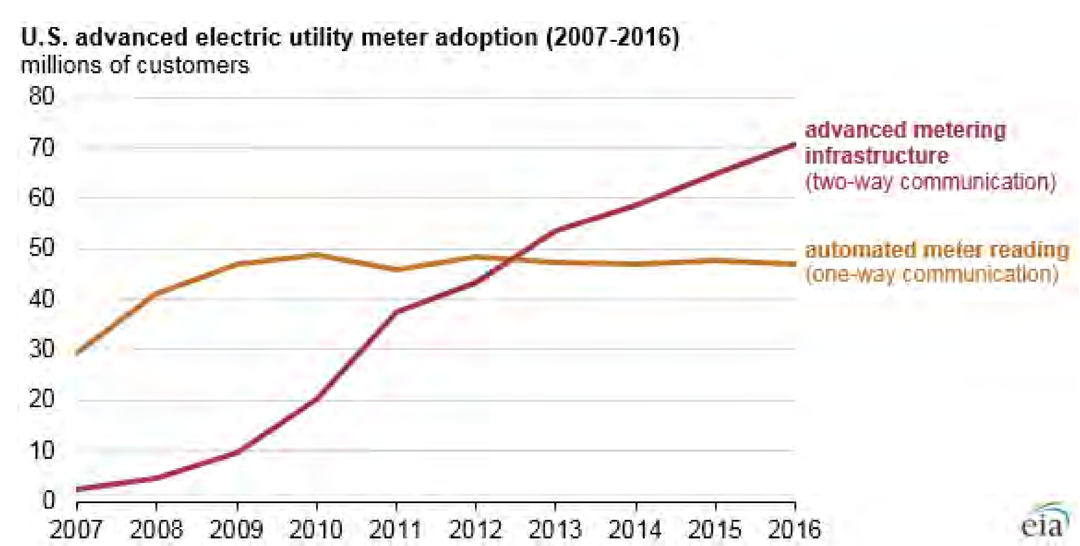
VIRGINIA TECH

PROBLEM STATEMENT and OBJECTIVE

Virginia Tech Electric Service (VTES) is yet to implement a 'smart meter' system for their nearly 7,000 customers in the Town of Blacksburg. Known as Advanced Metering Infrastructure (AMI), these meters allow for better and more sophisticated data management and network communication between utilities and their customers. Several years have passed since VTES has done research into AMI technologies and the feasibility of implementing an AMI system into the Town of Blacksburg. Our team was tasked with providing VTES a recommendation on whether an AMI system is feasible and justifiable. AMI systems are becoming implemented at many utilities due to their benefits. In reaching a decision, the AMI team researched many different aspects of these systems from different approaches. This decision considers the usefulness of implementing such a large and costly system, weighing both the benefits and drawbacks of doing so.

MOTIVATION

Many utilities across the United States are implementing AMI systems. In the recent years, AMI technologies have rapidly expanded, giving these systems the ability to perform complex tasks and provide both the electric provider and the customers enhanced features. Because these systems are expensive to implement and have a direct impact on the customer, it is important to verify that the enhanced capabilities of these systems provide both customer and provider justifiable improvements and qualities. The figure below shows the rate of adoption of AMI systems in the United States.

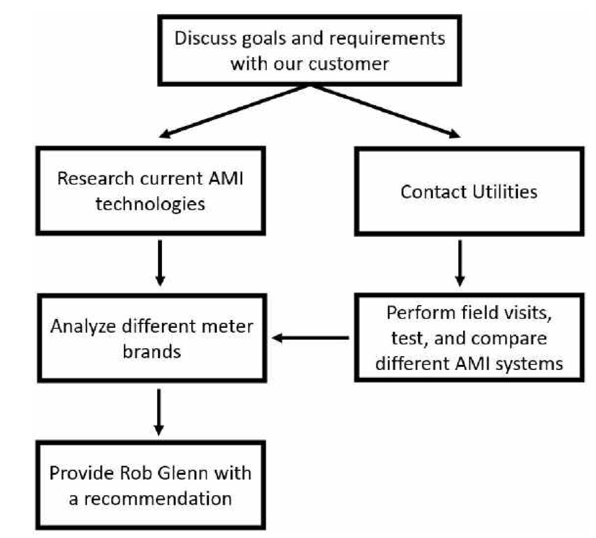


REQUIREMENTS

- Conduct relevant industry research into three AMI facilities similar to VTES
- Investigate current smart meters technology data and their significance and explain them to VTES
- Conduct an interview with VTES engineer to observe readings of current meters
- Interview three utilities who implemented AMI facilities to understand their process and decision factors
- Provide a 500-narrative to VTES customer for implementing AMI
- Recommend a smart meter manufacturer for VTES for future involvement
- Address privacy concerns associated with billing system and user readings to VTES
- Describe the scope of AMI data that overlap with a SCADA system

TECHNICAL DESIGN

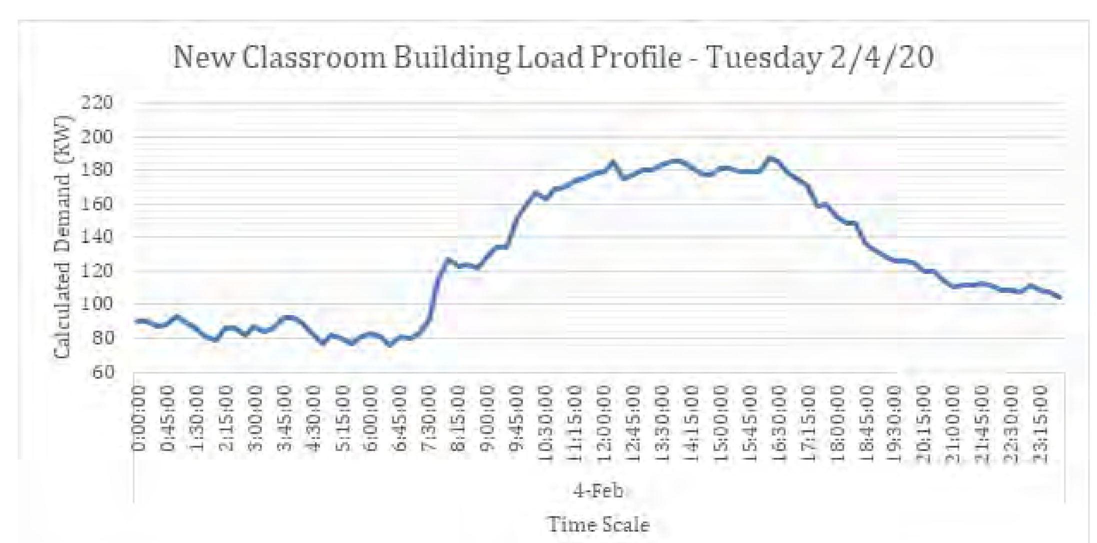
The image below is a visual representation of the technical design process we performed.

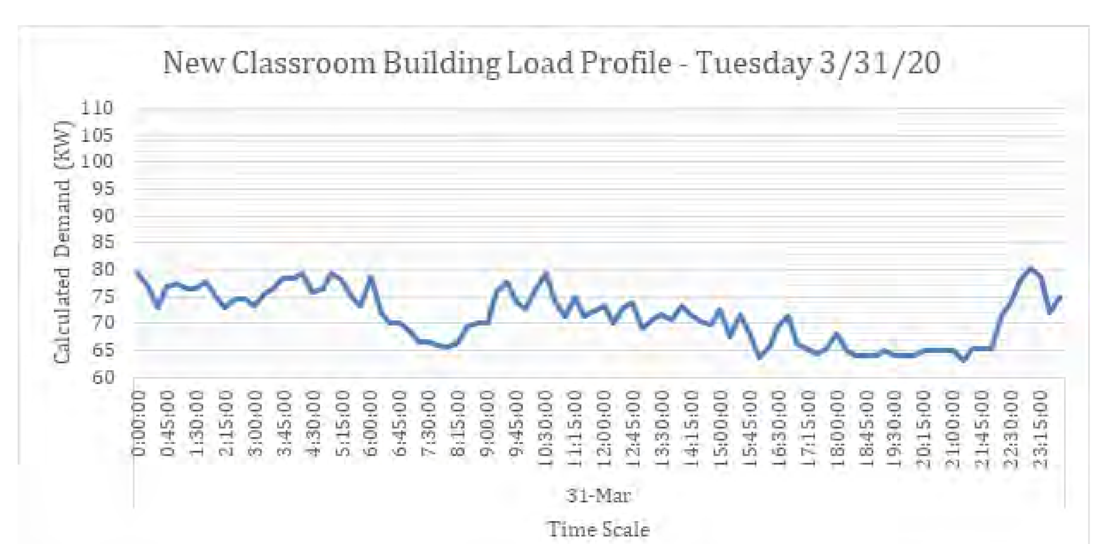


The team began by evaluating the existing VTES metering system. The following key elements were identified:

- Centron-Type C1SR Meters (Itron)
- 7000 meters
- Itron Field Collector (FC3000)
- Meter reading takes 4 days, plus daily starting/ending service

The team performed independent research and visited with utilities to better understand AMI systems. Simultaneously, on-campus Siemens meters were analyzed to generate load profiles to represent the capabilities of AMI systems. Shown below are two days of data for NCB on campus. A typical usage curve is represented on the plot of Tuesday, February 4. The plot from Tuesday, March 31 shows a very flat usage curve since it was no longer being used due to COVID-19.





The team visited with Harrisonburg Electric Commission (HEC), Wake Electric Membership Corporation, and Salem Electric to view different AMI systems. These utilities were picked to provide separate viewpoints on AMI systems, so that the team could get a well-rounded understanding of the different technologies available in modern AMI systems.

Harrisonburg Electric Commission (HEC)

- Year of Start - 2013
- Year of Completion - 2016
- Pilot Test - 2 years, 200 meters
- Service Territory - 18.5 sq. miles
- Number of Meters - 21,000 (18,500 residential)
- Meter Brand - Itron (Honeywell Elster for commercial)
- Communication System - RF Mesh
- AMI System Implementation - Eaton
- MDM System - Developed by Eaton

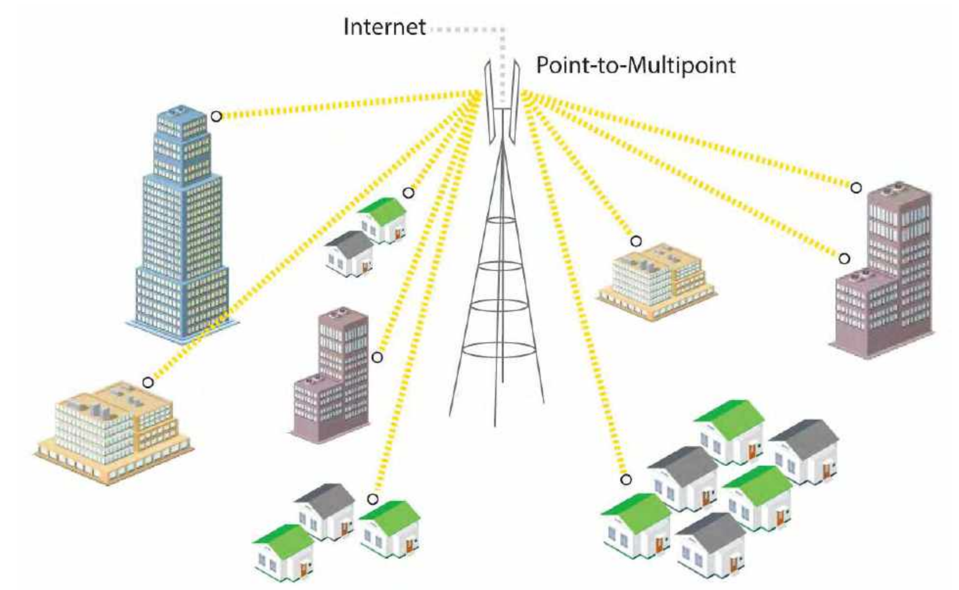
Wake Electric Membership Corporation (Wake EMC)

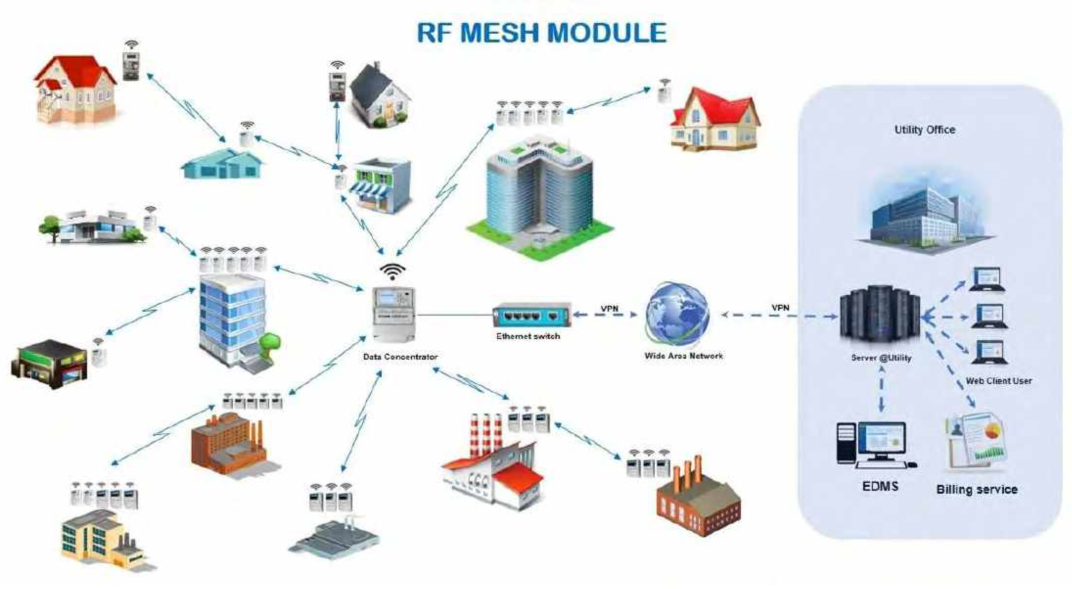
- Year of Start - 2012
- Year of Completion - 2014
- Pilot Test - 90 days, 200 meters
- Service Territory - 620 sq. miles
- Number of Meters - 47,000 (mostly residential)
- Meter Brand - Honeywell
- Communication System - RF Point-to-Multipoint
- AMI System Implementation - Sensus
- MDM System - National Information Solutions Cooperative (NISC)

Salem Electric

- Year of Start - 2019
- Year of Completion - Est. 2020-2021
- Pilot Test - None
- Service Territory - 15 sq. miles
- Number of Meters - 13,400 (10,000 residential)
- Meter Brand - Aclara
- Communication System - RF Point-to-Multipoint
- AMI System Implementation - Aclara
- MDM System - Being developed by Aclara

The figures below show conceptually how RF Mesh and RF Point-to-Multipoint communication systems work. These figures are representative of HEC's, Wake EMC's, and Salem Electric's AMI systems communications.

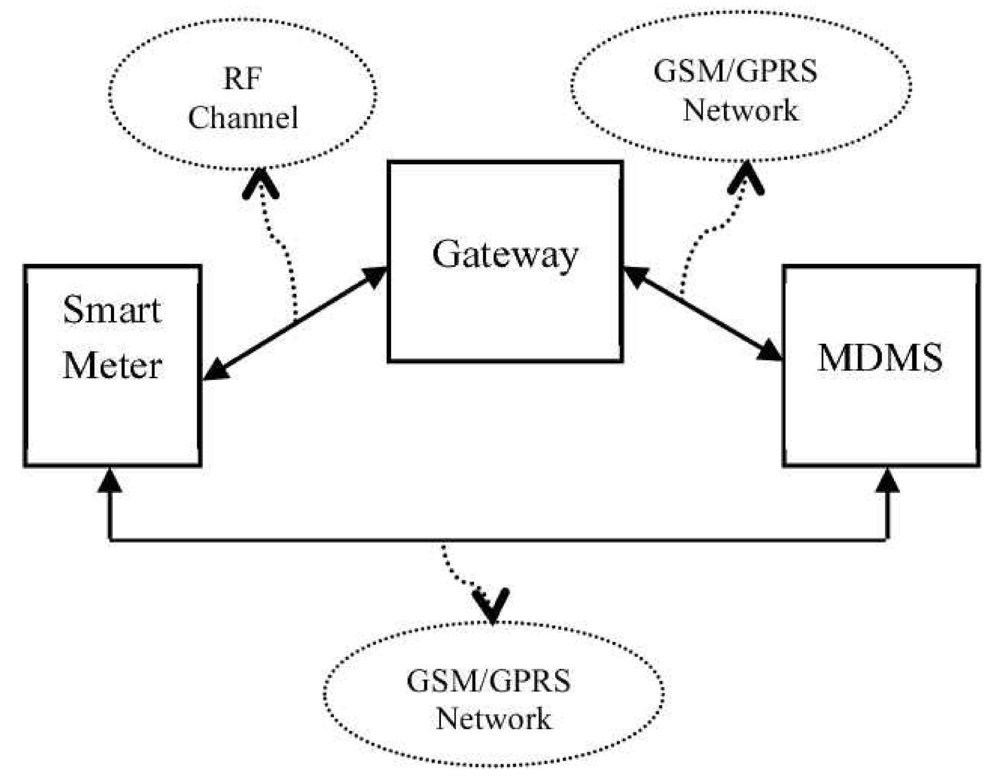




CONCLUSIONS

The AMI team decided that an AMI system for VTES in Blacksburg is both feasible and justifiable The recommendation includes a wireless form of communication and a system similar to the one found at Harrisonburg Electric Commission. Features this AMI system should include, but not be limited to the following.

- RF mesh
- Last gasp
- Auto populating outage map
- kWh monitoring
- Voltage monitoring
- kW demand monitoring (3-phase only)
- Autonomous meter reading
- Prepay system
- Availability to view hourly usage



ACKNOWLEDGMENTS

We would like to thank our mentor **Professor Gino Manzo** for his guidance and support through completing the project and MDE class requirements, our SMEs (**Professor Thaddeus Black for 4805 and Professor Virgilio Centeno for 4806**) for their continuous technical and professional guidance towards completing the project, our customer **Director Rob Glenn** for allowing us to work with him closely for this project throughout this academic year, the head contacts of the three utilities General Manager **Brian O'Dell** of Harrisonburg Electric Commission, Manager of Engineering **Chris Wright** of Wake EMC, and **A.K. Briele** Director of Salem Electric Department for their assistance during our utility visits, and to **Stephen Russell** from Siemens Ind. for obtaining energy data for some campus buildings.

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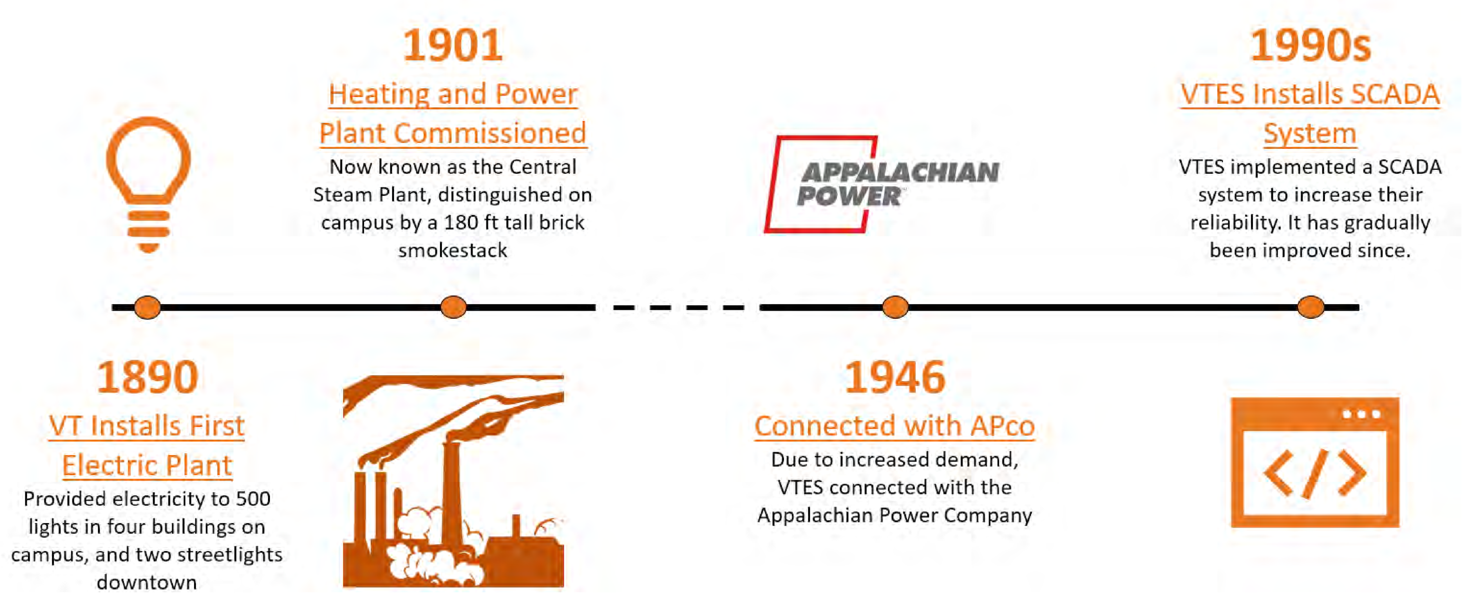
Upgrades to VTES SCADA System

Team: Alex Ford, Wan Nur Liyana Wan Halim, Hayden Mabalot, Bradley Snyder, Colton Stump
Customer: Rob Glenn, VTES **SME:** Dr. Chen-Ching Liu **Mentor:** Prof. Gino Manzo

Virginia Tech Electrical Service (VTES)



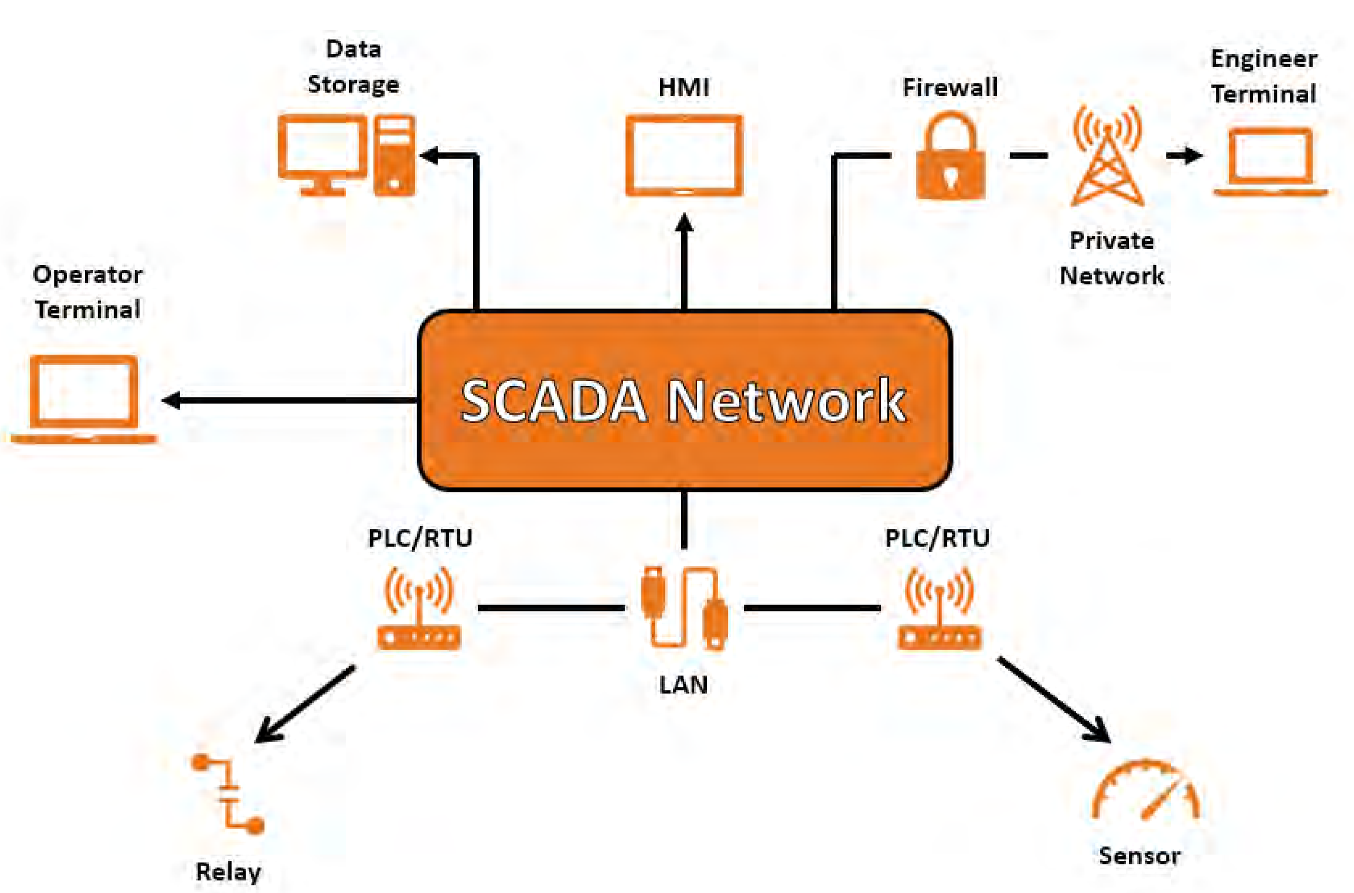
VTES Today: VTES provides electricity to the entire Virginia Tech campus, and to a portion of Blacksburg, VA.

- Customer Load (~60MW)
  - Virginia Tech and Corporate Research Center (60% of load)
  - Section of Blacksburg, VA (40% of load)
  - Critical loads - Dietrick Dining Hall, VT Rescue Squad
- Power Production
  - Primarily purchased from Appalachian Power Company (APCo)
  - Central Steam Plant (capable of generating 10% of load)
    - Electricity is created as a byproduct from steam

SCADA

Supervisory **C**ontrol **A**nd **D**ata **A**cquisition (SCADA) is a network that allows electrical utilities to **monitor**, **remote control**, and **acquire data** from their power grid. It consists of 5 Essential Components:

- Human Machine Interface (HMI)
- Supervisory System
- Remote Terminal Units (RTU)
- Programmable Logic Controllers (PLC)
- Communication Infrastructures



Project Objective

VTES implemented their current SCADA system back in the 1990s. It currently features:

- **Redundancy:** Dual lines with automatic switching
- **Cybersecurity:** Restricted physical access to SCADA room, individual logins, private network
- **Data Acquisition:** Metering at breakers/feeders in substations

The mission is to recommend upgrades to the current SCADA system to:

- Improve **resiliency**
- Increase **reliability**
- Increase **data acquisition**

Proposed Upgrades

1. **Increase remote data points to identify fault location**
2. **Add reclosers to areas that have a higher risk of faults**
3. **Incorporate power flow software (e.g. GridLAB-D) into VTES Planning**
4. **Separate Advanced Metering Infrastructure from the SCADA HMI**
5. **Record SCADA data from outages to help identify issues and for use in reliability reports**
6. **Install secure, remote access to the SCADA system via multi-step authentication**

Upgrade Benefits

Upgrade	Benefits
1	• Reduce fault location time • SEL relays report overcurrent faults to SCADA system • Impedance relays determine the approximate location of a fault on a line
2	• Will clear temporary faults in seconds • Improve reliability by reducing System Average Interruption Duration Index (SAIDI) • Unnecessary to send a crew to find and repair the temporary fault
3	• Allow for the balancing of VTES critical load with the steam generator • Better planning of grid upgrades • Power Quality management with the addition of solar cells to the grid
4	• Improve cybersecurity by reducing number of SCADA access points • Allows for both systems to function independently
5	• Data acquisition, analysis, and metrics (e.g. SAIDI) • Collaboration with Virginia Tech's Power and Energy Center
6	• Removes travel time to VTES for the purpose of viewing SCADA • Reduces outage duration

Power Flow Analysis

- **Power Flow:** An analysis of a system's capability to adequately supply the connected load
- **Objective:** Calculate voltages for a given load, generation and network condition
- **How does power flow analysis benefit the VTES system?**
  - Balance the loads and sources
  - Helps decide the best operation of the existing system
  - Assists in planning/designing the expansion of the VTES system
- **How can power flow be used with the future upgrades?**
  - Minimizes system loss and provides a check on the system's stability
  - Determines the best location for installation as well as optimal capacity of future generation
  - Evaluate the effects of the newly-added equipment to the system

Power Flow Analysis Resilience Test

- **Design**
  - Emergency situation: APCo interconnection unavailable
  - Resiliency Mode: Power VT Rescue Squad from steam plant
- **Build**
  - Use GridLAB-D: Model steam plant as power generator
  - Model underground line, transformer ratings, and critical load
  - Use multiple recorders to sample voltage magnitude and phase
- **Test**
  - Set load of VT Rescue Squad to varying power consumption levels to evaluate resiliency

VTES Resiliency Mode: VT Rescue Squad

- **Results**: Voltages are similar in magnitude and the phases are approximately 120 degrees apart. Since the system is balanced, the generator can supply the critical load, improving resiliency.

Load Voltage on Phase A	263.206∠-2.99° V
Load Voltage on Phase B	263.143∠-123.71° V
Load Voltage on Phase C	263.297∠115.90° V

MAGLEVT

Magnetic Suspension System – Team Alpha

Chase Murphy, Heyan Sun, Robert Crnkovich, and John Garmon

Sponsor: VPT Inc., Dr. Dan Sable

SME: Matthew Strehle

VIRGINIA TECH.

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH.

Abstract

Control theory is one of the pillars of electrical engineering. From thermostats to cruise control to nuclear power plants, billions of control systems have been designed and implemented around the world. **The purpose of this project was to design, build, and test control mechanisms to stabilize an inherently unstable magnetic suspension system.** We implemented both analog and digital control systems, designed and developed our own custom housings and PCBs and successfully suspended the ping pong ball in mid-air and passed it between solenoids.

Introduction

The goal of this project was to stabilize a magnetic suspension system.

The system requirements were:

- Implement Control Theory Concepts to Levitate an Object
- Stabilize the Object & Keep it Stationary
- Stabilize Against and Reject Outside Forces

The system was comprised of:

- **Solenoid Electromagnet** – Applies force on the permanent magnet
- **Hall Effect Sensor** – Measures the permanent magnet position
- **Control and Power Electronics** – Provides corrections to the solenoid current.

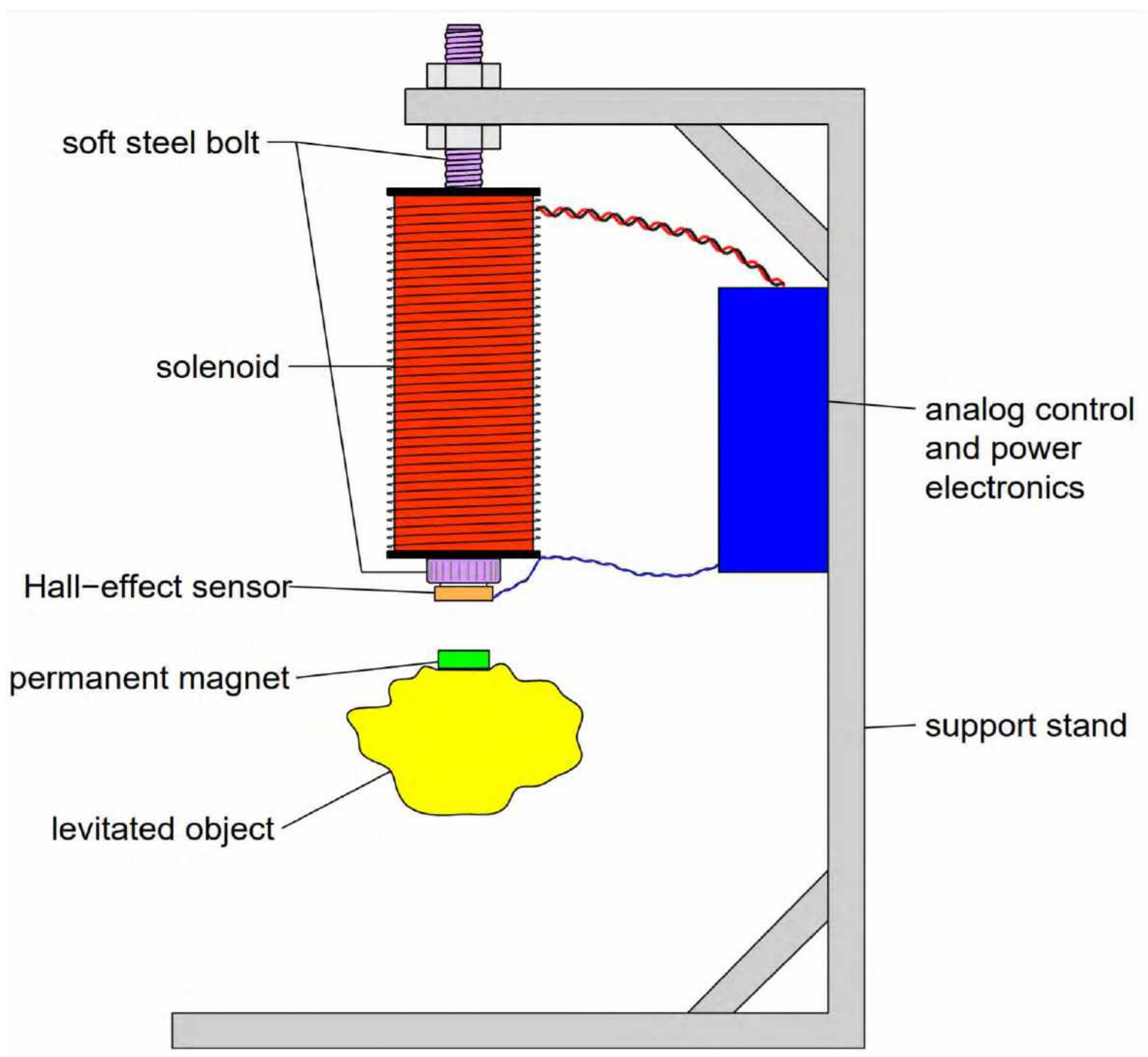


Fig: General Magnetic Suspension System Setup

Methodology

Analog Control

For analog control, we needed to design a controller circuit to stabilize the system. We:

- ***Analyzed*** the source of instability, examining the System Transfer Function, finding a right-hand pole (RHP).
- ***Designed*** a type-2 controller to "pull" the RHP to the left-hand side.
- ***Implemented*** this design with both protoboard circuits and PCBs to test our design.
- ***Coupled*** single-Maglev circuits to make double-Maglev circuits

Before Spring Break we were **just one step from implementing the triple-Maglev system**, we have three Solenoids together and all that was left was to apply the reference source.

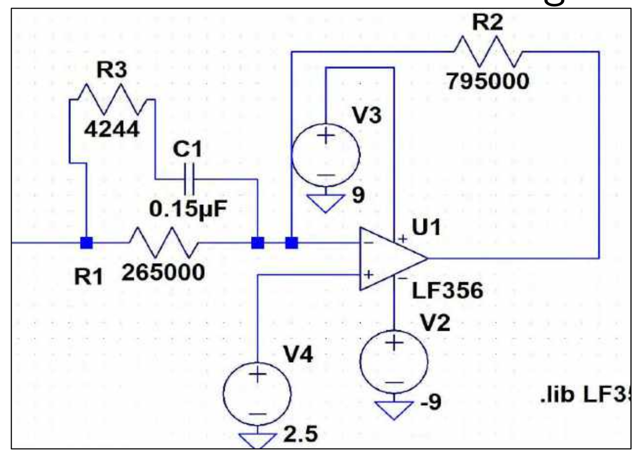


Fig: Type-2 Compensator Design

Printed Circuit Board (PCB) Design

3 PCBs were designed for this project: a single solenoid analog/digital board, a three-solenoid analog board, and a 6-solenoid digital board. The board designs implemented:

- Extra Sensor & PWM Measurement Pins – Enabling inspection of these key signals while the board is in use
- Jumper Break Point: PWM Generator – Allowing for the PWM Chip to be **swapped** with connectivity to an off-board microcontroller, **enabling Digital Control on the same PCB**
- Jumper Break Point: Post-Compensator – Allowing for the direct measurement of a **root locus plot** by connecting a Function Analyzer
- Top-Facing I/O Pins – **reducing wire clutter**

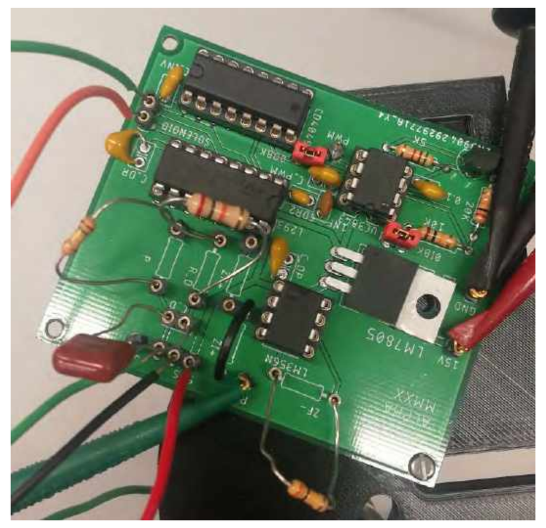


Fig: PCB Board in Action

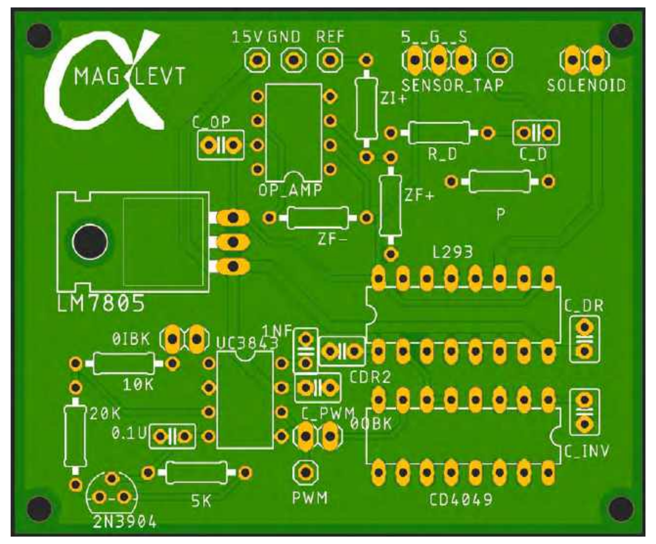


Fig: PCB Design Schematic

Digital Control

For digital control, we utilized the MSP432 Microcontroller from Texas Instruments to implement a feedback loop due to the board's fast internal clock (48 MHz). We implemented **proportional and derivative (PD) control** to suspend the magnet. The MSP432 reads in the Hall effect sensor voltage with a **14-bit ADC**. The microcontroller then computes the proper response and outputs a PWM control signal that is sent to the solenoid power electronics. **As of recent tests, this system is pseudo-stable** as it can reliably suspend the ball for just beyond 20 seconds before dropping.

```
float get_PD_Output() {
    // Initializes errors.
    float error = 0;
    float error_dot = 0;

    error = (desiredVal - outputVal);

    // Compute derivative of error.
    error_dot = (error - prev_error)/dt;

    // Compute PD control.
    PD_Output = (kp*error + kd*error_dot);

    // Save last error value for next derivative
    prev_error = error;

    return PD_Output;
}
```

Fig: PD Controller Code Snippet

3D-Printed Housing Design

The maglev system relies heavily on good, reliable sensing. And so, a housing was designed to stabilize and protect the hall effect sensor for reliability and consistency. The sensor housing is **3D-printed** and **clips** onto the top of a screw to help hold it in place. It is then tightened on with a nut to further ensure its stability.

The main housing suspends the solenoids and sensor housings. Several designs were 3D printed for testing. One allows for 6 solenoids arranged in a ring to simulate an orbit. The other has a 9x5 grid of holes to allow multiple different configurations of solenoids. The 6-solenoid orbital housing is shown below.

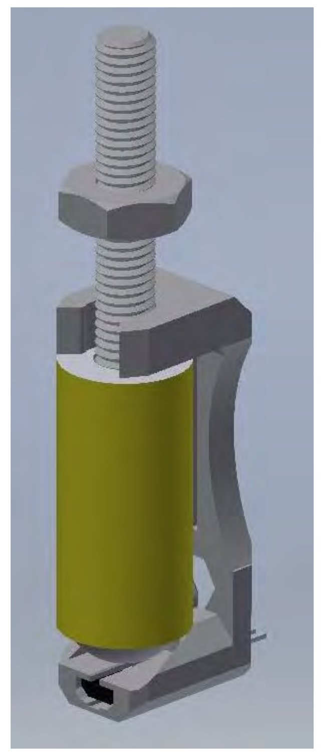


Fig: Sensor Clip-On Housing

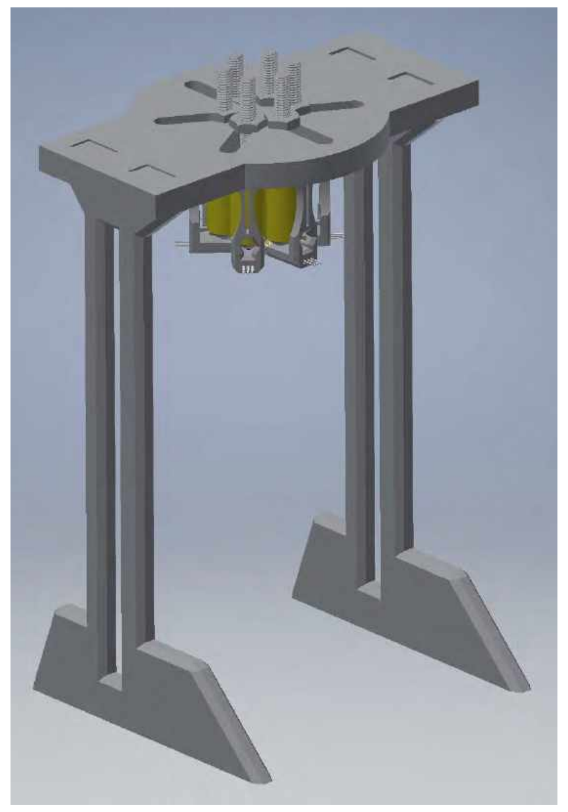


Fig: 6-Solenoid Orbital Housing

Results

The single-solenoid analog system:

- <u>**Successfully levitated**</u> a ping-pong ball
- Handled disturbances in the reference signal up to **1 Hz** and **780mV pk-pk**
- <u>**Displaced**</u> the object in the air by a maximum of 0.75 inches

The double-solenoid analog system:

- **Passed** the ball back and forth laterally between two solenoids

The single-solenoid digital system is **pseudo-stable:**

- **Levitated** the ping-pong ball for just **beyond 20 seconds** before dropping
- Actively being tested

The multi-solenoid system:

- **Ready** for initial testing
- **Not yet tested** due to COVID-19,

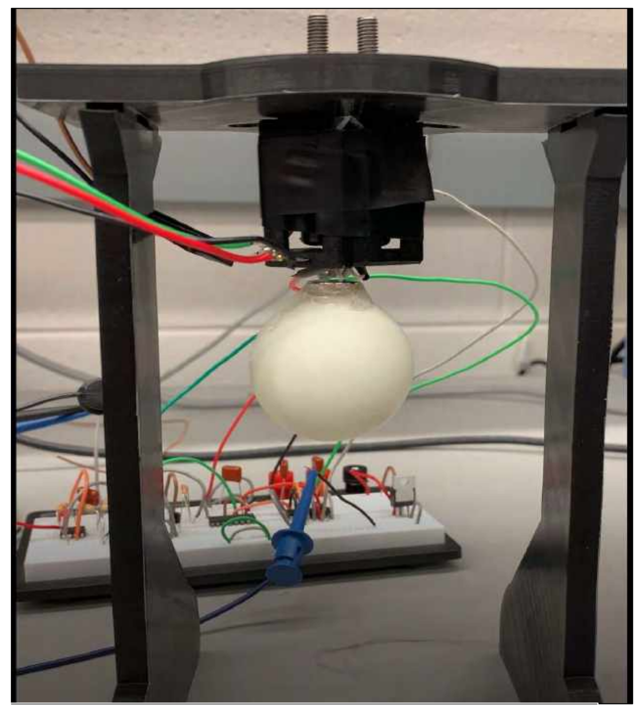


Fig: Suspension from 2-Solenoid System

Conclusion

Within this two-semester major design experience, we worked together to design, build, and test a magnetic suspension system and **have achieved levels of stability with both analog and digital control techniques**. We have successfully **implemented a two-solenoid levitation** system and had the initial design of the multi-solenoid system built but were not able to test due to the COVID-19 Pandemic.

Acknowledgements & Contact

Special thanks to the Virginia Tech ECE department with providing us a workspace in the Integrated Design Studio, and especially to Dr. Sable, Matthew Strehle, everyone at VPT Inc., and Jiayu Li for their guidance and support.

Contact:

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Robert Crnkovich crobert2@vt.edu	John Garmon jgarmon@vt.edu

Digital control of multiple electromagnets for object levitation

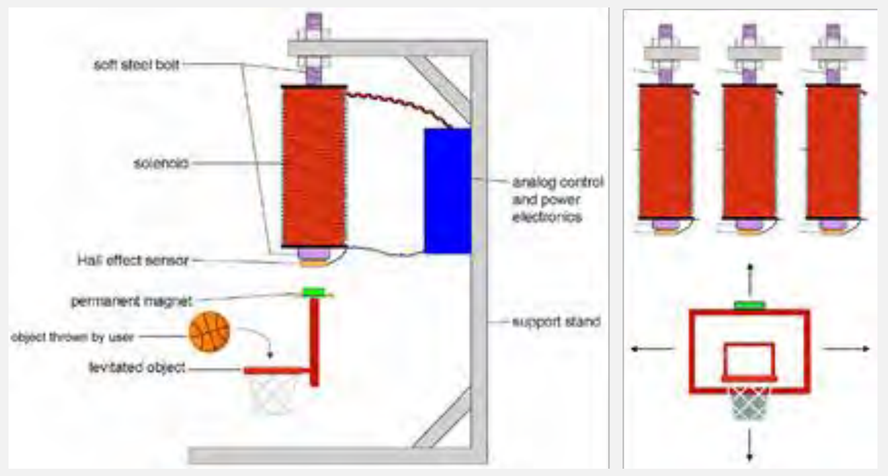
Team Members: Nhi Bui, Maggie Garrity, Matt Nicklas, and Zhengming Hou

Customer: Chris Mecka, VPT Inc. **SME:** Dr. Dan Sable **Mentor:** Dr. Scot Ransbottom

1. Motivation

To design and demonstrate a magnetic suspension system whereby an object attached to a permanent magnet can be suspended vertically in air by controlling the current through multiple electromagnets above the object.

Our creative application is a levitated miniature basketball game where a user bounces a ball off the table and into the hoop.



2. Objectives

- Analog circuit design and debug
- Design and analysis of magnetic elements
- Control loop design and analysis
- Closed loop optimization and performance measurement using advanced test equipment
- Use of a microcontroller for digital feedback
- Printed circuit board design and construction
- Mechanical design and use of a 3D printer
- Creative design approach

3. Design Architecture

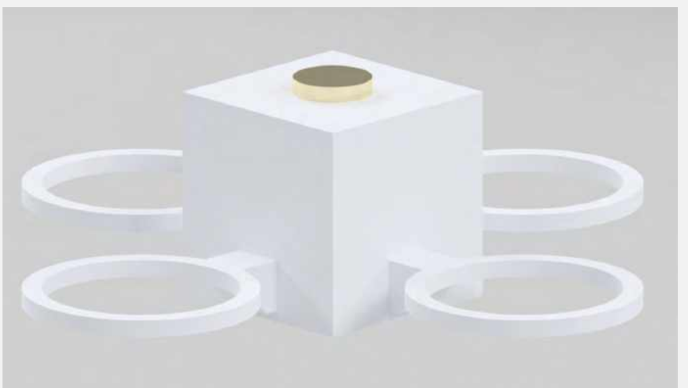
The final structure has several components:

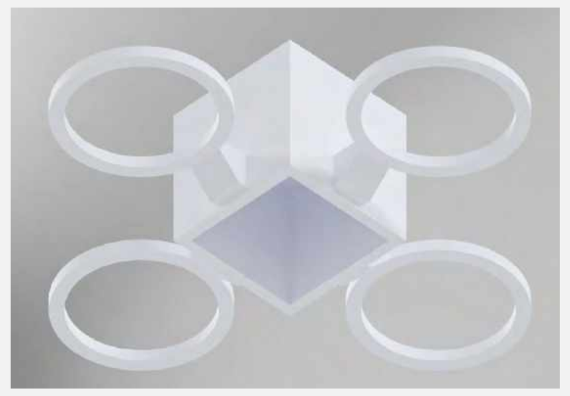
1. A 12 in. × 6 in. × 8 in. wooden stand
   - Backed with plexiglass to enclose thrown projectile
   - Adjustable plastic bar to change location of hall effect sensors
2. Three self-wound electromagnets
3. Three hall effect sensors
4. 3D-printed levitated quad-hoop
5. Aluminum enclosure for PCB and microcontroller

4. Levitated Hoop Design

The hoop needed to maximize size and minimize weight

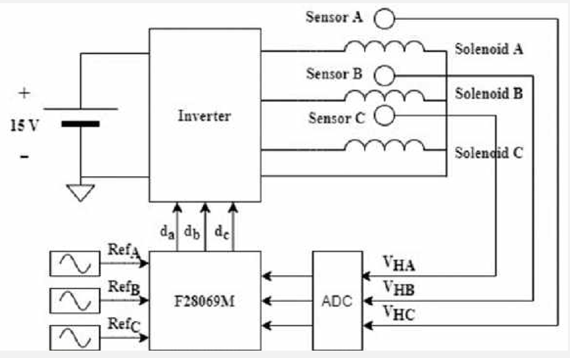
- 1.25 in. hoop diameter (to fit a projectile about the size of a marble)
- Four-sided hoop (to account for possible rotation)
- 23 g. weight (to improve dynamic control)



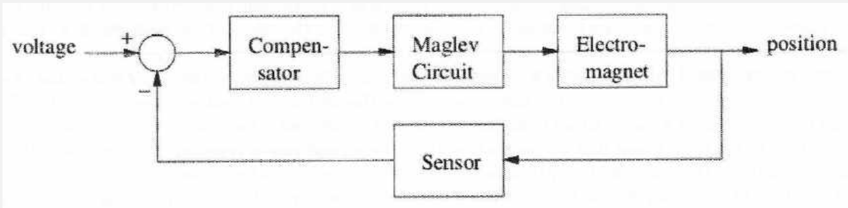


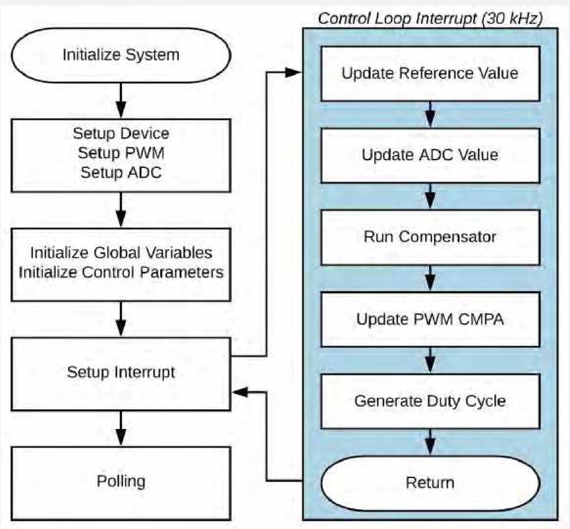
5. Controller Design

Digital control allows for easier tuning and advanced control techniques, such as adaptive control. The initial digital controller was derived from the Z-transform of our previous analog compensator.



The *Launchpad F28069M* microcontroller was selected with a sample frequency of 30 kHz to provide a responsive system with good transient response, while allowing sufficient clock time to sample the ADC and run the compensator.



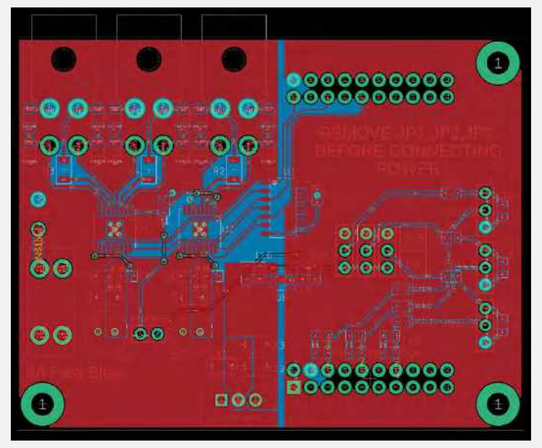


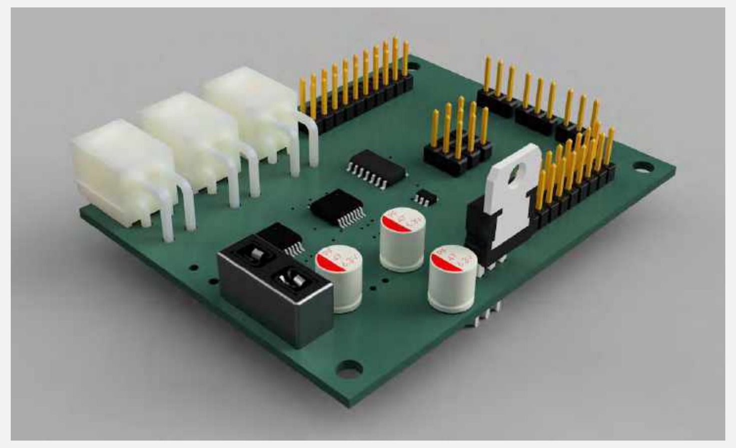
6. PCB Layout Design

This project requires a PCB to support the following functions:

- ***Power supply*** – Supply power to the electromagnet drivers, sensors, MCU, and other digital logic
- ***Signal Conditioning*** – Filter and level shift the analog voltage readings from the hall-effect sensors to feed the ADC
- ***Drivers*** – Convert the logic-level PWM signals from the MCU to a complementary PWM signal to power the electromagnets

Our PCB layout was completed and the PCB manufactured. Due to COVID-19, we will not be able to completely test the PCB with the rest of the system.





7. Analysis and Conclusions

Because of COVID-19, full testing of the digital system was not completed. Results from the previous analog system are presented.

Specification	Desired Value	Analog System	Digital System
Static Levitation Time	10 minutes	> 25 minutes	10 minutes
Max Sinusoid Input Amplitude	1 V_{pp}	0.6 V_{pp}	0.5 V_{pp}
Max Sinusoid Input Frequency	5 Hz	1.2 Hz	3 Hz
Oscillations Before Stabilization of Step Input	5	5	N/A

8. Challenges

- COVID-19 shut down the build of the project, limiting the final project as simulations and models
  - COVID-19 did, however, allow us to react to a significant unplanned event and learn how to make progress in light of a challenge.

9. Future Plans

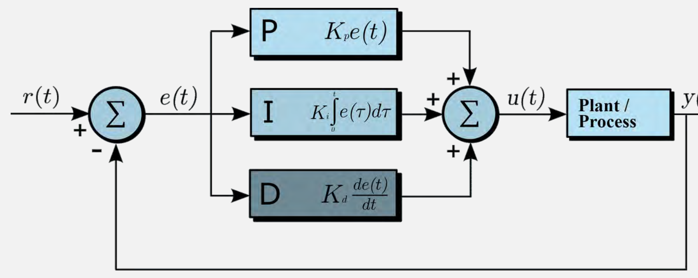
Because of COVID-19, the assumption was made that the self-wound electromagnets could levitate the 23 g hoop. The following is a test plan to validate and improve the design if that is not the case:

1. Adjust offset voltage
2. Add more windings to electromagnets
3. Thin out the walls of the hoop design or make it smaller, reprint, then repeat steps 1 and 2

Another plan is implementing a PID controller to allow for adaptive control to improve system response in the following occurrences:

- Changing the levitated object weight
- Adding a disturbance

Current plans call for only implementing a PD controller, figuring the pole for integral control would be placed at too low of a frequency to have a notable effect.



Acknowledgements

We would like the following people for their support throughout the project:

- Chris Mecka, our customer
- Dr. Dan Sable, our subject matter expert and sponsor
- Jiayu Li, our graduate teaching assistant
- Campbell Lowe, VPT Inc.
- Dr. Scot Ransbottom, our mentor

Magnetic Levitation System

Renad Bougis, Isaias Noda and Samuel Washburn

Virginia Tech ECE 4805/4806 Major Design Experience

Introduction

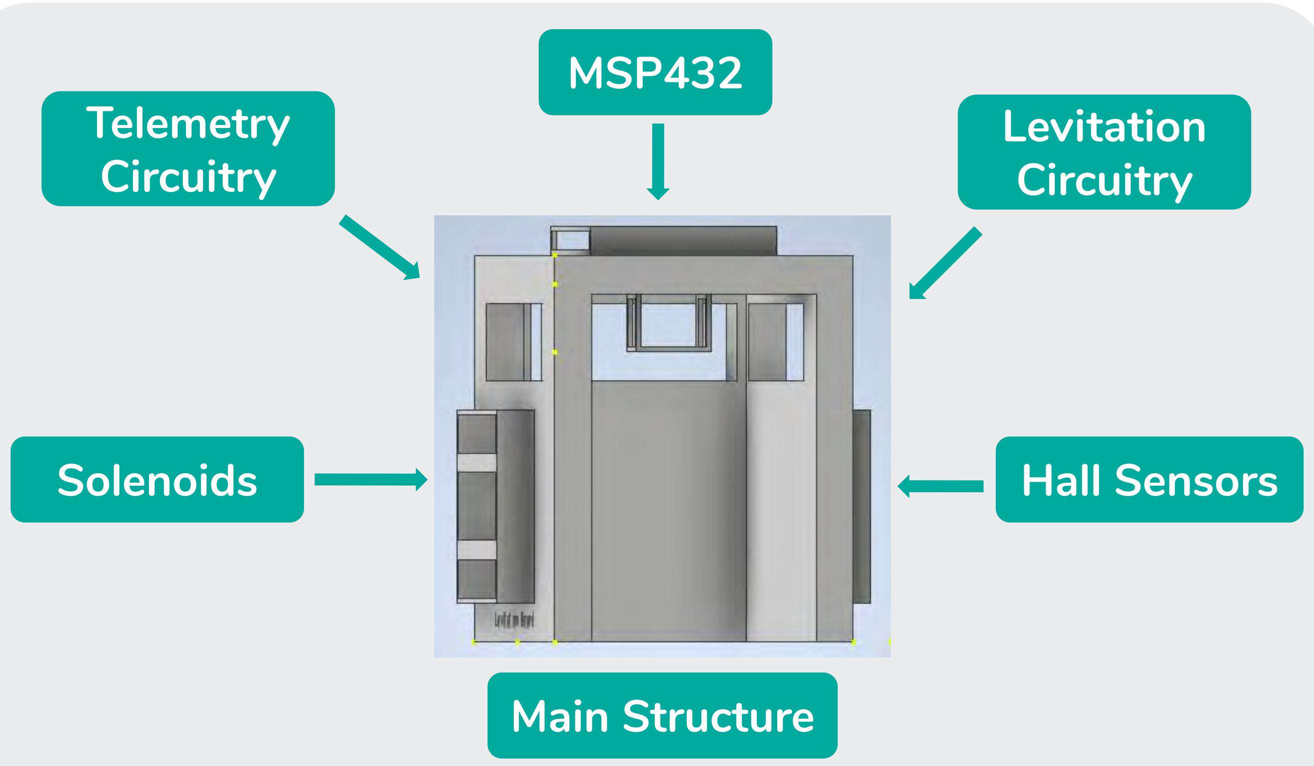
Magnetic levitation of an object is an **unstable system**, as the transfer function from solenoid current to object position presents a right half plane pole. Through **feedback** and the design of a **compensation network**, the system can be stabilized and magnetic levitation can be achieved.

Objective

The team will design and build a magnetic levitation system. The system will be able to:

- Levitate a **4g** object for at least **20 minutes**.
- Move the object **0.25 inches** vertically.
- Move the object **0.5 inches** horizontally.
- Produce a stabilized frequency response, reject disturbances, and track injected signals.
- Operate in 'digital mode', in which it uses **digital control** to achieve levitation.
- Utilize **telemetry**. Colored lights will be used to give real-time information about the system.

Approach



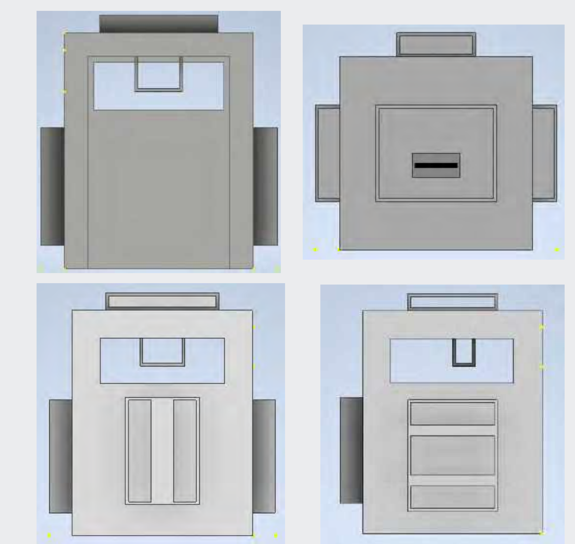
The team's levitation system consists of:

- A 3D printed main structure.
- Two solenoids and two Hall sensors.
- An MSP432 microcontroller with software.
- Two Levitation PCBs.
- A Telemetry PCB.

These subsystems work together to achieve the levitation, movement, stability, digital control, and telemetry objectives of the system.

System Design

Main Structure

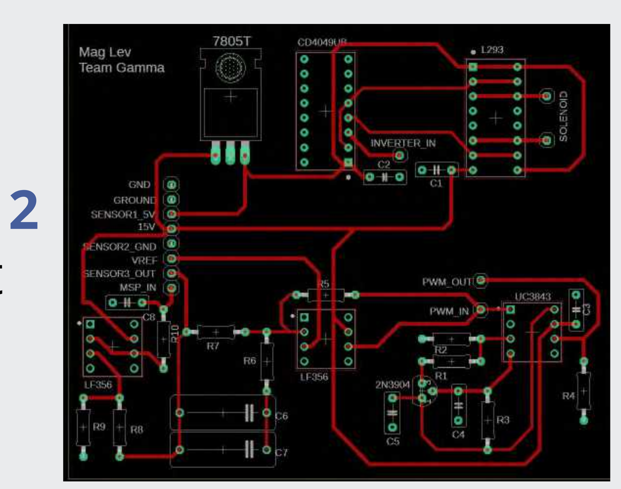


Autodesk Inventor was used to design the system's main structure. Four compartments are on the outside of the structure to house the two Levitation PCBs, the MSP432, and the Telemetry PCB. The compartment on the inside of the model houses the solenoids and Hall sensors. (top row views - front, top; bottom row views - back, left)

Solenoids and Hall Sensors

Two 12V 0.6A solenoids were chosen for the system. They are operated by two PWM signals that control attraction and repulsion strength. Two Hall sensors were chosen for the system. They output a voltage which is linear with respect to the distance from the object.

Levitation Circuitry

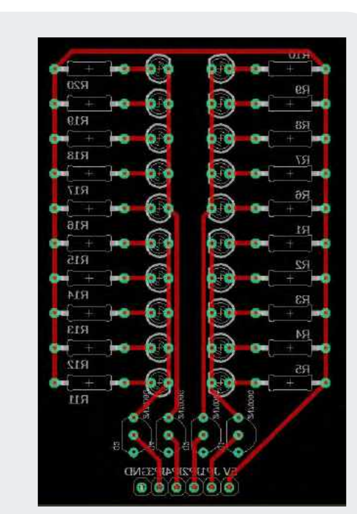


This circuit contains a feedback loop that receives an input from a Hall sensor and controls the current through a solenoid to maintain a constant levitation position. A **Type 2 compensation** network was designed to stabilize the right half plane pole in the control loop. One circuit is used per solenoid. The circuits can coordinate the solenoids for **horizontal movement** by using two offset sinusoids to inject their reference voltages.

MSP432

The digital mode achieves magnetic levitation through TI's MSP432, which acts as a **software compensator** and outputs a PWM signal. To compensate the system, a proportional-integral-derivative **(PID)** controller was designed. '**Intelligent control**' is also achieved by automatically adjusting PID parameters for varying object weights, object positions, and other conditions.

Telemetry Circuitry



This circuit has four LED arrays of different colors. The MSP432 handles data processing from the system, and sends control signals to toggle the LED arrays. The green array means "levitation active". The red array means "levitation not active". The blue array means "digital mode active". The yellow array means "intelligent control active".

Project Outcome

The team built the subsystems and **achieved** these objectives:

- Levitation weight and duration.
- Vertical and horizontal movement.
- Stable frequency response, disturbance rejection, and injection tracking.
- Levitation using digital control.
- Telemetry capabilities with four states.

Because of COVID-19, the team was unable to fully integrate all subsystems and fully test intelligent control and telemetry. This project taught the team about control theory, PCB design, programming, and 3D design.

Future Work

The team would like to explore:

- Handling more conditions for intelligent control (ex: object shape)
- Integrating more than two solenoids for larger horizontal movement.
- Increasing telemetry capabilities to communicate more system states.
- Integrating larger solenoids for stronger levitation strength.

Acknowledgements

- Thank you to Dr. Sable for his technical expertise and teaching.
- We are grateful for Campbell Lowe's guidance and readiness to help our team.
- We appreciate Professor Ransbottom for his guidance and coaching.

References

[1] D. Trumper, "Magnetic Suspension Techniques for Precision Motion Control," Ph.D. dissertation, School of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, 1990.

Net Zero Energy Data Center Design

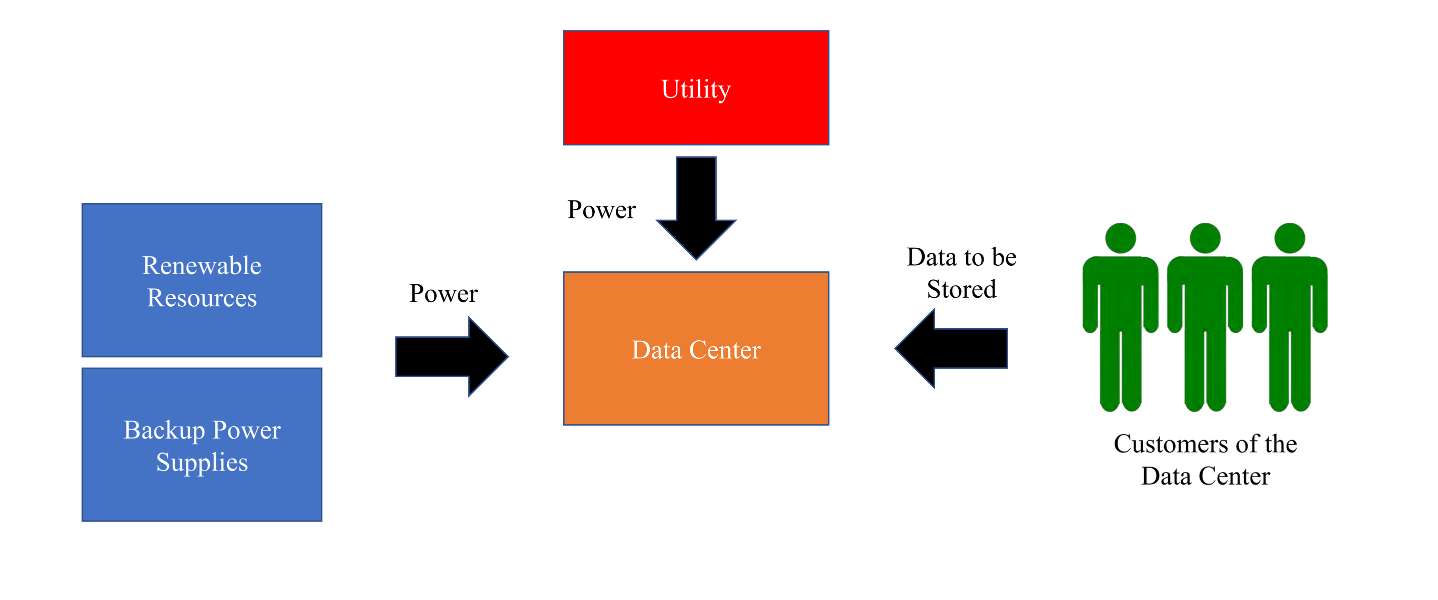
Team Members: Paul Benedict, Connor Kerr, Jack Langford, Gareth Li, Nicholas Luca
Customer: Dan Morton, Steve Bowman
SME: Jaime De La Ree **Mentor:** Toby Meadows **GTA:** Amrita Chakraborty

Project Requirements

We were tasked with designing a data center in Lynchburg, VA that fits the following specifications:

- The data center shall have 99.9999% reliability or up to 32 seconds of downtime per year
- The data center shall incorporate on-site renewable energy generation at 12.47kV to help data center achieve net-zero energy consumption.
- Land for energy production shall not exceed the square footage of the data center building.
- The center contains 160 racks and the design must consider a 25% growth in server racks

Concept of Operations



Power Sources

Power is provided to the center from three main sources: utility power, backup diesel generators, and renewable energy produced on site.

Utility Power

- Power is provided to the center via three feeders at 12.47 kV
- This utility power is then condensed down to 2 lines using transfer switches
- The power is stepped down to 480 VAC using 2 3000 KVA transformers
- Power from one side of the plant alone can power the entire data center alone; made possible due to a normally open tie breaker connected to each bus

Backup Diesel Generators

- These generators will start when power from the utility is disrupted
- Diesel generators were chosen over gas generators due to reduced noise levels, lower maintenance costs, and less volatility
- While the generator comes up to speed power is provided to the mechanical and server loads using Uninterruptable Power Supplies (UPSs)
- Each set of 3 generators can power the entire plant if needed

Renewable Power Sources

- A combination of renewable sources will be used to provide additional power to the data center to increase reliability
- Solar Panels will be used to charge UPSs as well as provide power for a portion of the server load if needed
- A Geothermal cooling system is used to help reduce the cooling load by replacing conventional chillers

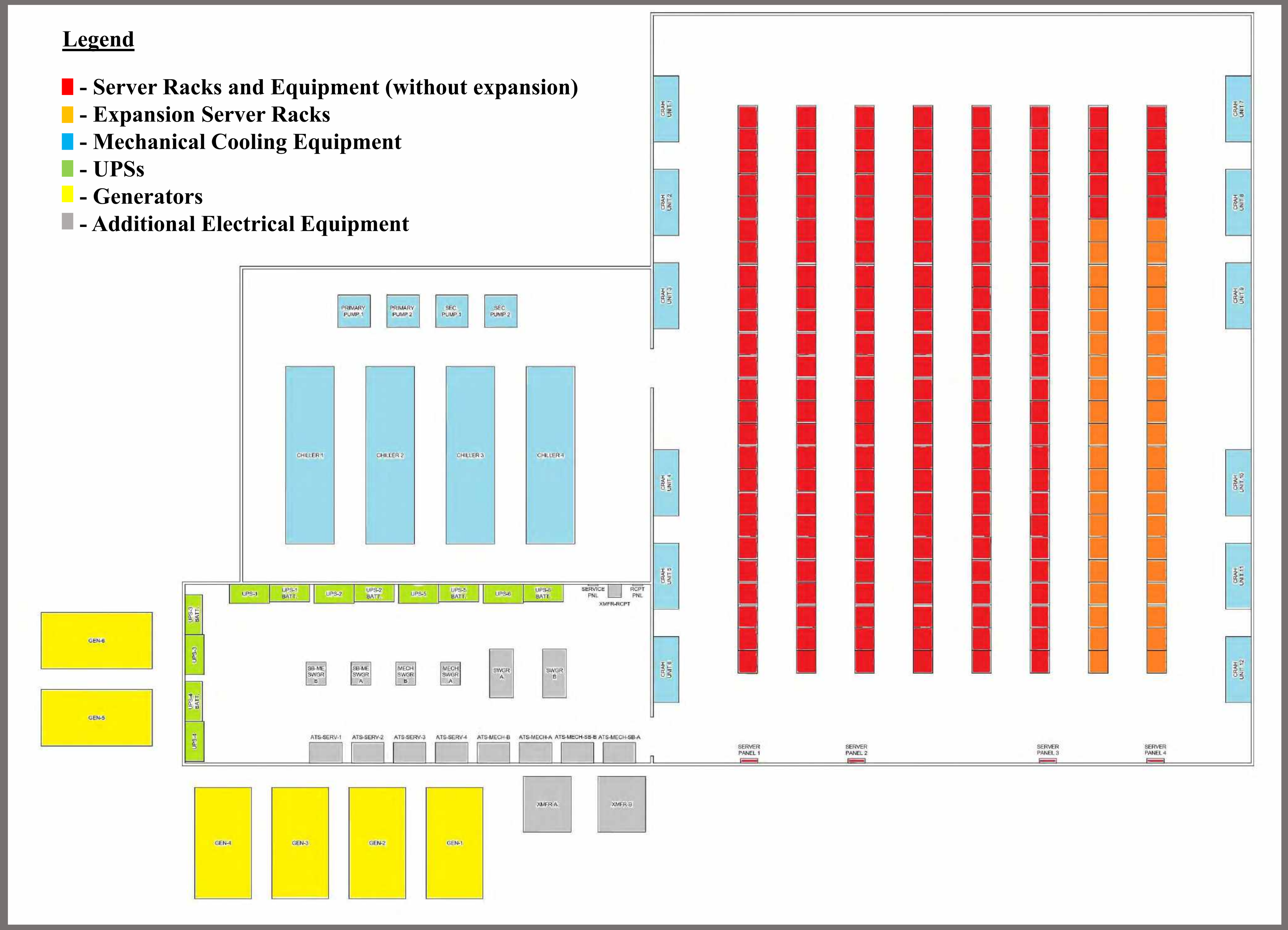
Reliability Calculations

Through provided utility downtime data and an army technical manual provided by the customer reliability of the system was calculated. The generators alone had 99.99998% reliability, due to the fact, four generators must fail to cut off power to the center. Regarding electrical equipment the following was found:

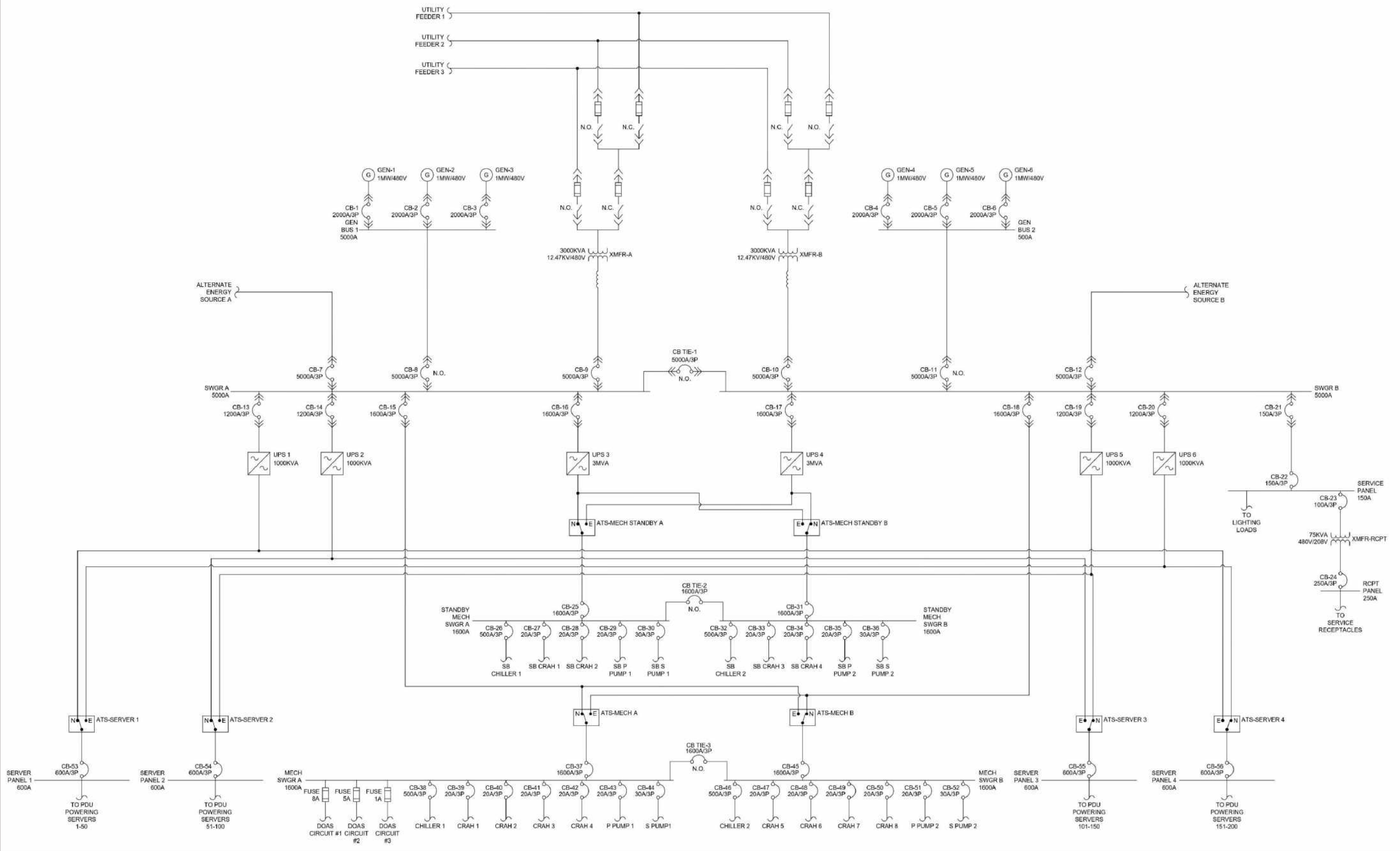
AVAILABLITY TO SERVER/MECHANICAL PANELS			
ITEM	ITEMS NEEDED TO FAIL	DOWNTIME	AVAILABILITY
TRANSFORMER	2	1.66358E-10	1
CIRCUIT BREAKER (DRAWOUT)	2	2.98269E-09	0.999999997
CIRCUIT BREAKER (MOLD CASE)	2	6.77329E-11	1
UPS	2	2.37276E-09	0.999999998
ATS	2	2.0359E-08	0.99999998
SWITCHGEAR	2	2.8218E-07	0.999999718

Every possible path was found to have at 99.9999% or higher reliability. The customer's requirement on reliability has been met.

Final Layout of Data Center



Single Line Diagram of Electrical Components

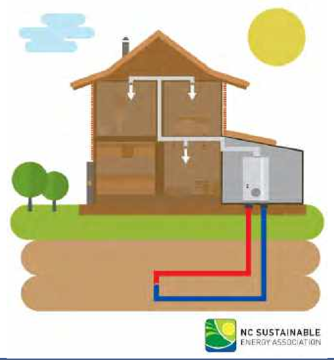


Solar Power

- Due to size constraints the solar farm was constrained to 40,000 square feet
- According to the National Renewable Energy Laboratory's PVWatts calculator high-efficient solar cells with 2-axis solar tracking mounts in Lynchburg would provide 26,200 kWh per day
- This alone is not able to power the center
- To provide enough power for the entire center, the solar installation must be increased by 60,000 square feet

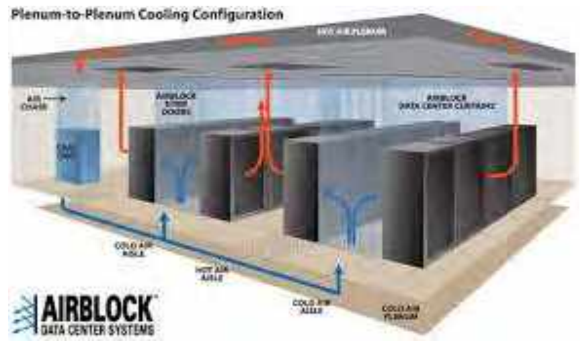
Geothermal Cooling

- Conventional cooling system has a load of 1.66 MVA
- For every watt of power a modern geothermal system will offer 4.1 watts of conventional cooling power; this means a Geothermal System would only have a load of 404.9 kVA
- The server load requires 380.73 tons od cooling which can be achieved through five 81-ton geothermal heat exchangers
- Installation costs will be higher; however the geothermal cooling could save the center money in the long term due to lower electric bills



Aisle Cooling Containment

- Hot cold aisle containment was found to be the most efficient server rack configuration
- This would increase cooling efficiency by 13%



Challenges

- Original prototype design did not consider short circuit currents
  - Series reactors added to the design
- Wiring between generators and transformers and building was problematic due to high current
  - Generators and transformers were placed closer to the building and used bus ducts instead of traditional wire
- Devices like 5000-amp breakers are not widely available and could provide problems to maintenance staff

Future Projects

- Design of a control system to have the system run autonomously
- Design of a SCADA system to control communication outside the center
- Do the same project, but in a different location

ECE 2804:

Integrated Design Project

As part of the total redesign of the sophomore curriculum in ECE, a course to provide students with an exposure to open-ended design was created. This course is intended to help students integrate and cement the knowledge they gain in the other six required courses by tackling an open-ended design project that requires understanding of both the electrical and computer engineering concepts they have been taught.

All sophomores are required to take this course before moving on to their chosen major in the junior year. The students work in teams of two or three and get to choose from three different projects each semester. Each project has some overall objectives with many ways to achieve the objectives. The students work on the project for twelve weeks and this extended timeframe allows for the exploration of alternative solutions and the time for creative problem solving that is not possible in normal class projects.

This term, the students chose from the following three projects:

- **Smart Home Project:** Integrate sensors, actuators, a microcontroller, and a smart phone app to provide features found in a smart home.
- **Wind Turbine Project:** 3D print a scaled version of a wind turbine and process the power generated from a 3-phase generator to provide a regulated DC output with high efficiency.
- **Audio Direction Finding Project:** Determine the direction of arrival of a 1 KHz audio source.

After choosing their project, the team generates milestones for each remaining three week interval. They write weekly reports documenting their progress, design details, test results, and any problems they have encountered. This document is the basis for their weekly meetings with their instructor. In addition, there are two oral presentations during the course of the project and a final report. It is hoped that this guided experience in scheduling, designing, simulating, building, testing and documenting a significant project will better prepare the students for the major design experience in their senior year.

This is the first semester the course has been taught and we offered student groups that did a particularly good job on their projects the opportunity to present their results at the major design experience expo for the seniors. Despite the extra challenges presented by the advent of the pandemic, four student teams ably overcame all of the challenges and were selected to present at the virtual expo:

Arduino Implemented Smart Home

Virginia Polytechnic Institute and State University
ECE 2804 : Integrated Design Project
Philip Works III, Joseph Reilly, Alec Yip

Introduction

Every system is moving towards software integration. From home security to entertainment, the "Smart Home" is inevitably in our future. A Smart Home encompasses hardware and software integration for one purpose: to aid home life. Our ECE 2804 project is building a Smart Home of the future. Our home has three categories: intrusion detection, appliance control, and a weather station. But we have one key component: Facial Recognition. Through our efforts, we combined hardware, software, and advanced algorithms into one package: the Smart Home of the Future,

Smart Home Features

The systems are as follows: Appliance Control, Weather Station, and Security System. The security system will be explained below, and the appliances are discussed on the right-most panel.

Security System

We created a security system has the following components: motion detector, Arduino, and (not included), a Raspberry Pi.

Parts used in our system: microcontroller, motion sensor, and amplifiers (for sound)

By creating our script and by combining our parts, we created a system where, if motion was detected, a signal would be sent through our script, and an alarm-noise would play (see bottom center image on the board). To disarm the system, the Raspberry Pi and facial recognition was used. See next panel for details.

Security System: Facial Recognition

The security system employed facial recognition to enable and disable the security system. Using a Raspberry Pi, our Python script incorporated the Eigenface algorithm. This process uses eigen vectors to isolate defining features of an object.

Example Eigenface model

Smart Home App

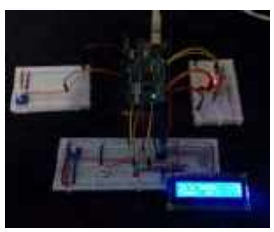
Raspberry Pi for facial recognition processing

Arduino Mega

Appliance Control

Weather Station

Security System



Arduino Appliance Control

Speaker circuit testing and weather station

Raspberry Pi for facial recognition processing

Facial Recognition (Security System)

The facial recognition software is divided into 3 parts: Training, model creation, and model implementation.

Training uses multiple pictures of an object generate negative images (color inverted pictures). Once gathered, the software isolates the defining features among the images.

Model creation makes a superimposed, prioritized image. For example, if 416 images show a sharp edge on the bottom of the image, the resulting image retains that edge. The result: image of the eigenface and an xml file (stores vector information).

Model implementation loads the model into our script. Then, images are taken from the camera and compared the camera input to the stored image. If a face is recognized, a signal is sent to the Arduino to enable/disable the security system.

Example declarations for our smartphone application

Appliance Control and Weather Station

The Arduino Mega 2560 Microcontroller provided the foundation for our systems.

With the purpose of controlling the security system and appliances, the microcontroller was the "backbone" of this project.

The key component of the home is remote connection through the microcontroller. For remote access, we used a smartphone. The phone uses the Smart Home application (we created) that displays a user-friendly interface to control home appliances, the security system, and receive weather updates (from our weather station).

Wehave an MCP 9700 thermistor and a CdS photocell for temperature and light sensing respectively. Our code converts voltages from the Arduino into useable information (i.e. temperature and brightness level).

Future

Our future goal is to integrate our project with the internet-of-things (IOT). As cloud computing is the future of data travel, we want to improve and extend our capabilities with the smart home.

RC Security Car

Jared Monseur and Cole Murphy

Introduction

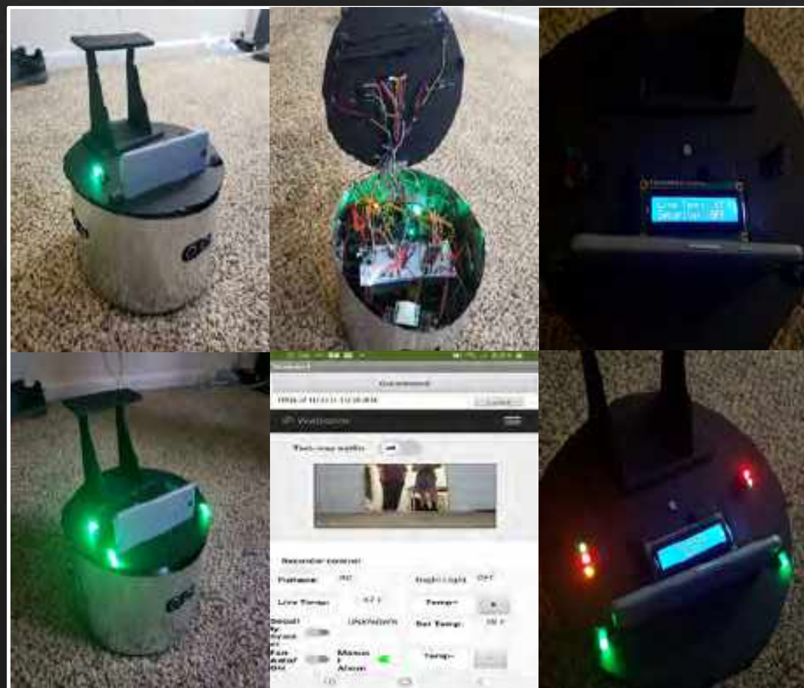
Our project brings the ideas of home security, adjustable comfort settings, and an automated RC car all into one to result in a security RC car that can be set up solely through Arduino, Bluetooth, and WiFi. With this security RC car, whom we have named Greg, a way of patrolling and notifying a family of threats that occur while they are away is possible. Also, while at home or away from the house, being able to control different appliances, like the A/C when it gets too hot, can be set to go off automatically or can be manually set by the user if need be. Overall, Greg offers a simpler way of controlling systems around the house while also giving the benefit of an added security measure while away from home.

Method

Greg works through the capabilities of the Arduino Mega. After uploading code through the USB port, everything through the app can be controlled wirelessly. After flipping a switch on the breadboard inside the chassis that enables the code, the RC car, which is driven by four 1.5 V batteries that power two electric motors, roams around the house. Using three distance sensors on the front, right, and left sides, after a certain threshold value is broken, Greg automatically starts turning and adjusting his direction to drive elsewhere. On the top of Greg are seven LEDs that specify different appliances that can be turned on or off, which are heat, A/C, fan, two LEDs that show when the security system is active, and two LEDs that turn on when it starts getting too dark, which is determined by using a photoresistor. An LCD display is used to report the current temperature and the status of the security system. Also, a slot for a phone is set up that will show a live video feed of what Greg is currently seeing and send it to the user's phone. Finally, a speaker is set up in the chassis that will play different audio clips when systems are turned on or off or security is breached. These systems can all be controlled through an app coded through MIT app inventor and works through Bluetooth capabilities, thus completing everything Greg can do.

Results

Finished products and different examples of our security RC car in action can be shown in the pictures below. The top left picture shows the outside view of the completed product of Greg. The top middle picture shows the inside view of the chassis and all the RC car's wiring. The top right picture shows the LCD display in action as it prints out the current temperature in the room from the value it receives from the temperature sensor. The bottom left picture displays the LEDs with the A/C light being turned on and the two LEDs in the front that serve as headlights being turned on from lack of light entering the photoresistor. The bottom middle picture shows the app set up and the live video feed on the app that the user will receive from the phone on top of Greg. Finally, the bottom right picture shows how Greg acts when the security alert system is triggered either manually from the user or the motion sensor inside the chassis picks up motion from the RC car being broken into.



Conclusions

After finishing our security RC car and going through everything Greg is capable of doing, we are overall happy with the outcome of the product, although we still have results we wish we could have improved and different functions we had ideas to implement but could not because of limitations from lack of resources and the COVID-19 pandemic. Future implementations that can overall improve Greg's design include but are not limited to using LIDAR instead of distance sensors to detect objects to avoid and paths for the security car to travel to, obtaining higher processing power for Greg to have artificial intelligence like current Roomba's so that it can scope out the area and decide the best path to take, and actually hooking the app up to household appliances through Bluetooth in order for them to be controlled by the user.

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https://arduino.stackexchange.com/questions/19756/how-does-serial-communications-work-on-the-arduino

https://www.electroschematics.com/wp-content/uploads/2013/07/HCSR04-datasheet-version-1.pdf

https://howtomechatronics.com/tutorials/arduino/ultrasonic-sensor-hc-sr04/

Arduino's website

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Cell: 251-401-2232

Smart Home Project

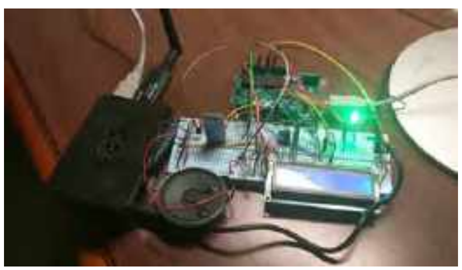
Risa Philpott and Bernie Cieplak

Objective

- Create an integrated smart home environment via Bluetooth and Wi-Fi communication.
- Develop a mobile application with Bluetooth functionality and a password protected website with Wi-Fi functionality.
- Website can be visited with or without cyber cybersecurity encryption.
- Have the following appliances; an automatic night light, an intruder alert system, an automatic air conditioner, a smart switch, and a weather station, which displays the current temperature and air conditioner status to the user.

Materials

- Arduino Uno
- Raspberry Pi
- Bluetooth module
- 16x2 LCD display
- 4 LEDs
- 3 buttons
- 5 resistors
- 8 ohm speaker
- Android phone



This figure showcases the hardware overview for the project.

Procedure

1. To begin developing the microcontroller, a 16x2 LCD display was wired up to an Arduino Uno.
2. Then, to simulate the desired appliances, a LED circuit was implemented and made Arduino controllable. This circuit was duplicated for the air conditioner, night light, intruder alert, and smart switch appliances.
3. Then, a button sensor circuit was designed and made readable by the Arduino. After software debouncing, this design was copied to independently control the intruder alert and smart switch appliances.
4. Functionality was added so the smart switch LED is on when the appliance is on, and vice versa. For now, control is simulated using a button.
5. Similarly, a temperature sensor circuit was built. The raw input serial data was converted by the Arduino to a Fahrenheit value.
6. Next, a photo sensing circuit was built, functioning as the control for the night light appliance. When it is dark enough, the corresponding LED is activated, and vice versa.
7. Then, a sound amplifier circuit was built. To pair with this, the Arduino plays a two-tone sound when the intruder alert system is on.
8. Also, the intruder alert.s corresponding LED flashes rapidly and the LCD display flashes the text, "INTRUDER ALERT."
9. Next, the temperature and status of all the appliances was shown on the LCD display, functioning as the weather station.
10. Once the microcontroller was fully integrated and functional on its own using simulation inputs and outputs, Bluetooth communication was added to the system.
11. First, a Bluetooth module was wired up to the Arduino Uno.
12. Then, it was made so that the device constantly sends one line of data over Bluetooth containing the current status of each appliance.
13. Next, it was made so that the device reads and parses any incoming Bluetooth data. By doing so, it knows when to change the status of an appliance.
14. Once the Arduino Uno could send and receive data over Bluetooth, development of the mobile application began.
15. First, a barebones application style was designed and built, including placeholders for the status of each appliance to the viewed, and non-automatic ones controlled.
16. Then, the application was configured, allowing the user to connect to a nearby Bluetooth device. The application also reads its incoming data stream.
17. Similar to the microcontroller, the mobile application was also extended to be able to send data over Bluetooth when a timer expires.
18. With the core functionality of the mobile app tested and confirmed robust, the design and user interface of the app was then improved.
19. The first extension added to the smart home environment was Wi-Fi functionality.
20. The website was served on a Flask application on a Raspberry Pi and communicated to the Arduino via the serial port.
21. Then, a website was built as a secondary way for a user to control and monitor their smart home environment.
22. The website constantly pinged the Arduino using JavaScript, then updated the status on the website.
23. After that, Nginx was used as a reverse proxy to password protect the website.
24. Finally, the website was forwarded and encrypted via SSL using the website localhost.run.

This figure showcases a screenshot of the website once the user logs in. Notice how the air conditioning is off; this is due to the temperature being below 70 degrees Fahrenheit.

This figure showcases the a closeup of the circuitry for the project. Notice the LCD is showing the status of all the appliances as well as the current temperature.

Discussion

- Agile development approach successful
- Thorough testing leads to robust product
- Planning and designing stages need dedicated time

Future Extensions

- Eliminate response delay for the intruder alert system
- Add Wi-Fi control option to the mobile app
- Improve readability for website and mobile app
- Improve aesthetics for website and mobile app

These figures showcase the mobile application. Pressing the help icon switches between these two screens. There is also an About Page accessible by the ellipses on the top right corner.

Acknowledgements

This project was possible because of the guidance of Prof. Peter Han.

References

1. *Font Awesome*, Fonticons, Inc., April, 2020. [Online]. Available: http://fontawesome.com

VIRGINIA TECH

Wind Turbine Design Project

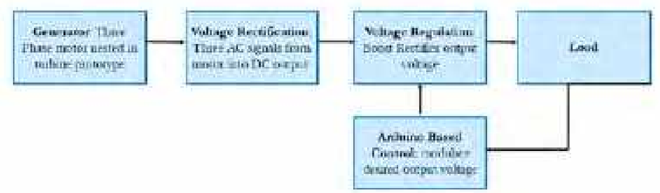
Alessia Scotto, Daniel Samtani, William Yu

Introduction

It is increasingly important for engineers to develop high efficiency systems to harvest renewable energy.

- the largest renewable energy generation today is coming from wind turbines
- It is imperative to drive down the cost of clean energy by increasing the efficiency of harvesting the energy from source to user

Project Objective: Use a three phase motor to generate an AC signal and output a constant 12 volts DC with maximum efficiency



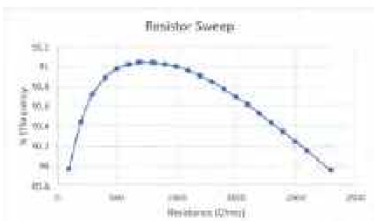
Three-phase and Rectifier

Three-phase generator testing:

- Per phase voltage: 3.3V at 0, 120, -120 ◦
- Frequency : f=61.3 Hz

Three phase full bridge rectifier

- 1N5817 Schottky diodes: minimize forward voltage drop
- Load resistor: 680 Ω
- Smoothing Capacitor : 100 μF



Boost Converter

Boost 5 Volts from rectifier to 12 V output

Nmos as switch

- Load and duty cycle modulated by Arduino
- Switching Frequency: fs=7812.5 Hz

Current Ripple: $\Delta i = 0.9A$

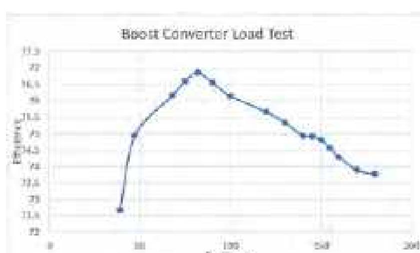
- $L = \frac{VinDTs}{2\Delta i}$ $=0.5mH$

Voltage Ripple: $\Delta v = 0.024\ V$

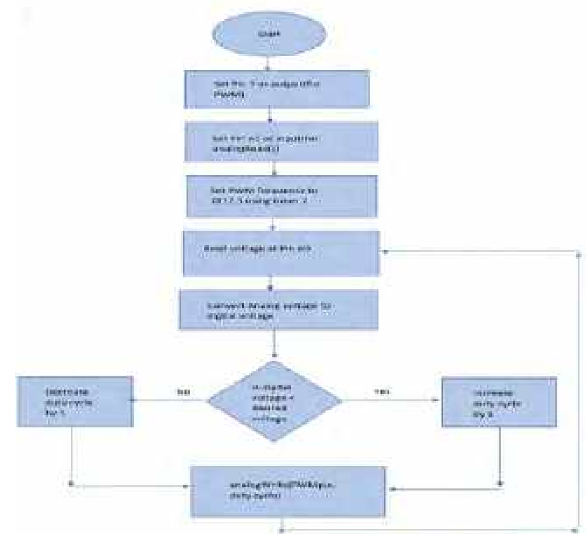
- $RC = \frac{VDTs}{2\Delta v} = 0.0082\ F * \Omega$
- $C = 100\ \mu F$
- $R = 82\ \Omega$

1RFZZN MOSFET

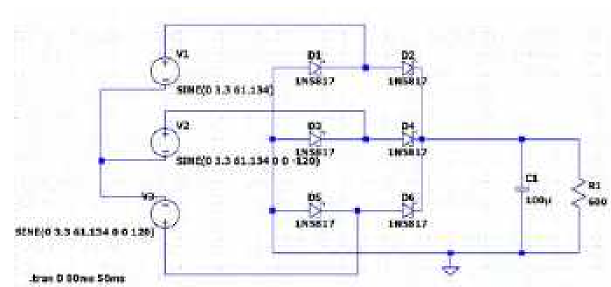
1N5817 Schottky diode



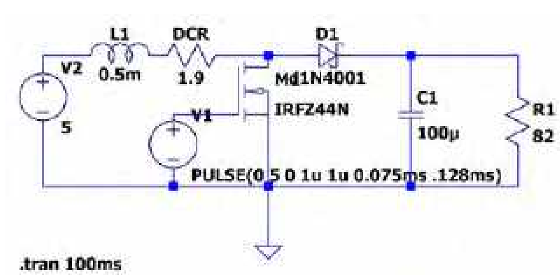
Arduino PWM Design



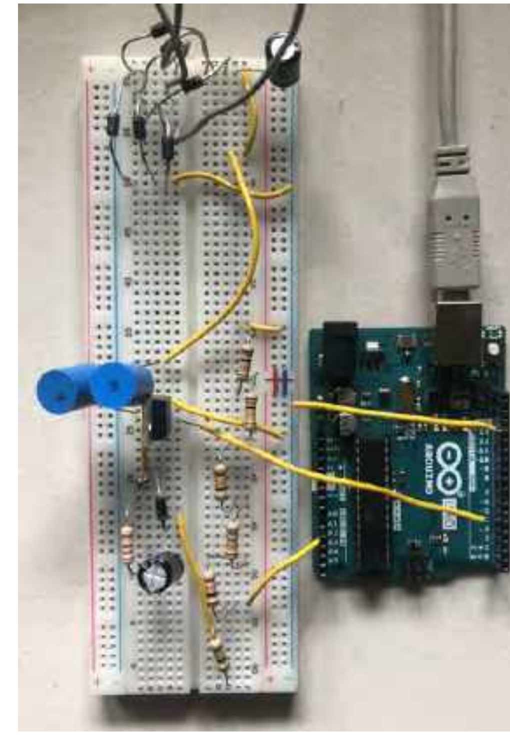
Rectifier Schematic



Converter Schematic



Complete Circuit



Conclusions And Future Work

Upon completing this project:

- Rectifier Efficiency : **91.04%**
- Regulator efficiency: **76.85%**
- Overall system efficiency: **67%**

Improve overall efficiency: complete an impedance matching stage

Synchronous operation: replace diode with a PMOS transistor

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