RUPIC

Robotic Utility Pole Inspection Collar.

A Proposal Submitted By:

Group 10

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Project Summary:

Throughout the United States Linemen test the durability of utility poles on an everyday basis. They do this every time before they climb a pole and if not done correctly, it could potentially be hazardous and lead to injury. Furthermore the utility poles are inspected every few

years as part of regular maintenance. The Robotic Utility Pole Inspection Collar will help to minimize potential dangers associated with climbing utility poles by inspecting the poles before. the climber begins his ascension. This could also provide a more accurate form of inspection that would be used regularly rather than every few years.

Table of Contents

List of Pictures

I. Introduction

A. Background

All over the United States we have different types of utility poles which work as the indispensable and essential backbone architecture to deliver some of the most basic types of services that everyone enjoys in society which have such an immense impact in our daily lives. Some of the most important and rudimentary services brought to everybody's homes by the utility poles include, power and light, cable, internet, and residential phone. Based on this short list of services, it can be quickly understood that without these poles, today as it is known, would not be possible. Hence, the importance thereof in ensuring that these poles are vigorous and robust enough to first endure the adversities of the unrelenting weather and ambient exposures, and second, to ensure that they are safe to climb by technical personnel whenever maintenance to the service lines or components attached to the electrical pole is necessary. The material utilized to build the pole will dictate the level of impact that weather and other decaying variables would have on the pole over time.

B. Statement of Problem

As an example, a simple comparison of the three most frequent types of materials implemented to build a utility pole can be used as a reference to better understand the time of service of a pole after it has been deployed to the field. The three most common materials employed to build utility poles include, concrete, metal, and wood. Based on this knowledge, it can be rapidly concluded that metal and concrete utility poles will have a greater probability of lasting longer than the wooden poles because their materials are more adept to withstand the hardships of weather and any other surrounding area activity or mechanism which causes decay or damage on the pole. Unfortunately, wooden poles are not only susceptible to a faster rate of decay due to the impact of harsh weather conditions, but other factors can also have a saying in deciding the longevity of service of the wooden pole. To delve deeper into grasping the understanding of the external factors that can have an impact on the length of time a pole stays on the field, it is necessary to mention some of them. Some of the external decaying factors that a wooden pole, and for most poles for that matter, are exposed when deployed to the field include animals, bugs, invasive plants, testing equipment and methodology to determine the decay level of the wooden pole, and equipment utilized by technicians to climb the pole and conduct maintenance, just to mention a few. All of these factors and many more have an impact in the amount of time needed to elapse before the wooden pole requires replacement. Nevertheless, even though wooden poles are the most susceptible to rapid decay based on the aforementioned information when compared to poles constructed from the other materials, these wooden poles can be found by the millions behind homes and in-service alleys across the country. Wooden poles play a major and critical role in assisting in the deliverance of services to important places like hospitals, government institutions, and in a more intimate and private setting, our homes. It is not only because of the services that these poles help deliver daily the only reason behind understanding why it is necessary to be aware of the decay levels of wooden poles, but also because fracture or damage poles represent real threats to everything that surrounds them independent of the stage. They represent broken wires on the street exposing people to hazardous and likely lethal electrical shocks, or aiding on the start and development of ferocious and implacable fires which devour residences and could burn for months. In a different scenario, this wooden pole can break in the middle of a surgery of a loved familiar rendering a hospital powerless and doctors and nurses helpless. In a different scenario, these poles can also cause serious injury and damage to maintenance personnel or personal property. If the level of the decay is extreme in the pole and a technician climbs it to conduct maintenance, the results could be fatal and catastrophic, especially if the pole is located in an alleyway between houses. Nonetheless, even though the application of wooden poles does not seem like a smart or logical implementation for the development, expansion, and upkeep of the service lines, this is truly far-fetched from the reality. As a matter of fact, the benefits of the wooden poles are the main reasons behind why wooden poles continue to be installed and replaced by the thousands every year. Some of the basic factors which drive the implementation of these poles include manufacturing cost, weight, ease of transportation, and cost and time of deployment to the field. Nevertheless, one of the major advantages which solidifies the continuous implementation of the wooden poles, is that they are the only types of poles that are climbable. In other words, wooden poles are the only type of pole which a technician performing maintenance on the lines is able to climb. Another great advantage of this type of pole is that it can be positioned in hard to reach areas. This allows technicians to perform maintenance on these lines to ensure that everyone, everywhere is able to access the service. In order to ensure the continuous delivery of service through these wooden poles, it is essential to have in place a certain type of standard operating procedure (SOP) that outlines the processes and methodologies necessary to determine the decay level of a wooden pole and determine its overall health. With this information in hand, important decisions can be made on whether or not the wooden pole meets the minimum safety requirements and specifications to continue to provide uninterrupted service to households, or in a more technical manner, that the wooden pole has the strength to support a technician who needs to climb it and perform routine, or any type of maintenance on the lines or equipment. Some of these tests to verify the decay level are old and therefore, although efficient, they are not helpful for the overall health of the wooden pole. As a matter of fact, some of the most widely used techniques to conduct tests on the decay level of a wooden pole include the hammer test which consist of striking the wooden pole with a hammer various times and reflecting on how deep the orifice left by the hammer is. The person implementing the hammer test also listens to the sound emitted by the pole when struck by the hammer. Afterwards, the technician makes a determination based on the hammering of the pole. Another testing method includes driving long drill bits through the pole to determine the decay level. Just from what needs to happen to these wooden poles to conduct these tests, it can be inferred that they do not help in any manner to slow the decay on the pole and on the opposite, these tests harm the wooden pole and likely assist in increasing the overall rate of decay. It is important to mention as well that these types of tests are considered to be invasive to the pole since they cause some damage to the structure when being conducted. Not only are these tests antiquated and invasive to the structure of the pole, but also they are time consuming and require some effort to be set up and completed by the technician. Consequently, new manners to conduct decay experiments on the pole to identify its decay level is necessary. Moreover, it is essential to expedite the conduction of the testing process while also guaranteeing the safety of the personnel and the surrounding areas. By improving on the type of the test and the time it takes to conduct it, more poles will be able to be visited and examined on a daily basis, and hence reducing the probabilities of a fracture pole causing some damage or injury because its service life has reached an end and the next pole decay analysis is a couple of years away.

II. Scope of Work

A. Overview

Based on this information, this project centralizes on addressing both of these aforementioned issues through the development of a lightweight robotic collar which can be manipulated by anyone with minimum training. The robotic collar will be divided into different sections which in itself, will be housing other components which are necessary for the collar to have the ability to climb a wooden pole, stop at random heights, conduct decay tests, and descend the pole. The results from the examinations will be quickly analyzed by the system and relayed to the technician for interpretation. This project will also implement a novel, state of the art, non-invasive technique to conduct the examination of the decay state of the pole by emitting ultrasound waves through the wooden poles. The final goal of the project is to design a lightweight robotic collar that can be easily and rapidly be installed on any wooden pole for inspection by an operator. Afterwards, the operator will be able to send commands through an application to the robotic collar to make it ascend and descend the wooden pole. The operator will also be able to stop the robotic collar at arbitrary heights to conduct the ultrasonic decay experiment on the wooden pole. Then, the results from the tests will be sent to the application for the operator to make the necessary decisions based on the decay state of the wooden pole. With this solution, the participants of the project intend to reduce the overall amount of time and effort it takes to set up the equipment necessary to conduct the decay examination of the wooden pole and ensuring the safety and integrity of the personnel utilizing the robotic collar and its surrounding areas while also minimizing the damage inflicted to the pole when conducting the test. In order to aid the team in the development of the preliminary design of the robotic collar, extensive research has been conducted by the members in order to develop a general idea of what can be useful and logical to create and develop based on the designs specifications. To obtain the current picture and approach of the preliminary design attained in this project, it was necessary to search for any patents with ideas that are similar to the design which the team is trying to achieve.

B. Literature Review

Since the complete solution of the project possesses a high probability of necessitating a patent, it is prudent to be aware of what other solutions are out there and how these solutions relate to the final product that the completion of the project will achieve, so that no rule nor laws are violated in the process of developing the final design. In the following pages, a variety of different patents with similar characteristics to the final solution that the team is trying to achieve, are introduced. It is necessary to mention that these patents were introduced by different members of the team with a brief description of the patent and how they relate to the robotic collar project. These patents can be found below:

Patent 1

1. **Team member reviewing patent:**

Carlos Gross-Martinez

2. **Pertinent patent information:**

Number: *ES 2,352,930 A1*

Title: *"Robot Platform for Climbing"*

Inventors: *Francisco Jose Alvarez Gonzalez, Juan Diaz Gonzalez, and Jose Manuel Sierra Velasco*

Assignee: *Universidad de Oviedo*

Date Filed: *Nov 23, 2010*

Date Granted: *July 18 2011*

Number of claims: 12

Link to Patent: ES2352930A1 - Robot platform for climbing posts - Google Patents

3. **Summary of Patent:**

This patent describes an apparatus which has the ability to climb different types of posts or tubes. It was mainly designed to be lightweight and portable. Once installed and calibrated on the pole, this device has the capacity to ascend the post or tube and descend afterwards. It is necessary to mention that the tires will have to be utilized as a reference to position centrifugally the complete mechanism against the pole or tube. In its most basic description, the instrument is mounted in a manner in which it wraps around the pole or tube. Afterwards, the pressure mechanism is calibrated to apply pressure against the pole or tube. Once completed, the tool can be controlled remotely to send the necessary instructions and operate the equipment.

4. **How the Patent Applies to the Utility Pole Inspection Collar:**

One of the main objectives that need to be addressed in our project is to develop an apparatus that can be installed in electrical utility wooden poles and conduct some experiments to determine the decay condition of the pole and decide if the pole has the capacity to sustain the weight of a person to climb it and conduct maintenance. To calculate the level of decay in the pole, different tests and metrics need to be conducted and collected at different heights of the pole. Based on this information, it can be seen that a device that has the ability to move up and down a pole in order to conduct the experiments and gather the data is essential in the solution of our utility pole climbing robot project. Therefore, this patent which basically describes an apparatus with the ability to climb up and down a pole can be utilized as an important source to reference when designing our own pole climbing robot. Based on this patent design, there are a few ideas that I can utilize in order to improve our own design. First, I like how this patent secures the components of the apparatus between two frames collocated at the top and the bottom. I believe that implementing this approach will greatly reduce the overall weight of the device. Moreover, I also like that this device applies two tires per every branch of the device that reaches the pole. I believe this will add more traction against the surface of the pole and provide more overall stability. Finally, the tightening mechanism, although this mechanism is manual in this patent, I believe a motor with a threaded tip can replace the manual part of the tightening mechanism. In this manner, the apparatus can be controlled through sensors to apply the necessary pressure against the pole removing this tedious and repetitive task from the technician.

Patent 2

1. **Team Member Reviewing Patent:**

   Matthew Maggio

2. **Patent Information:**

   Number: US 5,804,728

   Title: *"Method and apparatus for non-intrusively detecting hidden defects caused by bio-deterioration in living tree and round wood materials"*

   Inventors: *Frank Carroll Beall, Richard Len Lemaster, Jacek Marek Biernacki*

   Date Filed: *Sep. 7, 1994*

   Date Granted: *Sep. 8, 1998*

   Number of Claims: 33

   Link to Patent:

   https://patentimages.storage.googleapis.com/dd/7b/b4/703b82d07f0460/US5804728.pdf

3. **Summary of Patent:**

This apparatus was designed specifically for round wooden structures. The main objective for this device is to non-invasively test the internal wooden structure for rot and other bio-deterioration. The device incorporates a pulsing ultrasonic transducer and a receiving ultrasonic transducer placed at opposite sides of the wooden pole. The transducer transmits ultrasonic signals which are propagated through the wood structure interior. The signals are then processed and analyzed. The resulting information used for analysis includes storing the average signals and processing those signals to produce the time and frequency domains. The two transducers are secured via coupling apparatus.

4. **Relation to the Utility Pole Climbing Robot:**

This apparatus bears a similar objective to the Utility Pole Climbing Robot, to non-invasively test the internal structure of a wooden utility pole. Furthermore, the specific method of testing using two ultrasonic transducers is outlined in our projects design and implementation section. There are several design ideas that we could emulate using concepts and ideas from this patent. One is that we could mirror the technique of processing and analyzing the signals produced by ultrasonic transducers. Coupled with the goal of having the robot climb vertically with the pole, the pulsing and receiving transducers could send signals at any location throughout the pole. The patent also includes several apparatuses used for securing the two transducers to the pole. This could prove useful for when it is time to connect the sensors to the robotic collar.

Patent 3

1. **Team Member Reviewing Patent:**

Kyle Mason

2. **Patent Information:**

Number: US 7,660,438 B2

Title: *“Method and apparatus for object tracking prior to imminent collision detection”*

Inventors: *Theodore Armand Camus*

Assignee: *SRI International Inc*

Date Filed: *Jan 22, 2009*

Date Granted: *February 9, 2010*

Number of Claims: 38

Link to Patent: https://patents.google.com/patent/US7660438B2/en

3. **Summary of Patent:**

This invention features an apparatus for collision detection which utilizes an object tracker and a collision detector. The collision detector is triggered when an object being tracked is within its operational range, thus executing a safety measure based on the classification using the collision detector. The system enhances object tracking and collision detection through its ability to classify target types, track objects over time, and utilize target information over shorter operational ranges, enabling it to take the appropriate safety measures based on the classification of objects within its range.

4. **Relation to the Utility Pole Climbing Robot:**

An important feature to be included in the Utility Pole climbing robot is that it must be capable of automatically halting the climbing process should it ascend past the intended height, or come too close to telecom facilities and other possible objects on the pole in which it may collide with. To achieve this, we intend for our design to utilize sensors to detect obstacles that may be too close to the robot, forcing it to stop ascension. This patent includes an apparatus which detects objects within range of the system and sends a signal which may be used to execute the necessary safety measures.

Patent 4

1. **Team Member Reviewing Patent:**

   Miguel Barragan

2. **Patent Information:**

   Number: US 2017/0137260

   Title: *"REMOTE-CONTROL VERTICAL ASCENDING AND DESCENDING WORKSTATION"*

   Inventors: *Thomas K. Barnhill*

   Date Filed: *Jun 20, 2016*

   Date Granted: *Pending*

   Number of Claims: *Pending*

   Link to Patent:

   https://patentimages.storage.googleapis.com/9d/a7/5e/7982f92b96717d/US20170137260A1.pdf

3. **Summary of Patent:**

The purpose of this device is to be able to move objects and possibly people up and down column-like surfaces. This apparatus was designed specifically for column-like structures like poles and trees. It is designed to be a workstation with locations for attaching equipment and cameras so that they can be moved up a pole. The frame for the workstation is expandable, making it able to fit the circumference of different sized vertical structures. The apparatus ascends and descends due to a drive system mounted on each of the compression supports. The drive system works and looks similar to the drive system in a tank and is connected to motorized track climbers.

4. **Relation to the Utility Pole Climbing Robot:**

This building of this apparatus covers multiple fundamental aspects of the Utility Pole Climbing Robot that we are trying to build. One of the most important fundamentals of these robots is to get the compression supports correct. This is the system that maintains a constant pressure so that the wheels have enough friction to be able to rotate up the pole. The tank tracking system that they used is actually very smart as it gives the wheels more area to grip on the pole, there is potential to use these for the pole climbing robot, but our studies suggest that this is not the best solution to implement to achieve positive results. The patent for this apparatus covers a robot that can climb up a pole which is one of the main goals we are trying to achieve but that is all that relates this patent to our project.

C. Alternative Solutions

An alternate solution to the RUPIC project would be to design something similar to a human robot with robotis in arms and legs with the ability to climb the pole with its extremities and conduct testing as well. Nevertheless, this approach will be less cost effective and more complex to develop when compared to the RUPIC collar. Furthermore, this type of project would also require more parts, sensors, and programming in order to properly control the robot. Pursuing a solution of this magnitude would require a bigger team to be able to develop the robotic solution in the same amount of time as the RUPIC initiative. In reality, there are no complete alternate solutions specifically designed and developed as RUPIC. The formation, design, and evolution of the project finds its roots in the description, necessities, and project requirements of the solution set forth by the project sponsors. Although other alternatives to climbing poles in general exist, a solution capable of allowing an operator to manipulate a lightweight robotic collar to conduct decay inspections through a non-invasive ultrasonic decay test in wooden utility poles is not yet available. Therefore, the RUPIC solution initiative, to our knowledge, is the first collar prototype of its kind in the field.

D. Evaluation

In order to develop the robotic inspection system, all the different requirements were taken into consideration and evaluated in detail, to be able to build a comprehensive solution capable of performing the different functionalities necessary for a successful prototype. The following outlines the functional, usability, and safety requirements of the RUPIC solution which were used as the blueprint and foundation for the creation of the overall solution.

Functional Requirements:

F.1. The system shall climb up and down FPL wooden utility poles

F.2. The system shall attach to poles of with diameters varying from 30 to 40 inches

F.3. The system shall relay all status information and inspection reports through the corresponding app.

F.4. The system shall accept user input through an app.

F.5. The system shall send diagnostic report to wherever the user specifies

Usability Requirements:

U.1. The system shall attach to utility poles quickly

U.2. The system shall have 1 hour minimum battery life.

U.3. The system shall send information stored to the app for display.

U.4. The system shall not weigh more than 50 pounds

U.5. The system shall be able to operate in temperatures over 100 degrees F.

Safety Requirements:

S.1. The system shall detect when it is too close to cables and transformers and stop.

S.2. The system shall detect if it slips and locks up to prevent collision.

S.3. The system shall warn when the battery is running low and take preventive measures

E. Decision

Based on the necessities of the system requirements and research, different concepts were explored in order to approach the solution. Nevertheless, the current deliverables of the engineered prototype consist in what the team conjunctively believe is the most plausible approach which guarantees the proof of concept of the intended solution design. Moreover, the different components and tools implemented in the project were chosen based on the fast prototyping capacities of the components, fast programming techniques, and to the best of the team's ability, economically accessible, which are openly obtainable in the market and Internet.

III. Plan of Implementation

A. Research

Extensive and in depth research has been conducted by all members of the group in order to achieve two different prototypes with the proof of concept to the RUPIC initiative. The research consisted not only in the literature review aspect of the assignment, but also in the component research, development, and overall integration of the project. It is imperative to note that to some extent, as the project progressed in development, adjustments to different initial decisions and approaches were conducted in order to adapt to the unexpected challenges of the design and integration of the overall solution. All annotations, research, and adjustments in regards to the different tests and procedures conducted to complete the overall project can be located through the MS Teams app, in the files tab or through the link provided below.

RUPIC Project Deliverables Folder

B. Design

The pole inspection collar is a device that tests the integrity of wooden poles. This device has the capability to open and close due to a clamp on one side, and on the other, there is a tightening mechanism to secure it safely around a pole. The system will conduct the inspection by ascending and descending the pole through the 4 motors that move it. Sensors will be placed along the inside of the collar pointed towards the center of the pole, this is to measure and record accurate data from the pole. The system will have Bluetooth and will relay the data to an app through Bluetooth. The sensors and motors will be connected to a microprocessor that is the central processing unit. After the pole inspection is complete you will be able to review the information as it is recorded, this way you can make more assumptions of the integrity of the pole.

The housing of the pole inspection collar is broken into two halves and has all the components and sensors attached to it. Most of the components will be attached on the inside of the collar. The collar will be made from Acrylonitrile, Styrene, Acrylester and Polycarbonate plastic blend.

The collar has to meet the requirements of lightweight, water resistant, shock proof and durable. The system has to be lightweight so that the motors are strong enough to turn the wheels and get the system to move up the pole. The system has to be durable from high drops, water resistant and shock resistant because these are possible harsh conditions.

The electrical components consist of the motors, the sensors, the 12volt batteries and the CPU. All the connections in the system will be made through wires and will be hidden from exposure to water or the elements.

C. Deliverables

All documentation in regards to the development of the RUPIC project can be found in the deliverables folder located in the MS Teams app, in the files tab or through the link provided below.

RUPIC Project Deliverables Folder

D. Tasks

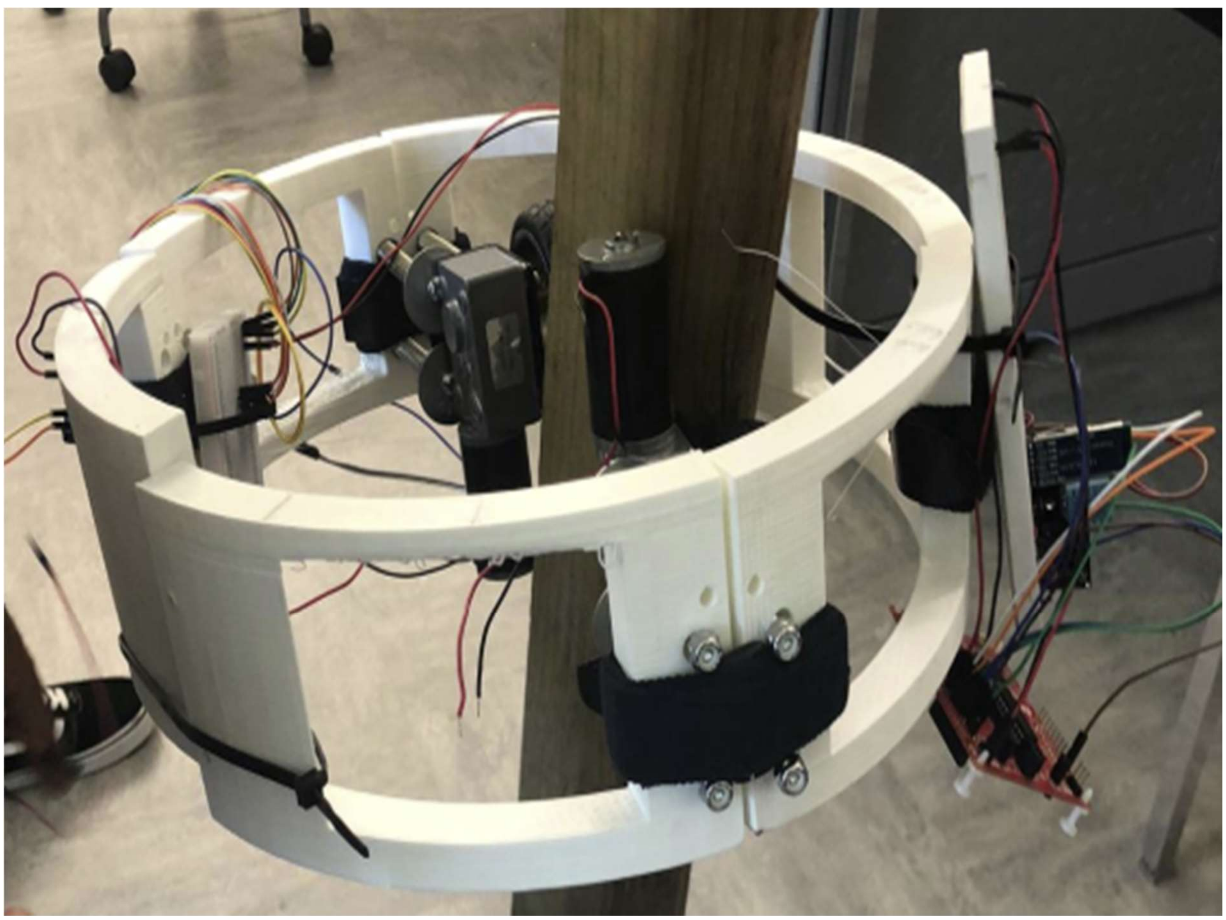
In order to ensure the timely completion of the robotic utility pole inspection collar project, different tasks were created for every member of the group with emphasis on the subsystem which each member is responsible for developing. These tasks include specific dates for when the task is expected to be completed and every task is subdivided into one or multiple subtasks that when completed will fulfill the tasks development requirements. These tasks and dates can be adjusted as necessary to accommodate any unforeseen event which may evolve while working on the robotic utility pole inspection collar. The layout of the tasks, subtasks, expected completion date, and the group member in charge of developing each subsystem can be accessed through the MS Teams app, in the planner tab or through the link provided below.

RUPIC Full System Development Planner

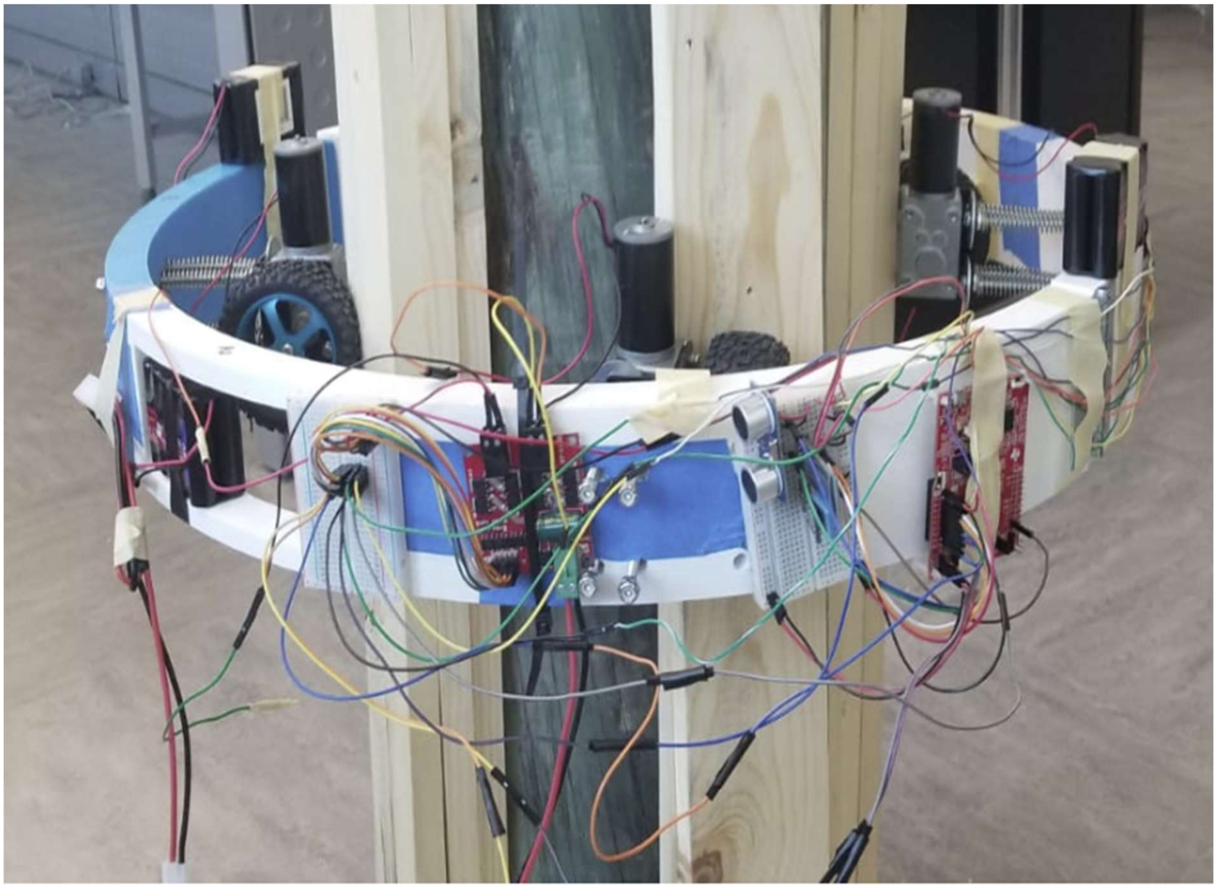
It is necessary to mention as well that although each member is responsible for specific tasks for the overall development of the system, there will be collaborative events between the members to ensure that all the projected tasks are completed as scheduled in the planner.

E. Prototype Construction (if any)

There were two collar prototypes and one application prototype created and tested in order to conduct the proof of concept behind the RUPIC idea. Through each prototype, design changes were made in various aspects in order to address certain prototype concerns. Nevertheless, further development is still necessary in order for the solution to be used as intended. The pictures from both collar prototypes can be seen below:



Picture 1: RUPIC Prototype 1



Picture 2: RUPIC Prototype 2

IV. Implementation Details

A. System Specifications and Functionalities

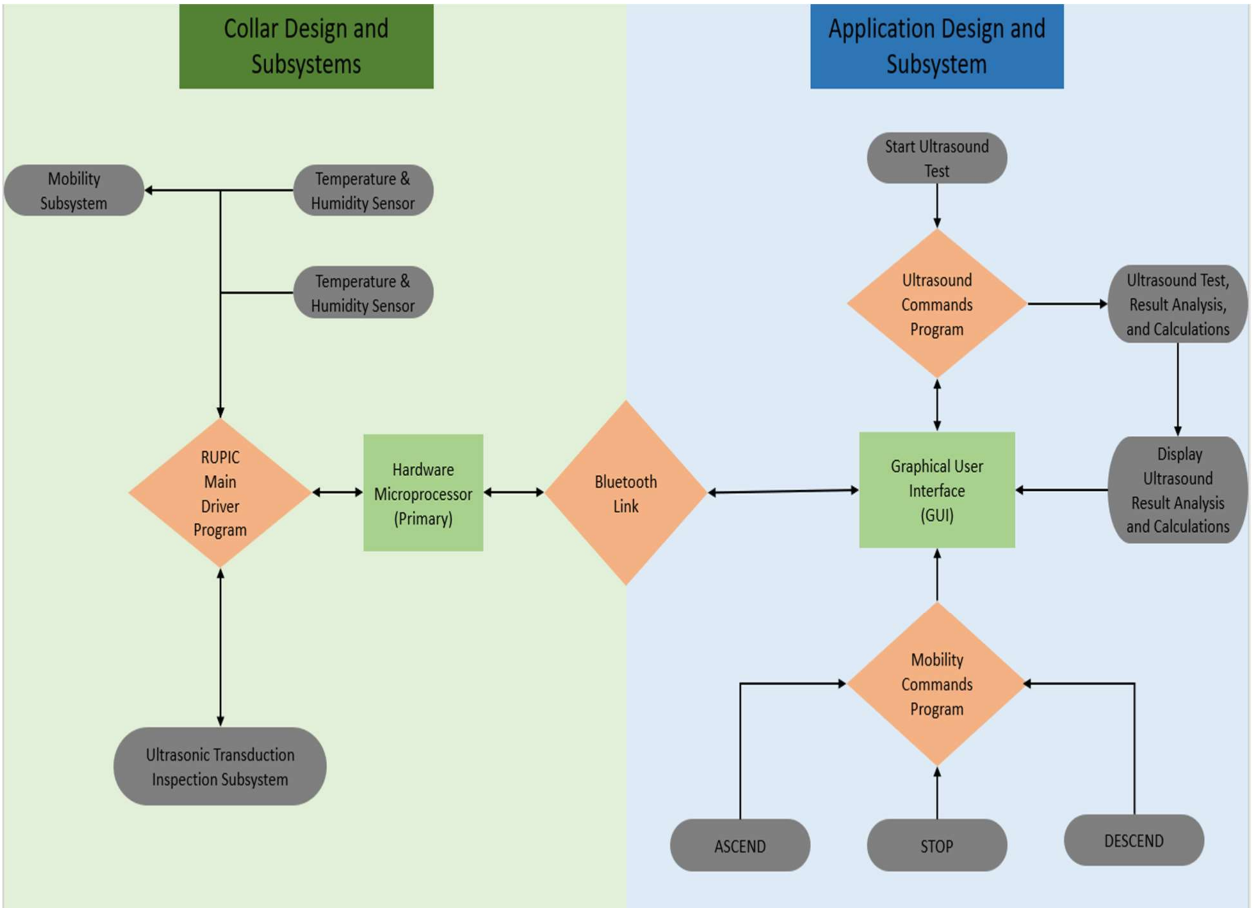
In order to be able to design the RUPIC project, the main objective required the team to divide the concept into five different segments of development. Each segment addressed specific system specifications as well as functional requirements in order to meet the demands of the overall solution. Moreover, four segments of the development of the project became known as subsystems. While the last segment consisted in the development and design of the physical collar housing some of the different subsystems in order to provide functionality to the collar. The segments and subsystems of the RUPIC development are as follows:

1. Collar design development and engineering
2. Main application mechanism or subsystem design and engineering
3. Communications mechanism or subsystem design and engineering
4. Mobility mechanism or subsystem design and engineering
5. Ultrasonic Transduction Inspection mechanism or subsystem design and engineering

More in depth specifications and functionalities for each subsystem and how they integrate will be provided in the following subsections after the overall system design block diagram.

B. Overall System Design with Block Diagrams

The pole inspection collar is a device that fits around poles like a collar. Once fastened to the poles an operator has the option to turn on and activate and control the collar via app. Once the collar is activated the collar will tighten up creating more pressure and produce more friction around the pole. Once the right amount of friction is produced the wheels will start rotating and then start to climb the pole. After conducting a test and collecting data that will depict data in regards of the integrity of the pole, the collar will then descend down for retrieval. At the bottom the data will be collected, and it will be sent through Bluetooth communications to an application. While ascending and descending the pole, the collar will have sensors to protect the collar from colliding with wires or prevent it from sliding down. The overall system design block diagram can be observed below:



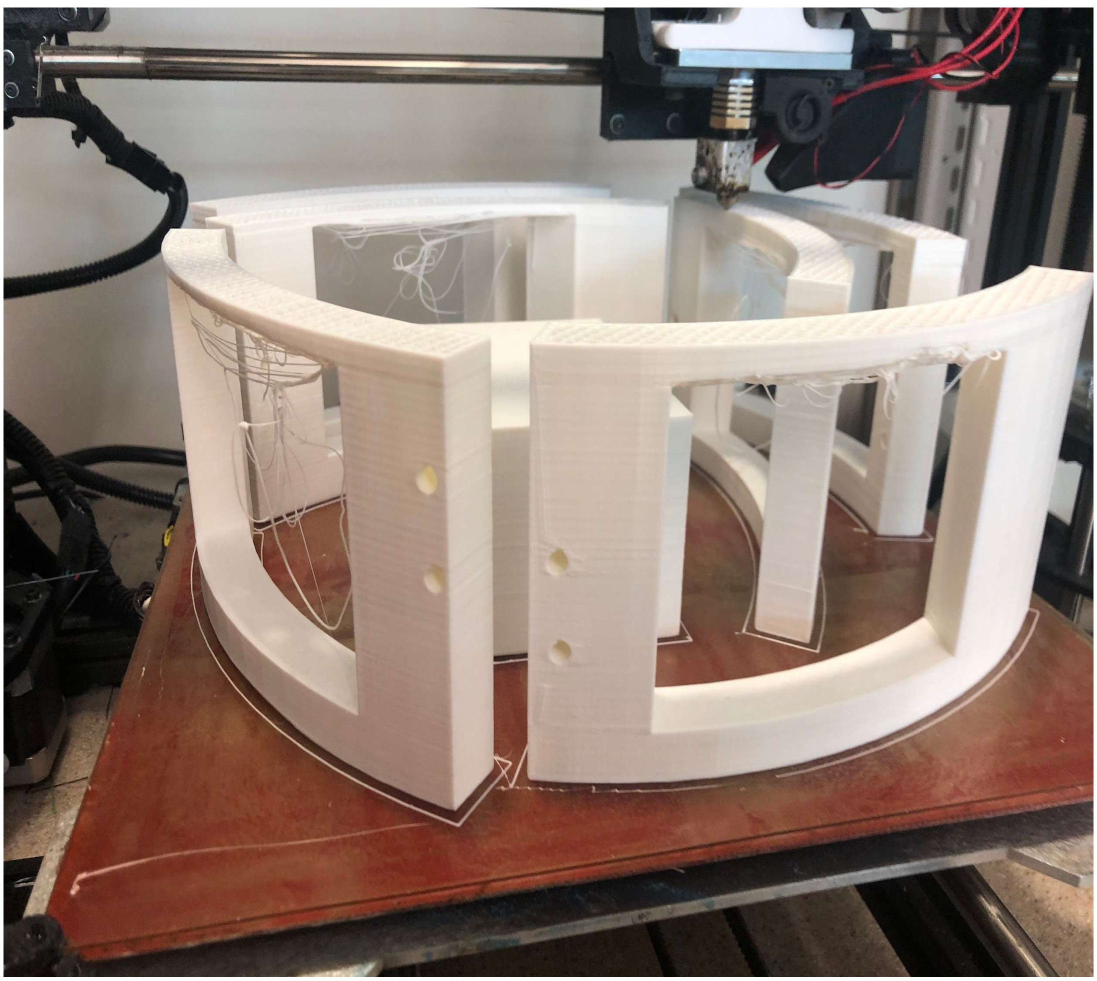
Picture 3: RUPIC Block Diagram

C. Circuit Diagrams and Flowcharts

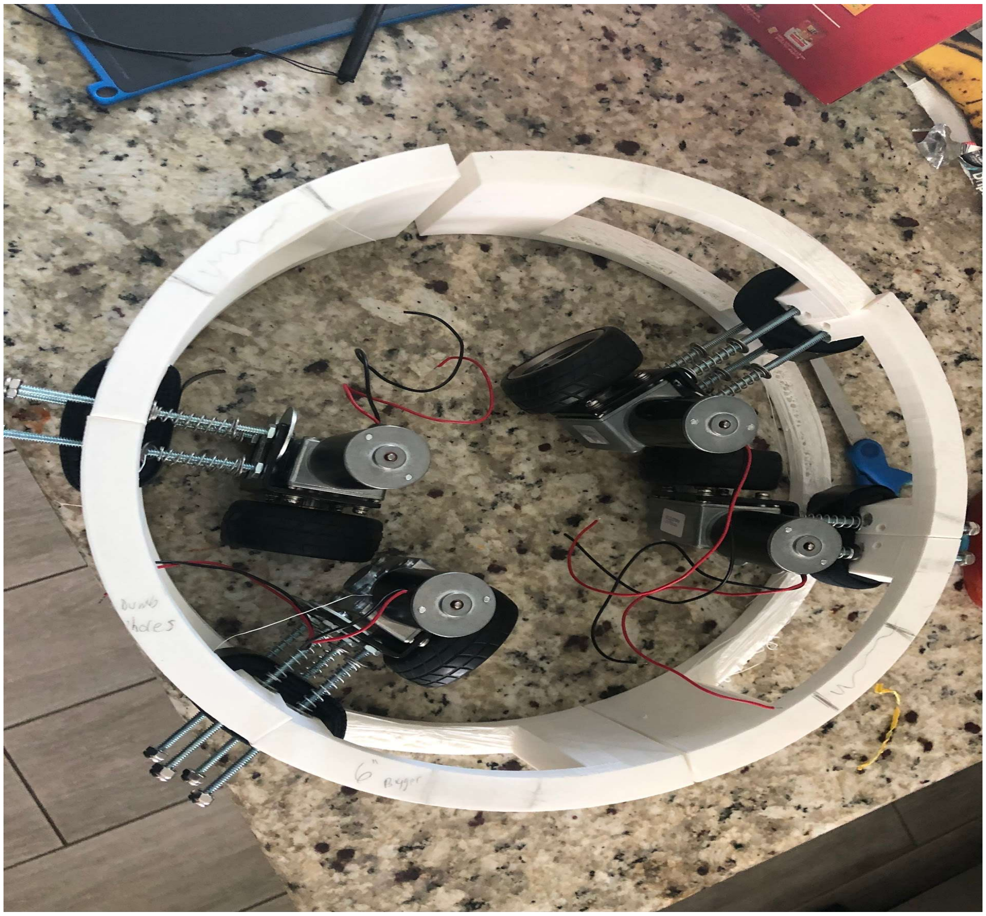
All the different components for each subsystem as well as their individual circuit diagrams and flowcharts can be observed below

<u>Collar Design Development and Engineering</u>

For the collar I began by using Solid Works 2019 after receiving a link from the instructor. From here I began by creating a circle on the top plane, this circle would be the inner diameter, I then created another circle that would be bigger than the previous circle by 1 inch, this was my outer diameter. After creating the diameter I extruded the circles to make a cylinder. Knowing I needed to split the collar, I opened the plane that split through the collar and placed a line from the origin through both sides. From here I use a square to place over the line as thin as possible to cut through the collar. After placing the square I then press the extrude cut, where I'm then prompted to extend the square's depth. Pressing enter allows you to choose which you would like to cut through, pressing enter again finalizes the cut. Now I have 2 solid pieces that can be used for the collar, at first I created a collar that had many openings to allow for components to be housed within, but after realizing the opening just made it harder to work with. This caused me to change the design a little bit by removing most of the openings and only leaving 2 openings on opposite sides. Before printing I was instructed to cut the collar down into 6 pieces to allow them to properly fit on the 3D printers.

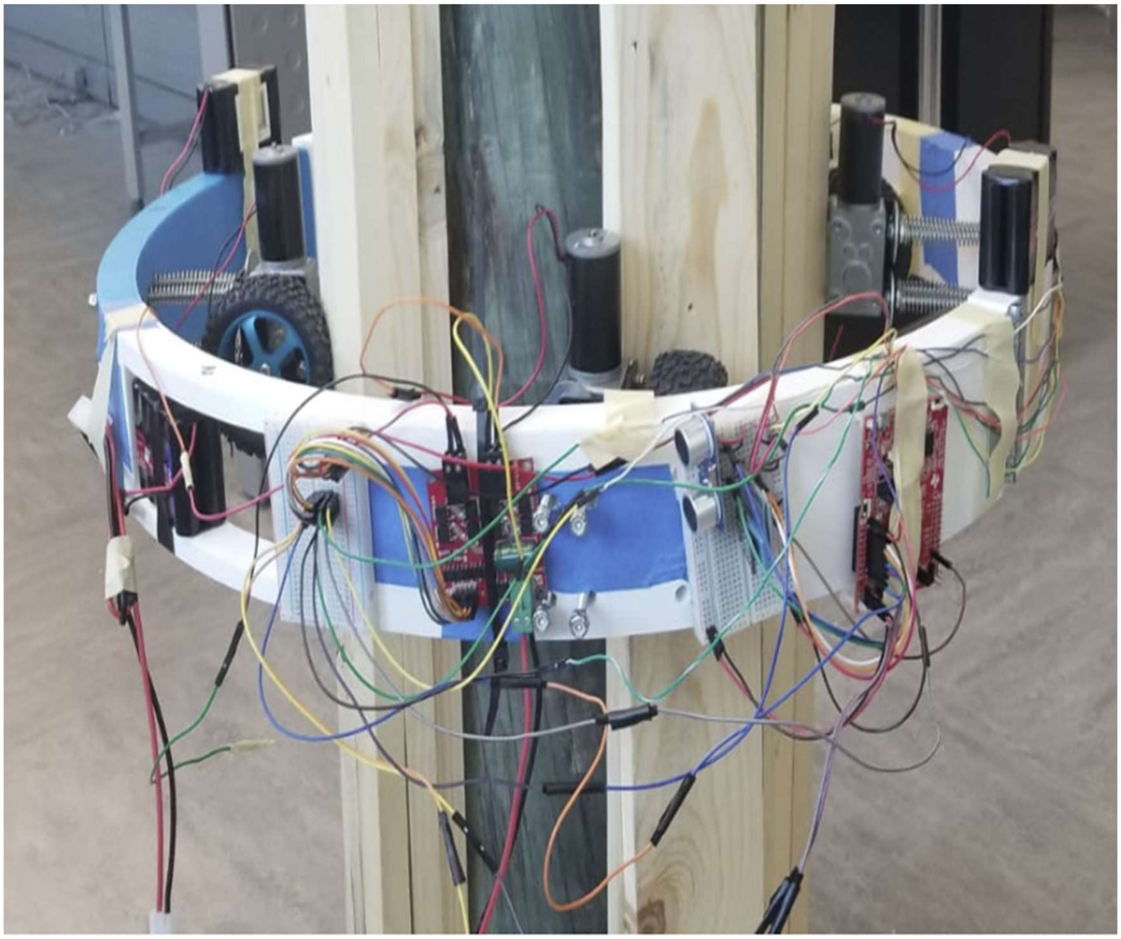


Picture 4: 3D Print of Physical Collar



Picture 5: Mobility Subsystems Mounted on Physical Collar

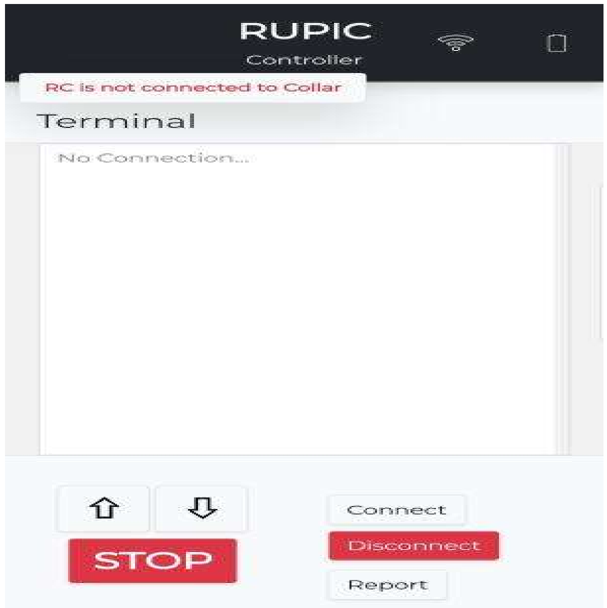
After going in and cutting the 2 pieces down We finally had our first print of the collar. After building and setting up the collar we came to the realization that the collar was very small, too small to be able to place the collar around the pole, to at least be able to test this we found a post used for fencing and attempted to have the pole ascend with only 2 wheels. Although we were successful, we were not satisfied with it. I redesigned the collar, increasing the diameter. Once I received the collar I sanded and glued the collar and left it to cure overnight. Once the team and I met up we soon realized the collar was now too big, so we submitted a final print. The final print was not submitted in time so we needed to improvise to make the collar fit around the pole, so we used planks of wood to cover the gap needed. From here we built the collar and placed it around the pole to test. With the planks we were successfully able to ascend and descend the pole as described.



Picture 6: Robotic Collar & Hardware Subsystems Attached to Pole

Main Application Subsystem Development and Engineering

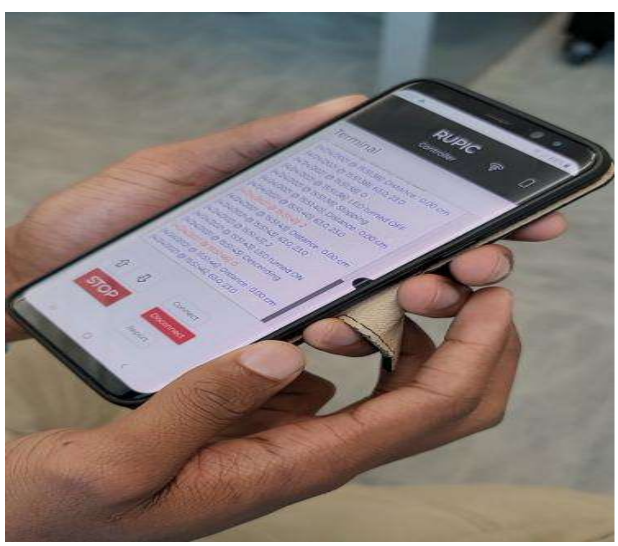
In order for the Robotic Utility Pole Inspection Collar to be able to have a simple to access and user friendly interface, a web application was developed. To ensure connectivity the application has been designed utilizing the Web Bluetooth API, which enables web applications to communicate with Bluetooth devices. By doing such, the application can be accessed and used to operate the controller on any device so long as the device has access to a compatible web browser and is capable of bluetooth functionality



Picture 7: Software Application Design

Technologies used in Software Application Development:

- HTML5
- CSS
- Javascript
- Web Bluetooth API



Picture 8: Software Application Operating RUPIC in Real Time

Components required for Software Application Operation:

- Device w/ Bluetooth Capability & Web Access
- Web Browser w/ Web Bluetooth API Compatibility
- BLE (Bluetooth Low Energy) Compatible Bluetooth Sensor (On Robotic Utility Pole Inspection Collar)

Communication Subsystem Development and Engineering

In order to ensure that there exists a channel of constant and consistent communication between the robotic collar and the application the communication's subsystem was developed. This subsystem ensures that as the directives from the application are sent, to provide the collar with the ability to quickly react and therefore provide the uppermost responsiveness to the incoming instructions from the application. In this manner, unwanted behavior between the application's signals and the robotic collar response can be diminished. Moreover, this subsystem will be the main component which is responsible for transmitting and receiving data to and from the main application. The main reasons behind the components choice for this subsystem include that the components are lightweight, possess low power consumption capabilities, and are great for prototyping system designs accurately, efficiently, and quickly. In essence, a bluetooth module and two other sensors will be connected to a microprocessor to work as the communications channel between the application and the primary microprocessor to transfer the necessary signals to operate the robotic collar and conduct the ultrasonic test, as well as transmitting the results back to the application so that the data can be analysed. In order to build the communication subsystem, it is important to acquire the different electronic parts which integrate it. The list of components can be seen below:

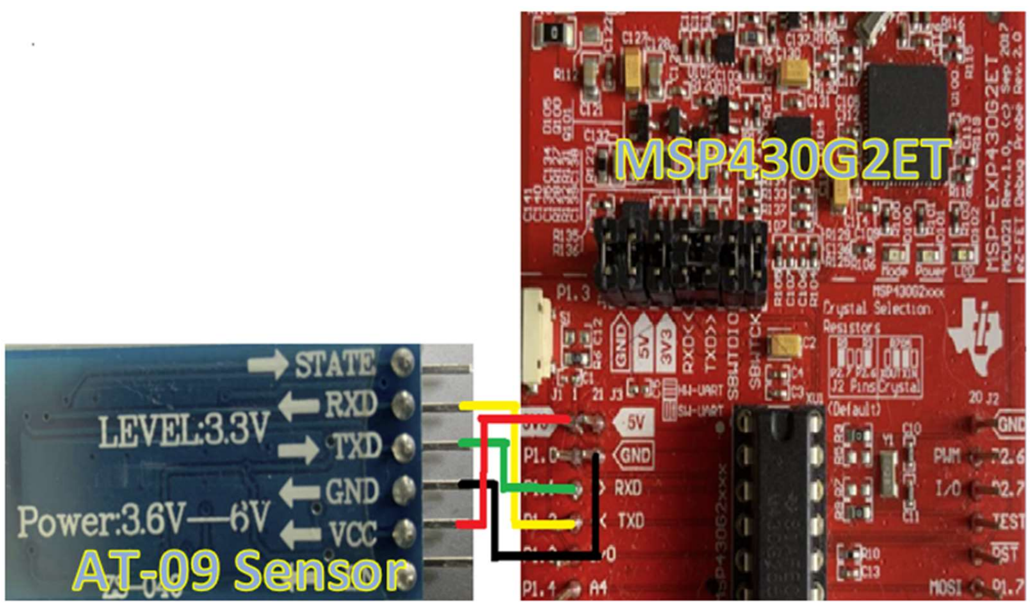
- MSP430-EXP430G2ET launchpad with MSP430G2253 microprocessor chip

- AT-09 (CC2541) BLE Bluetooth 4.0 Module
- HC-SR04 Ranging Detector Mod Distance Sensor
- DHT11 Humidity and temperature sensor

With the list of components completed, the next step consists of providing the wiring for each component interfaced with the microprocessor. The first wiring schematic shown is the bluetooth module wiring diagram. In order to wire the bluetooth sensor, there are four connections between the MSP430 launchpad and the AT-09 module which need to occur in order to complete the wiring. These connections are as follows:

- Pin GND in AT-09 module to pin GND in launchpad
- Pin VCC in AT-09 module to pin 3V3 in launchpad
- Pin TXD in AT-09 module to Pin 3 (RXD) in launchpad
- Pin RXD in AT-09 module to pin 4 (TXD) from launchpad

A picture with the completed wiring of the AT-09 sensor and the launchpad can be observed below:

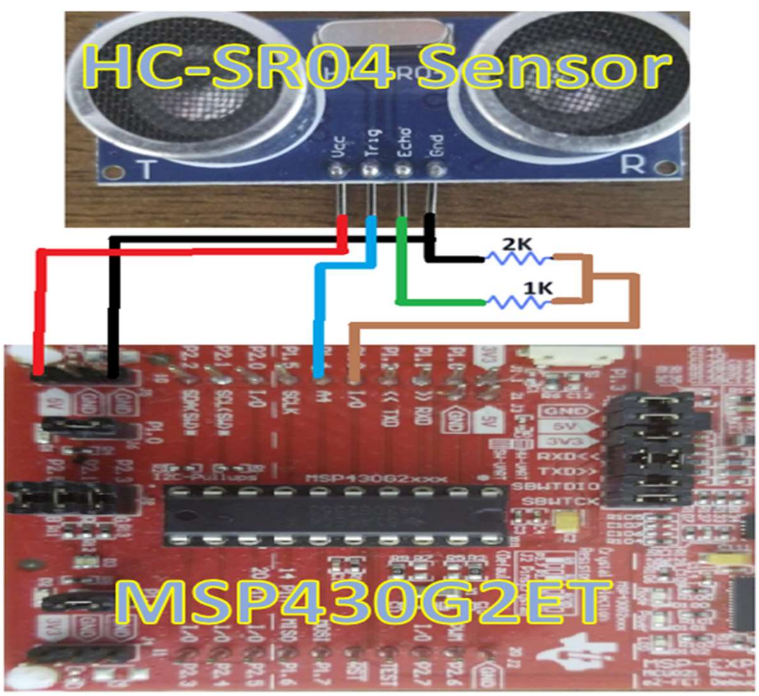


Picture 9: AT-09 Sensor Wiring

The second wiring schematic shown is the Ranging Detector Mod Distance sensor wiring diagram. In order to wire the Ranging Detector Mod Distance sensor, there are various connections between the MSP430 launchpad and the Ranging Detector Mod Distance sensor which need to occur in order to complete the wiring. These connections are as follows:

- Pin GND in HC-SR04 module to pin GND in launchpad
- Pin GND in launchpad to 2K resistor
- 2k resistor to pin 5 in launchpad
- Pin VCC in HC-SR04 module to pin 5V in launchpad
- Pin echo in HC-SR04 module to 1k resistor
- 1k resistor to pin 5 in launchpad
- Pin trig in HC-SR04 to pin 6 in the launchpad

A picture with the completed wiring of the HC-SR04 sensor and the launchpad can be observed below:

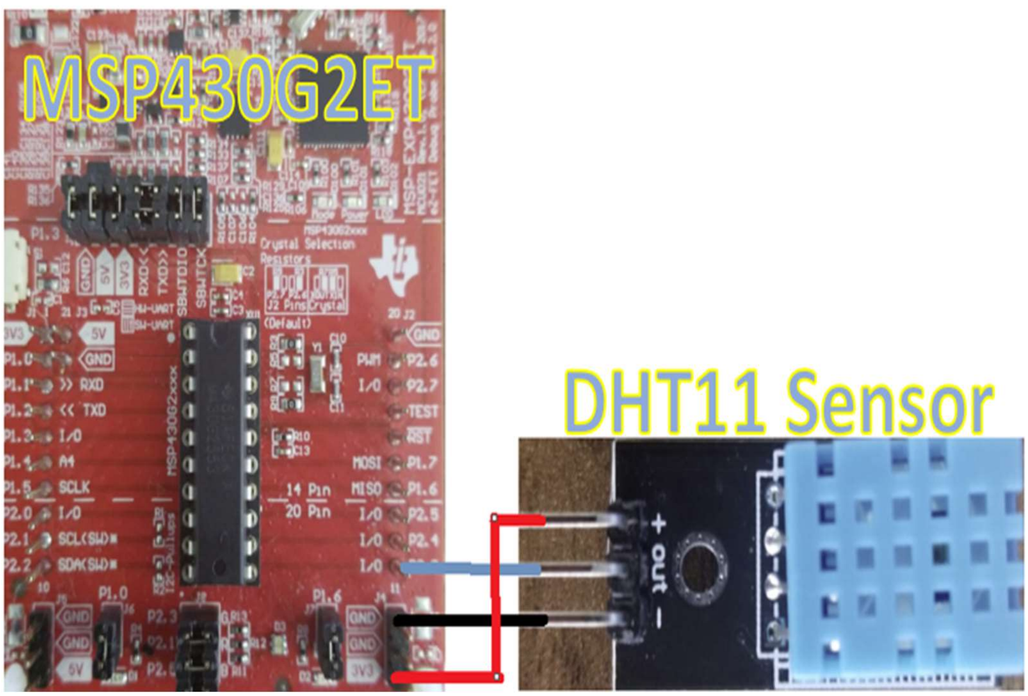


Picture 10: Ranging Detector Mod Distance Sensor Wiring

The third wiring schematic shown is the humidity and temperature sensor wiring diagram. In order to wire the humidity and temperature sensor, there are various connections between the MSP430 launchpad and the humidity and temperature sensor which need to occur in order to complete the wiring. These connections are as follows:

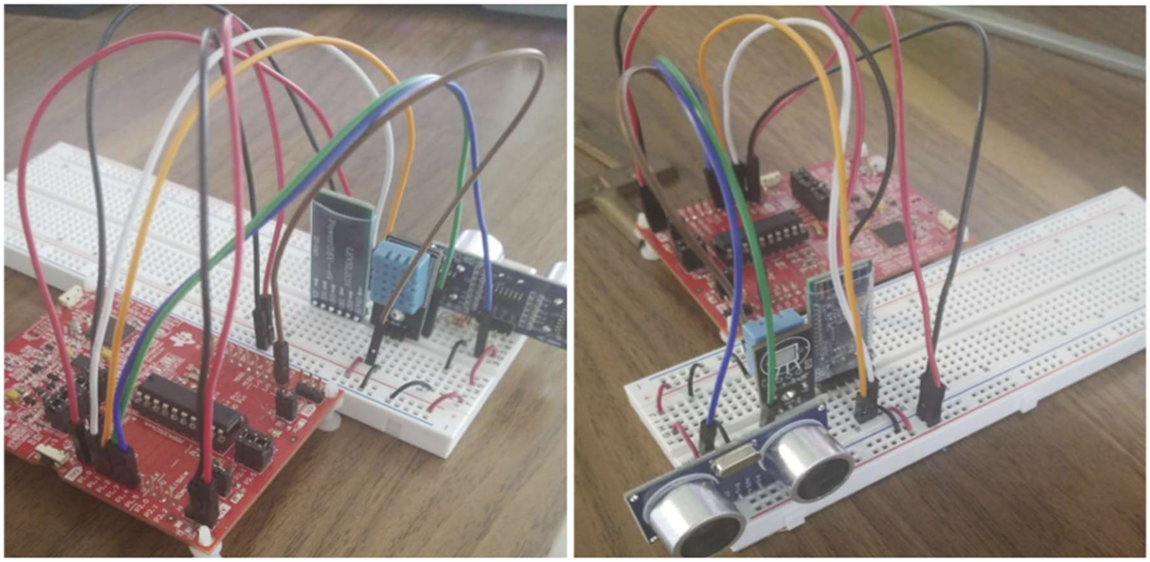
- Pin GND (-) in DHT11 module to pin GND in launchpad
- Pin VCC (+) in DHT11 module to pin 3V3 in launchpad
- Pin OUT in DHT11 module to pin 11 in launchpad

A picture with the completed wiring of the humidity and temperature sensor and the launchpad can be observed below:



Picture 11: Humidity and Temperature Sensor Wiring

With all the wiring for the different components of the communication subsystem completed, the next step consisted in assembling the different components of the subsystem with the microcontroller. A picture with all the different components of the communication subsystem interconnected can be observed below:



Picture 12: Communication Subsystem Complete Wiring

Once the communication subsystem wiring has been completed, other subsystems can be integrated into the microprocessor and communications with the main application can be established.

Mobility (Ascending) Subsystem

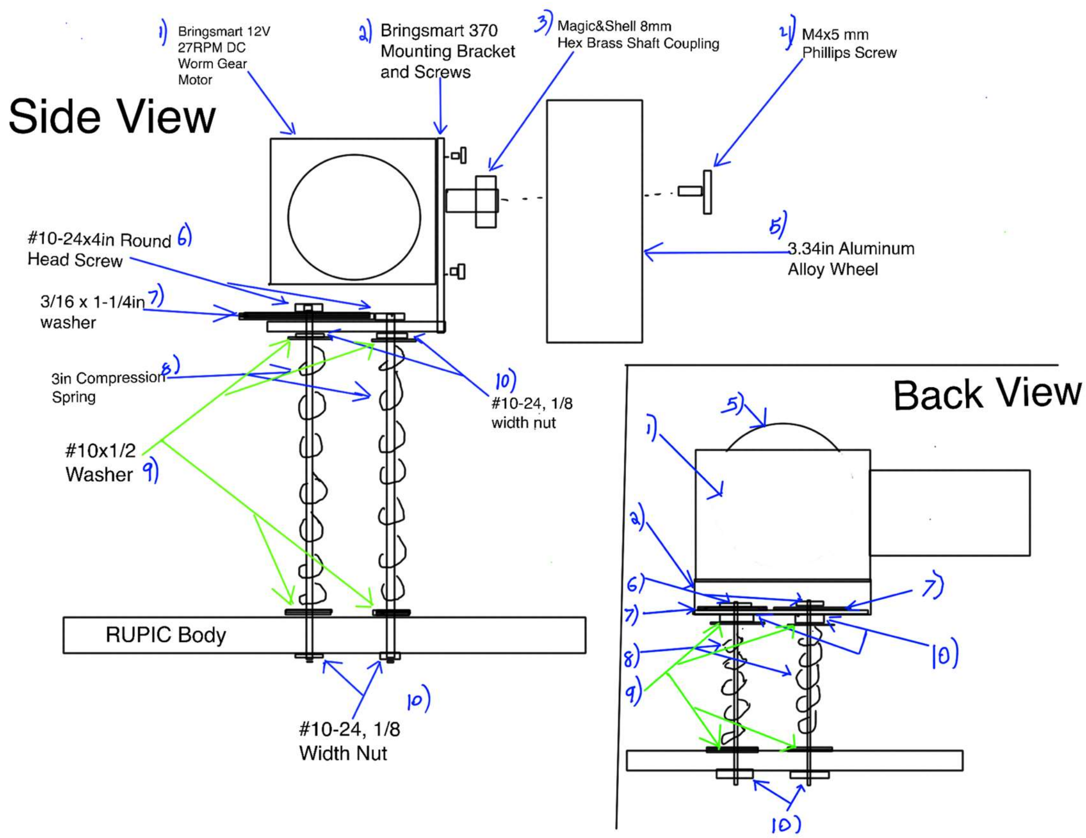
Components Used to Build Ascending Subsystem

Below is a list of the components needed to build the Ascending Subsystem

- Bringsmart 12-volt 27 RPM High Torque DC Worm Gear Motor
- Bringsmart 370 Mounting Bracket
- Mxfans 3.34 Aluminum Alloy Wheels
- Home Depot 3in Spring
- Magic&Shell 8mm Hex Brass Shaft Coupling
- L298 Drok Dual H-Bridge Motor Drive
- Tenergy NiMH Battery Pack 12v- 2000mAh
- Tenergy battery charger for NiMH

- Venom Tamiya plug set, male/female
- #10-24x4in Round Head Screw .
- M4x5mm Phillips Screw
- 3/16x1-1/4in Washer
- #10x1/2 Washer
- #10-24, 1/8 Width Nut

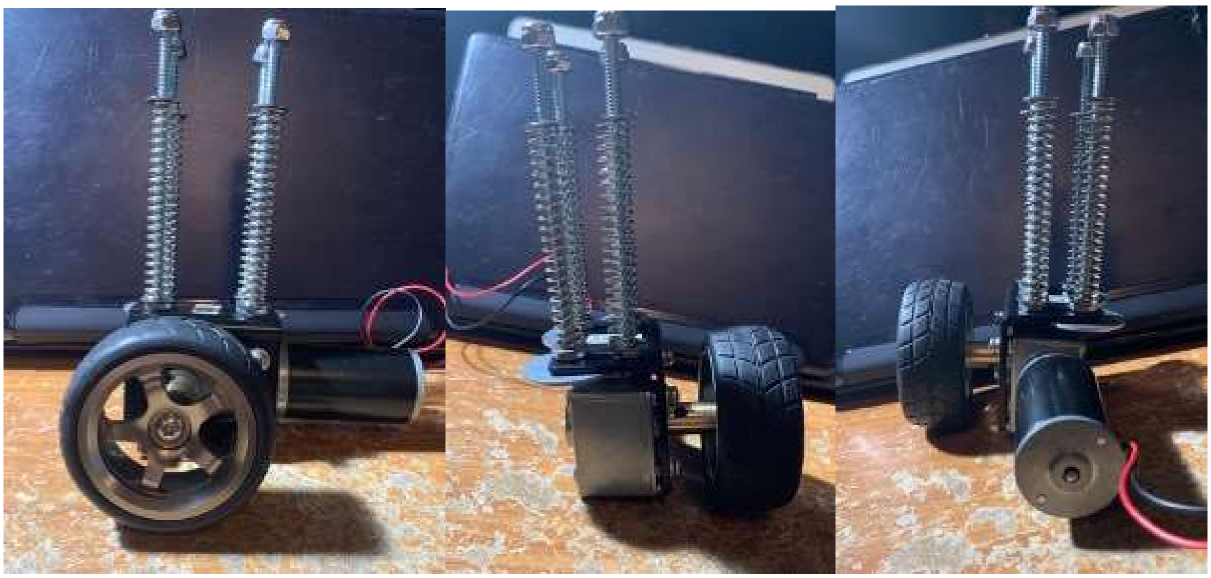
Once all the components where acquired the design ended up changing a bit, below is the final design that was settled on.



Picture 13: Mobility(Ascending) Subsystem Build Guide

The image above shows how all the components are connected to build the ascending subsystem; the image excludes the battery, dual H-bridge drive and the wiring connections that go to the Microprocessor. After building the motor you can move on to wiring the battery to the dual H-bridge drive.

The images below show a fully assembled Ascending Subsystem Motor.

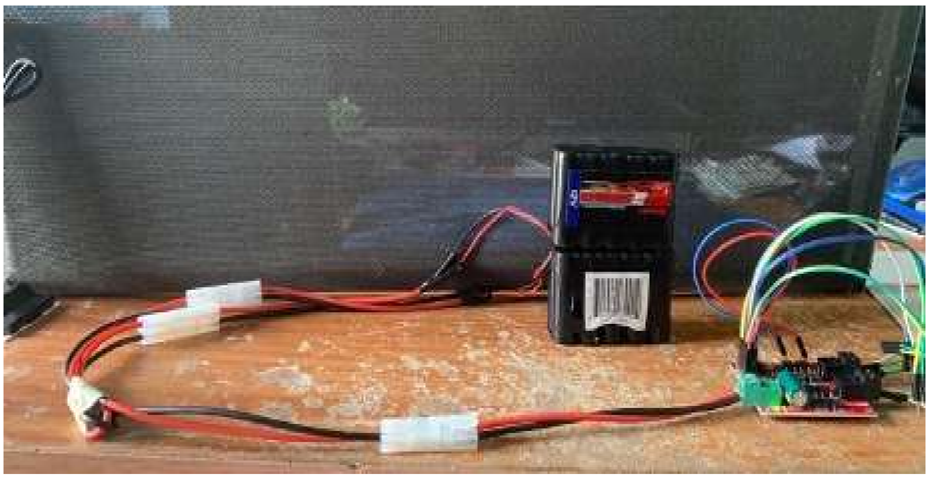


Picture 14: Mobility(Ascending) Built Subsystem

Hardware for 12v-2000mAH batteries connected to the H-Bridge Drive.

- L298 Drok Dual H-Bridge Motor Drive
- Tenergy NiMH Battery Pack 12v- 2000mAh
- Tenergy battery charger for NiMH
- Venom Tamiya plug set, male/female

The female end of the Tamiya plug is connected to a battery terminal through the red wire connected to the red battery terminal wire and the black end connected to the black battery terminal wire. The male ends that connect to those female ends are set up in parallel by connecting red wire to red wire and black wire to black wire, furthermore another female end is connected to those wires through, red to red and black to black connections. Finally, a male end is connected to the dual h-bridge drive through the red wire connected to left input of h-bridge drive and a black wire connected to the right input. The batteries connected in parallel this way leads the 2 12v 2000mAH batteries combining to form a 12v 4000mAH battery that will be used to power the motors. The batteries connected this way also have another plus being that the charger male end can be used to charge both batteries together, or you can disconnect them and charge one battery at a time.



Picture 15: Mobility(Ascending) Subsystem Power Wiring

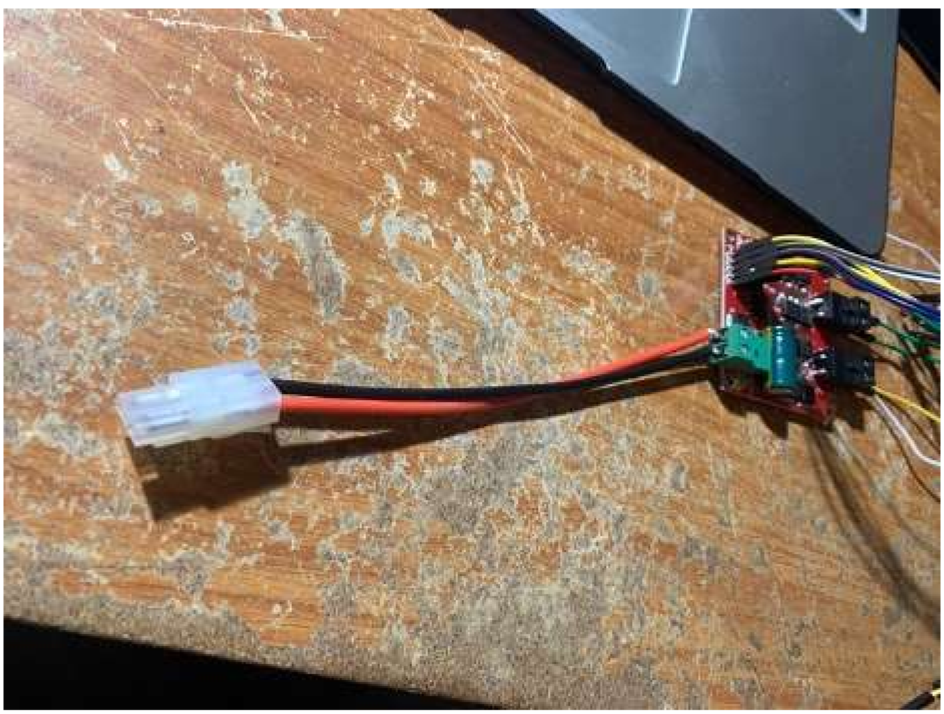
The image above shows two batteries connected in parallel to each other then connected to a dual-h bridge drive.

Picture 16: Mobility(Ascending) Subsystem Battery to Female Wiring

The image above shows how the battery terminals are connected to a female end connection.

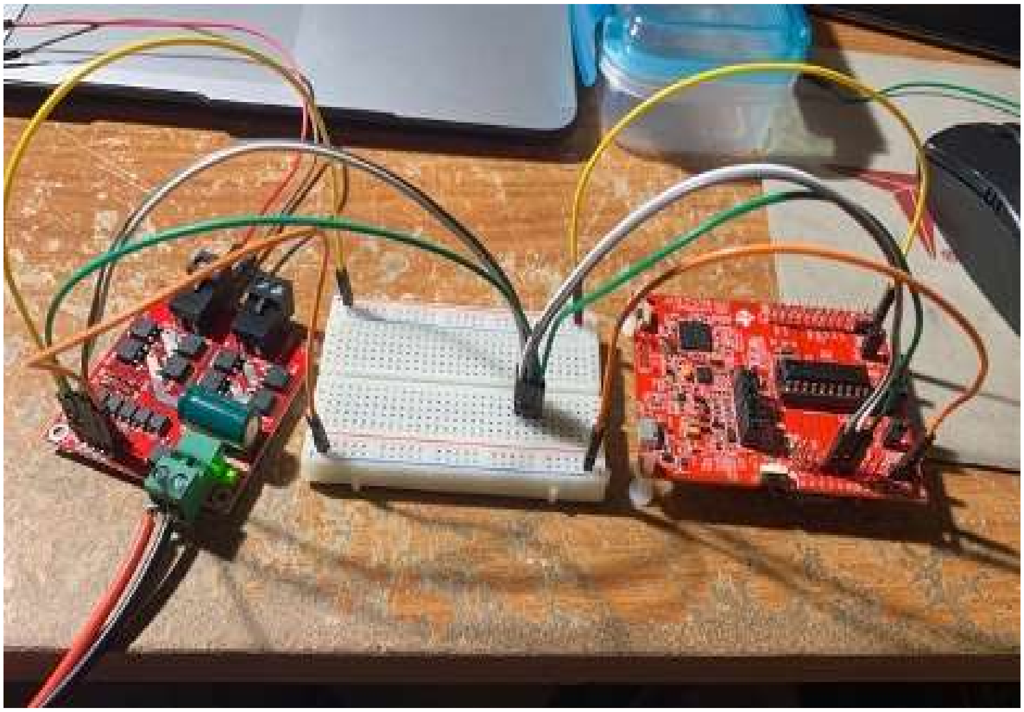
Picture 17: Mobility(Ascending) Subsystem Parallel Battery Wiring

Two male ends are connected in parallel then connected to a female end.



Picture 18: Mobility(Ascending) Subsystem Male End connected to H-bridge Drive

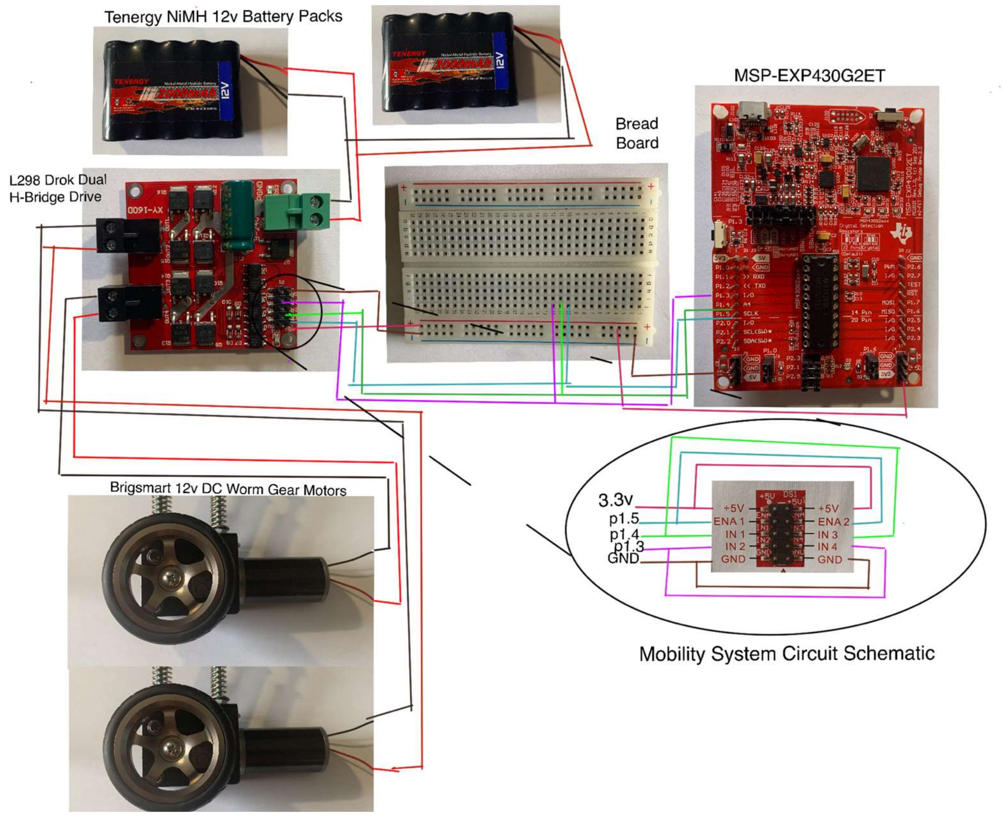
The 3 images above when connected together show the wiring to connect the batteries in parallel, this is done so that it becomes easier to connect the batteries to the dual H bridge drive.



Picture 19: Mobility(Ascending) Subsystem Microprocessor and Dual H-Bridge Drive Wiring

Picture 20: Mobility(Ascending) Subsystem Battery, H-Bridge Drive and Motor Wiring

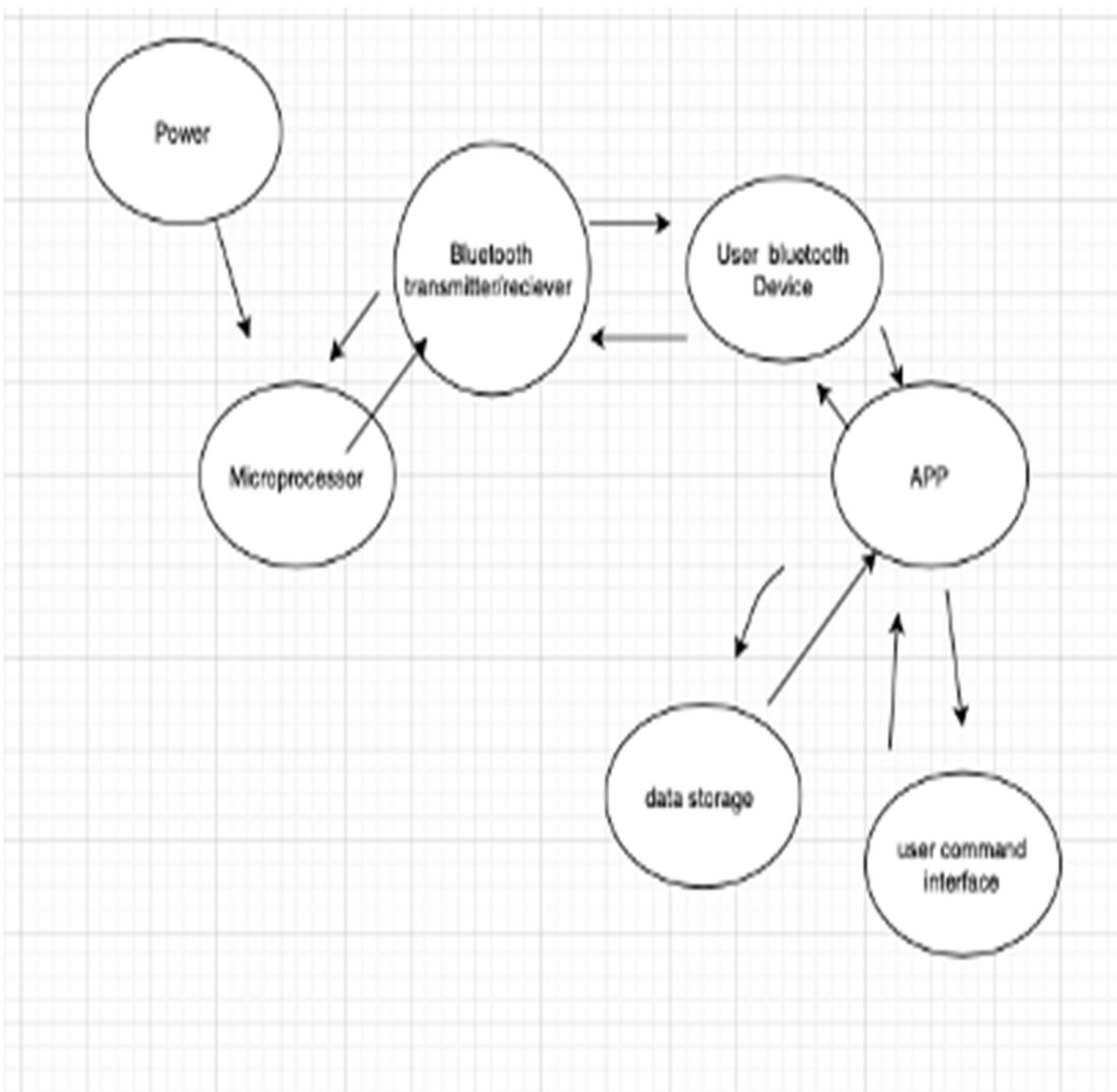
The two images above go together and show the connection to drive 1 motor using 1 battery.



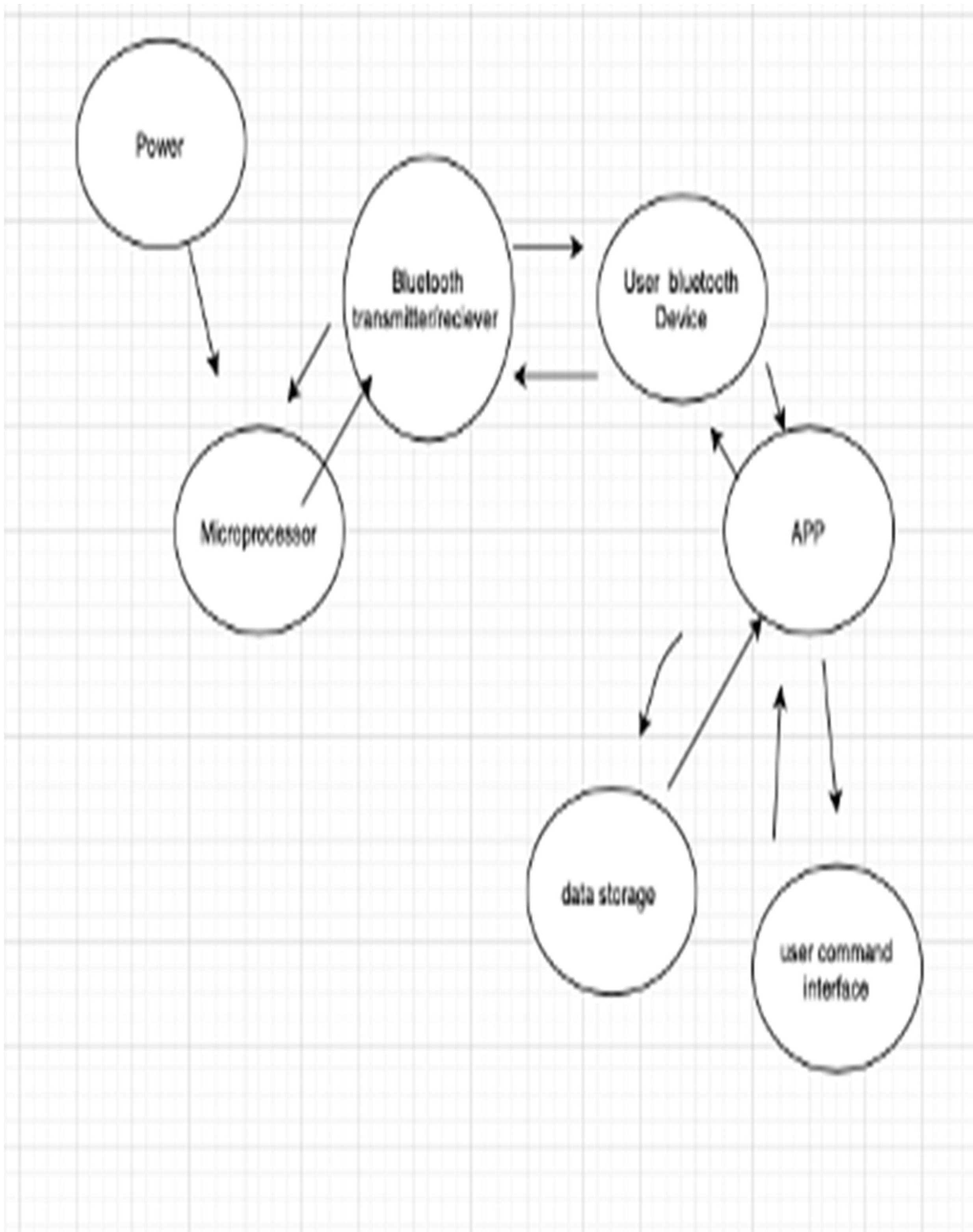
Picture 21: Mobility (Ascending) Subsystem Wiring Schematic

The schematic above shows the wiring for 2 of the motors. The 2 12v 2000mAH batteries are connected in parallel this way they combine amperage and can be seen as a 12v 4000mAH battery. The positive red wire and the ground black wire goes to the power inputs of the dual H-bridge drive to power. The dual H-bridge drive has two outputs to drive two motors, and that's where the outputs of the motors are connected. The motor is capable of spinning forward and reverse so if one of the motors is spinning in the wrong way you can just switch the inputs to the motor wires to switch the polarity and have the wheels rotate in the opposite direction. You have to connect 5 pins of the microprocessor to make the motors rotate. The pins that are needed to do this are 3 input pins, a ground and a 3.3v pin. These 5 pins connect to the H-Bridge drive through 5 connections; they are labeled as +5v, ENA1, IN 1, IN 2, and GND. One of the 3 inputs from the Microprocessor will be a pulse width modulated signal that is attached to the ENA, and the other two inputs will be able to switch from high to low signals and are attached to IN1, and IN2.The 3.3v signal from the microprocessor will attach to the 5v pin of H-bridge drive and the grounds will be attached to each other. If you want to attach 2 more motors, you will have to get two more 12v batteries and attach them in parallel then connect them to another dual H-bridge drive. The 5v, ENA1, IN1, IN2 and GND of the second H-bridge drive can be attached to the same wires as the first dual H-Bridge drive through the bread board.

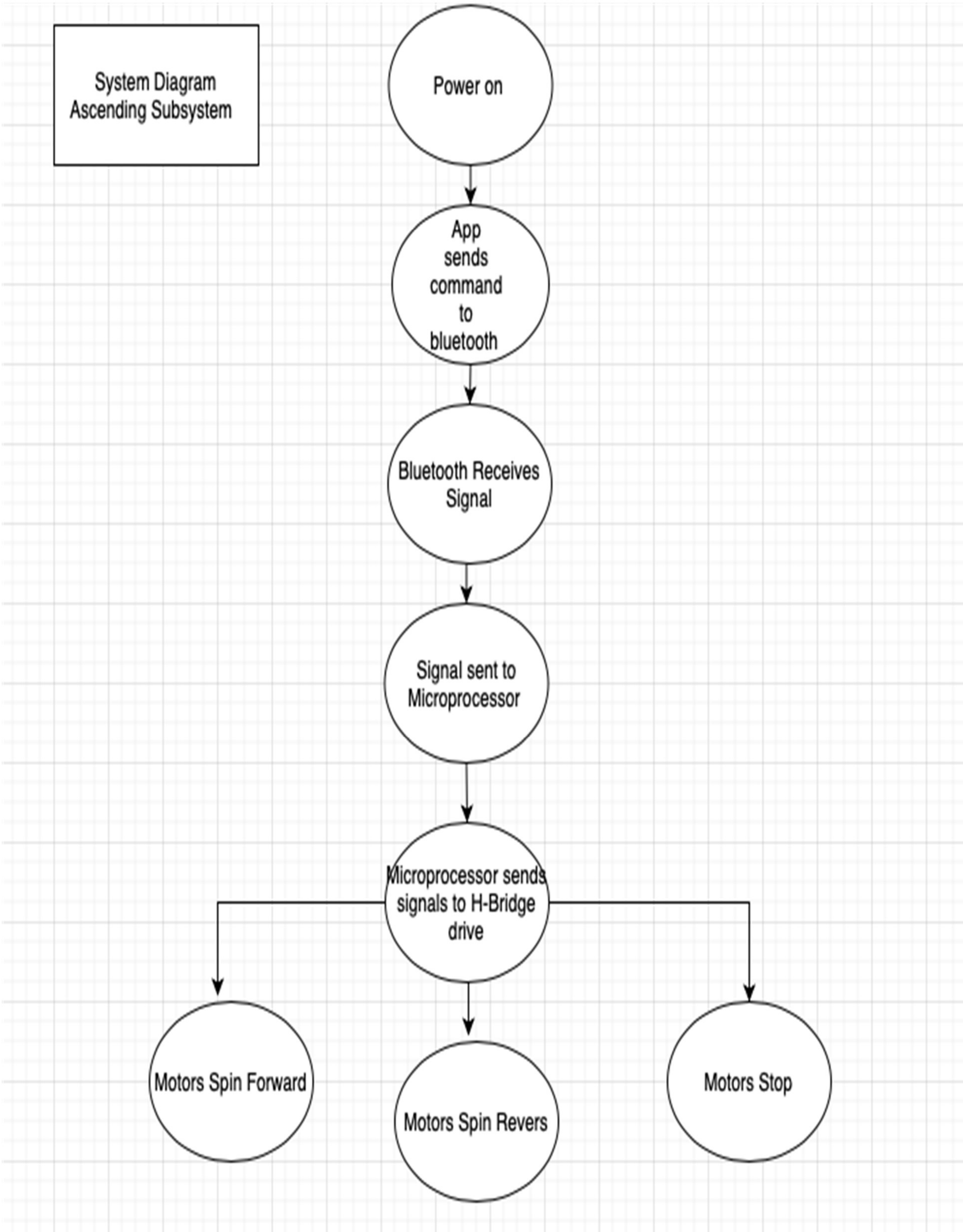
B. Overall System Design with Block Diagrams



Picture 22: User End Device Subsystem

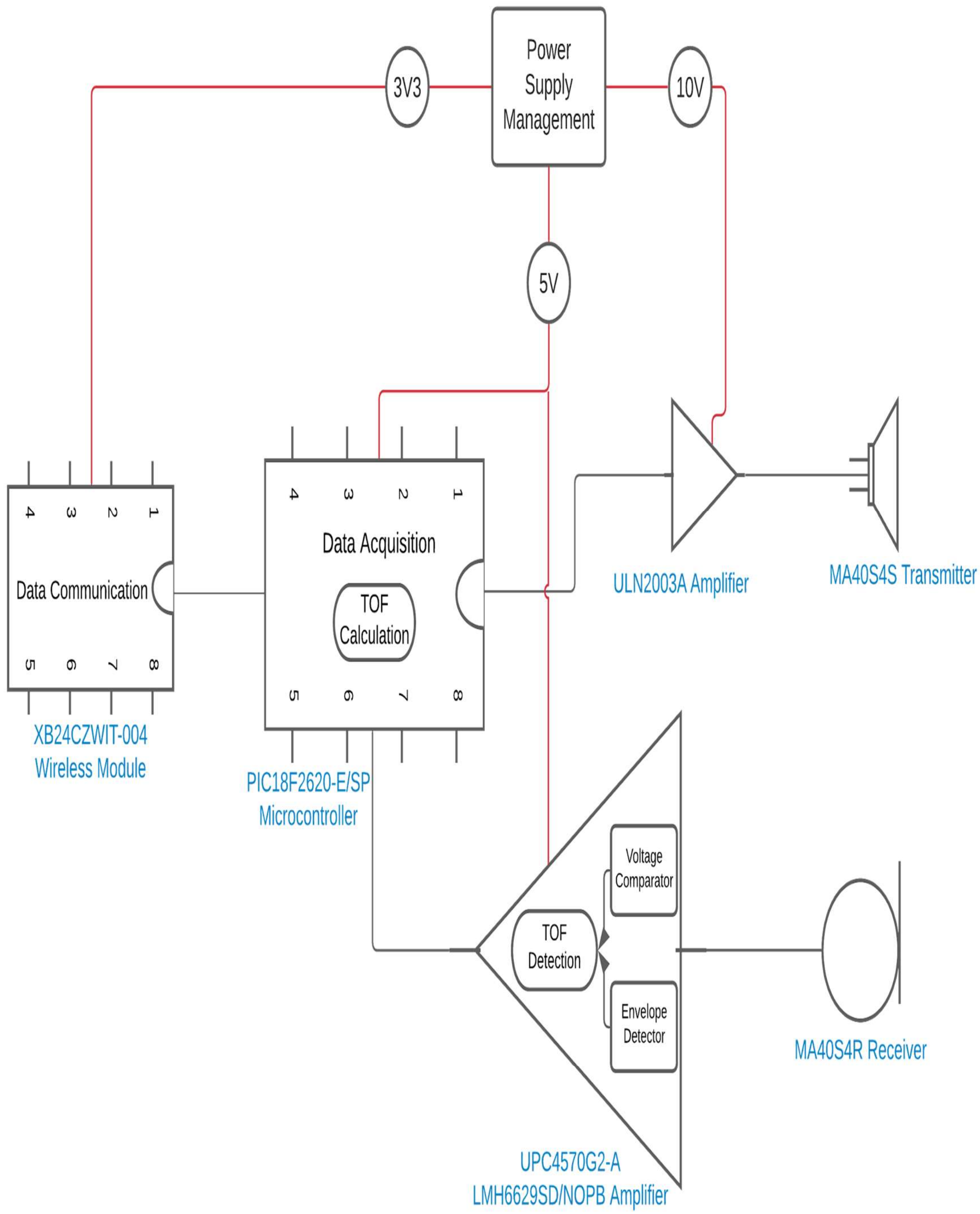


Picture 23: Ultrasonic Sensors Subsystem

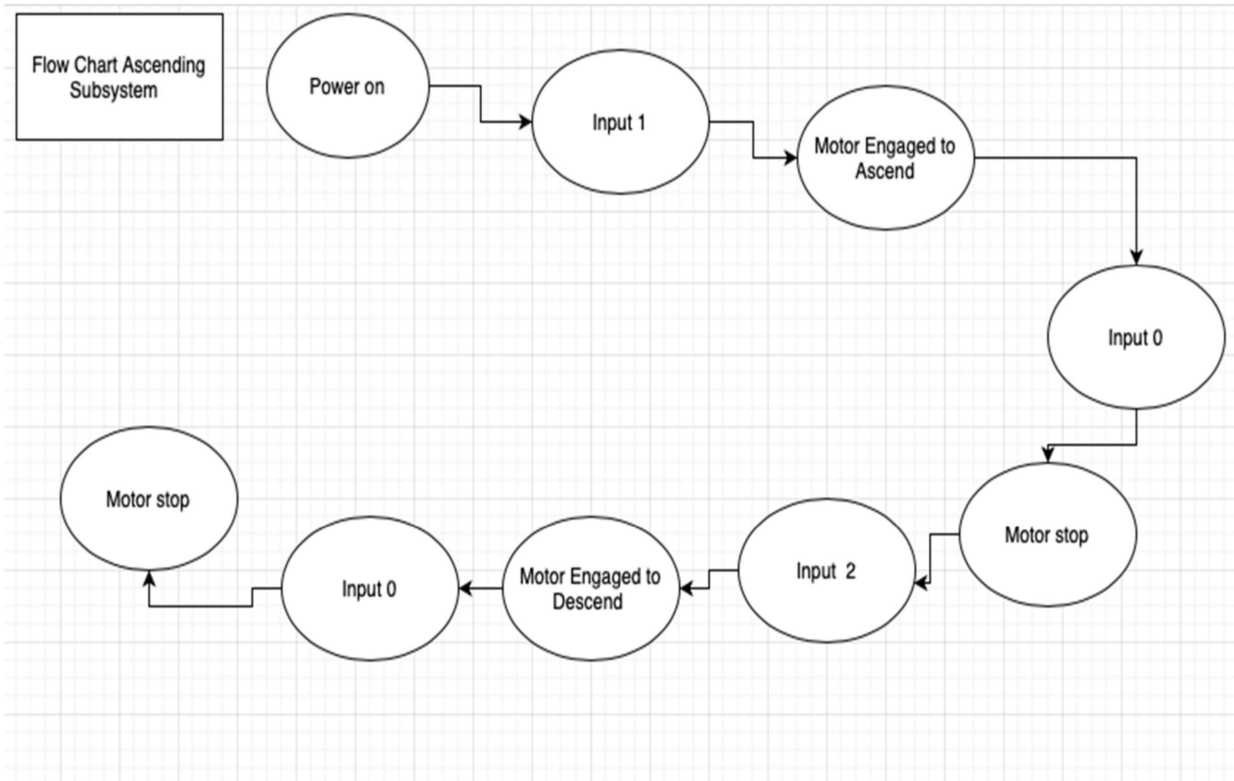


Picture 24: System Diagram Mobility(Ascending) Subsystem

C. Circuit Diagrams, Flowcharts, Use Case Diagrams



Picture 25: Ultrasonic System Diagram



Picture 26: Flow Chart Mobility (Ascending) Subsystem

The image above shows the flow chart of the mobility system, as you can see the motor can not go from forward to reverse in one step, there must be an intermediate stopping step in between. If you don't stop before switching directions you could potentially end up damaging the motors and the H-bridge drives.

Ultrasonic Transduction Inspection Subsystem Design and Engineering

1. Introduction:

FPL has approximately 1.1 million of wooden utility poles across South Florida (NextEra Energy, n.d.). To comply with safety guidelines and regulations, FPL Lineman are required to inspect these poles for defects and efficiency conditions. Currently, FPL Lineman uses a testing method called the “Hammer Test”, it involves striking the pole with a hammer and listening to the sound produced from the impact. Defected pockets inside the pole will produce a less profound rebound and dull sound compared to that of a non-defective pole (Labor, n.d.). The hammer test is limited in that it does not provide a quantitative assessment on the internal structure of the pole in question. The resulting flaw of this test is that it is susceptible to error and can possibly miss or misinterpret a defect from inside the pole.

There are several alternatives to the traditional hammer test and ultrasonic through transmission remains the most efficient and cost-effect one. Ultrasonic through transmission involves a transmitting and receiving transducer that are placed at opposite ends of the given material. The pulse wave emitted from the transmitting transducer propagates through the material. When the propagated wave arrives from the transmitter, the receiving transducer collects pulse wave information such as time of flight, amplitude, phase width, and velocities of the various directional waves.

The difference in acoustic impedance in air compared to the impedance of wood structures is extremely large (Kommareddy, Air-coupled ultrasonic measurements in composites, 2003). Thus, the implementation of conventional piezoelectric transducers that propagate through air as the medium, is nearly impossible. Conventional ultrasonic transducers must rely on a coupling medium such as petrolatum to avoid the large impedance mismatch in order to be effective.

The proposed Robotic Utility Pole Inspection Collar (RUPIC) features the ability to move vertically along the utility pole. Hypothetically speaking, if conventional ultrasonic transducers were attached to the RUPIC, then the collar would have a mechanism to continuously emit the coupling medium along the pole as it moves up and down. The inference from this is that the whole concept of a coupling medium applied to the RUPIC is difficult and terribly inefficient.

Contrary to conventional ultrasonic transducers, air-coupled non-contact ultrasonic transducers provide a reliable means to efficiently transmit waves through wood material. An air-coupled ultrasound (ACU) system does not require physical contact and uses air as the coupling medium.

2. <u>Air-Coupled Ultrasonic Transduction:</u>

The concept of air-coupled ultrasonics (ACU) was first implemented in 1973 in which a study was conducted by propagation of waves through metal plates (M. Luukkala, 1973). Since then, there have been numerous studies leading to the significant advancement of ACU. There are many applications as well as testing methods for ACU leading the industry to conclude that air-coupled ultrasonic transduction (ACUT) is a viable, cost effective, and non-destructive method used to evaluate defects in wood composites.

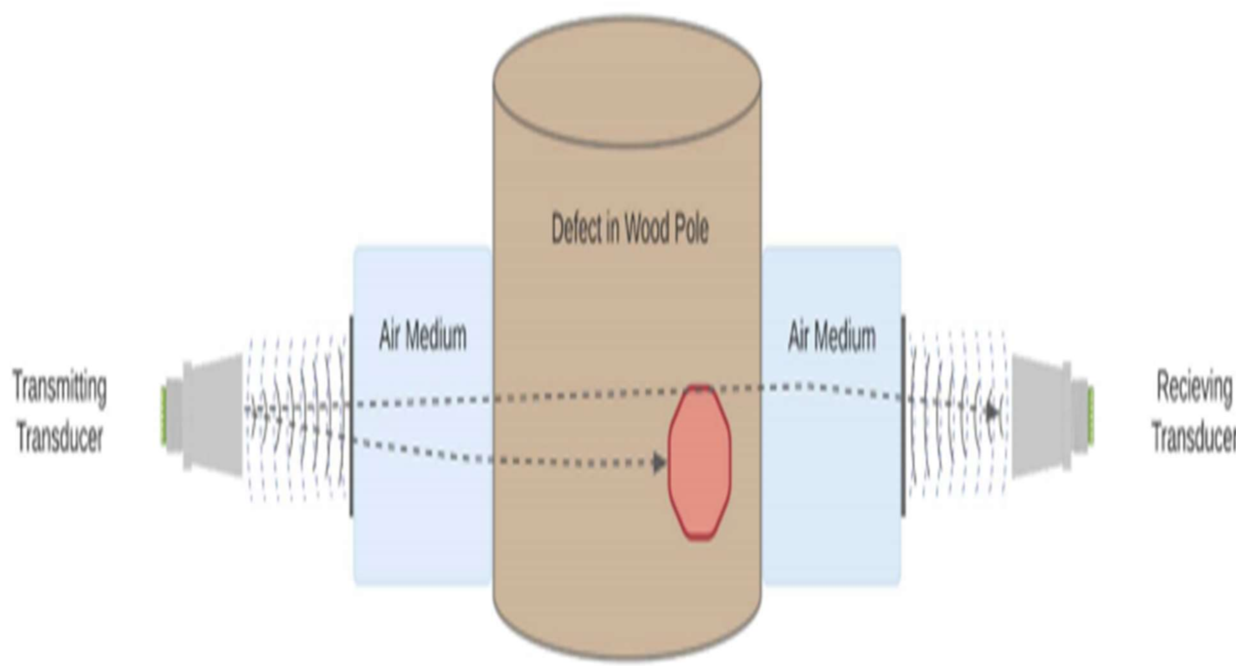
Conventional ultrasonic methods use a liquid or water immersed coupling agent. The direct contact, leading to the inevitable damage, as well as the need for a coupling agent to continually be dispersed along the surface of the pole would conclude that conventional ultrasonics would not work for our application.

Because of the high impedance mismatch between air and most sound producing materials, most of the ultrasonic transmission wave energy is reflected at the medium interface and only a small amount of energy is propagated through the material. (Kommareddy, Air-coupled ultrasonic measurements in composites, 2003). Therefore, a large amount of energy needs to be transmitted into the material in order to reach the receiving transducer.

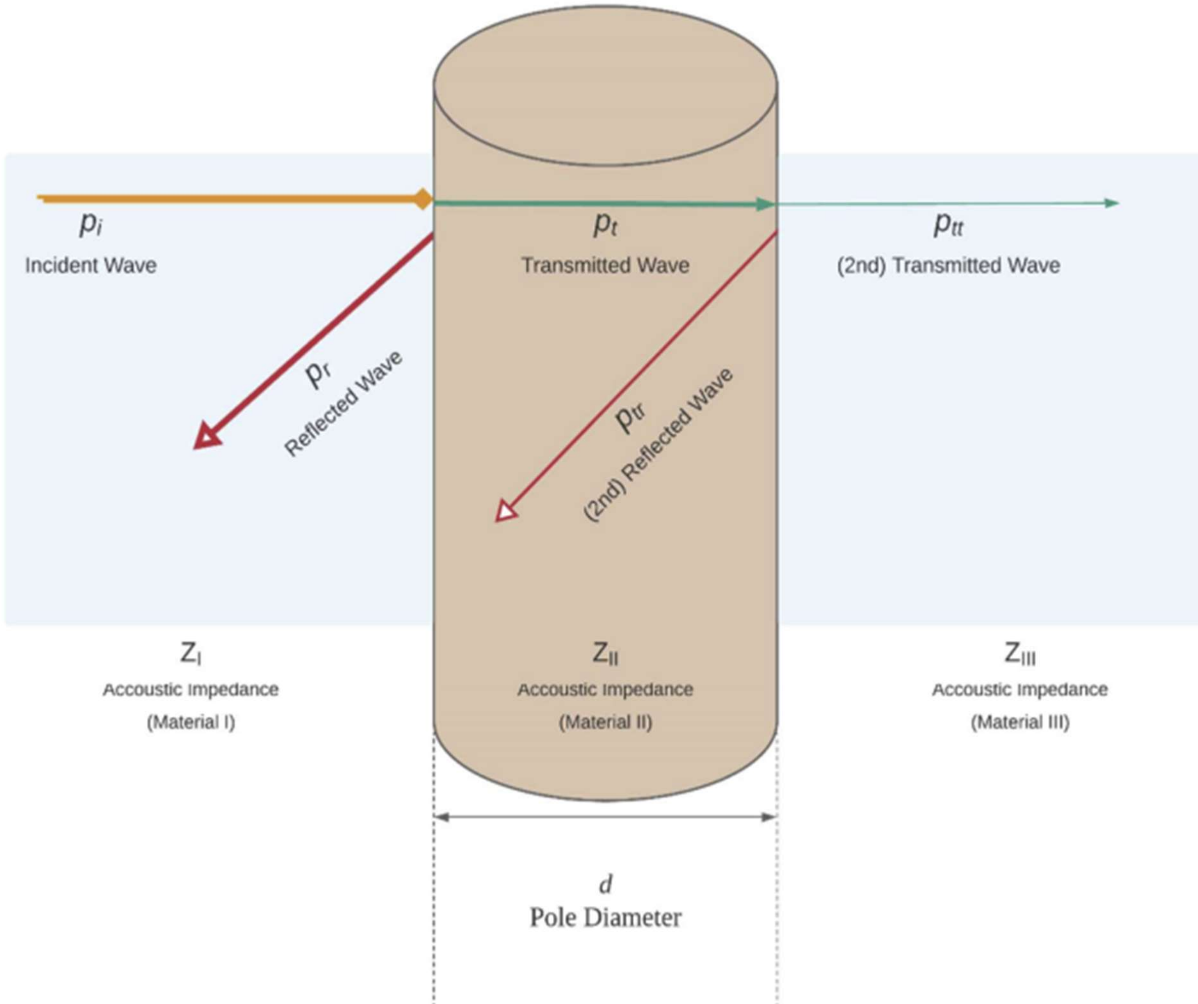
3. <u>Through Transmission Testing:</u>

To meet the functionality requirements of this project, a technique and testing method known as through transmission will be used. This method involves two transducers: one transmitting unit and one receiving unit. The transducers will need to be placed at opposite sides of the pole, collinear across the diameter of the pole.

The acoustic impedance of air is approximately 415 Rayleigh, compare that to the large acoustic impedance of most wood structures being around 1.57 X 10^6 Rayleigh (Fleming, 2005). This impedance mismatch results in only a small fraction of energy being transmitted into the propagation medium. In oak wood, 99.94% of the incidence energy is reflected and only 0.06% is transmitted into the wood (David K. Hsu, 2009). There are multiple points of transmission loss that occur as the energy waves propagate from the transmitter to the receiver in through transmission. As the incident wave enters the first material or medium, a small fraction of the wave's energy is transmitted into the material while the rest is reflected. The process continues as the wave crosses the different mediums and finally reaches the receiving transducer. This process is illustrated in figures 27 and 28 below.



Picture 27: Through Transmission Representation for Defect Detection



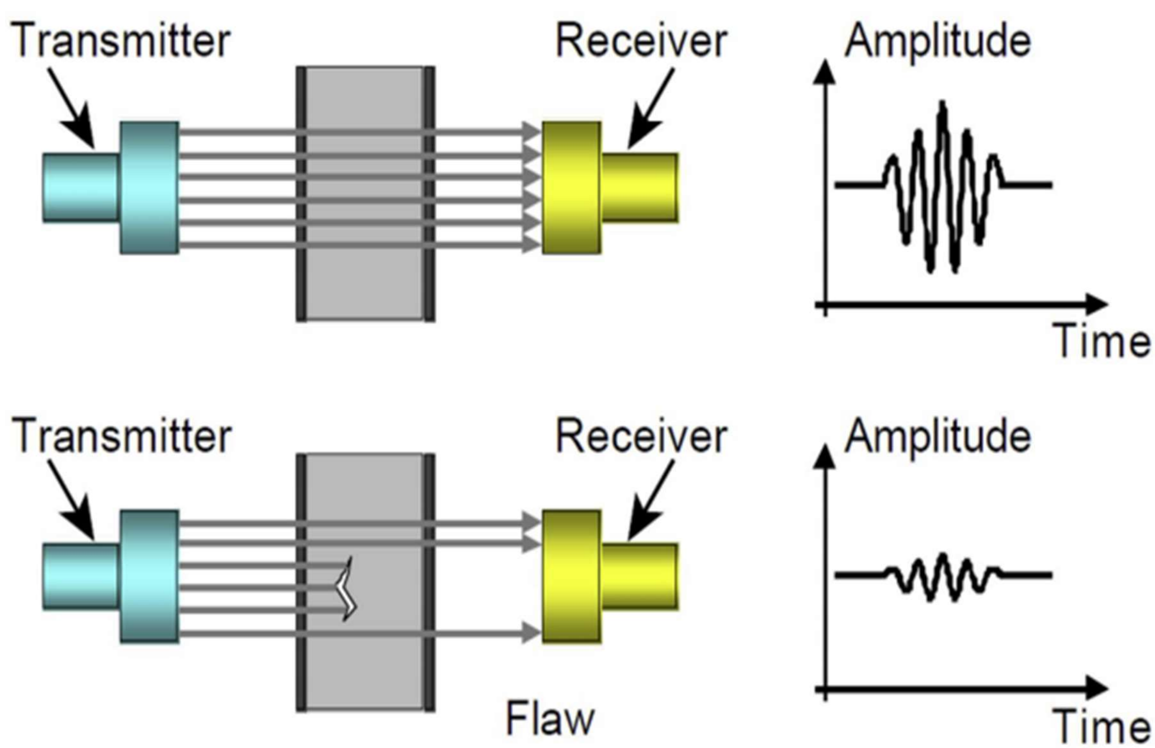
Picture 28: Through Transmission Wave Transmission and Reflection

Through transmission representation for defect detection Figure 27: Through transmission wave transmission and reflection As stated above, reflected, and transmitted waves are generated as the result of acoustic waves traveling from one medium to another. The amount of energy transmitted from one medium to another depends on the ratio of their acoustic impedances. Wave velocity measurements in a cross section of red-pine utility poles has shown to decrease an average of 20% when encountering a hole or void in the radial direction across the pole (Fernando Tallavo, 2013). Furthermore, ultrasonic waves have been proven to detect decay areas as small as 6 cm in diameter (Tallav´o, 2009).

Given that wood is a cylindrical orthotropic material, uncertainties exist for its elastic, mechanical, and environmental properties. This is associated with evaluation complexities and further consideration regarding wave velocity and attenuation is needed to fully access the condition of the pole.

4. <u>Materials and Methods:</u>

Scans will first be established using a baseline measurement showing no defects or degradation and an expression for the transmission coefficient is derived. The recorded time of flight will be taken continuously as the collar traverses up the pole. Any irregularities from inside the pole will affect the transmission amplitude and be measured and compared to the baseline observations. The sound waves will most likely not provide enough energy to reach the receiving transducer if there are any holes or cracks. A decrease in the amplitude of the transmitted signal, compared to the signal of no defects, indicates a flaw (Kaufmann, 2008).



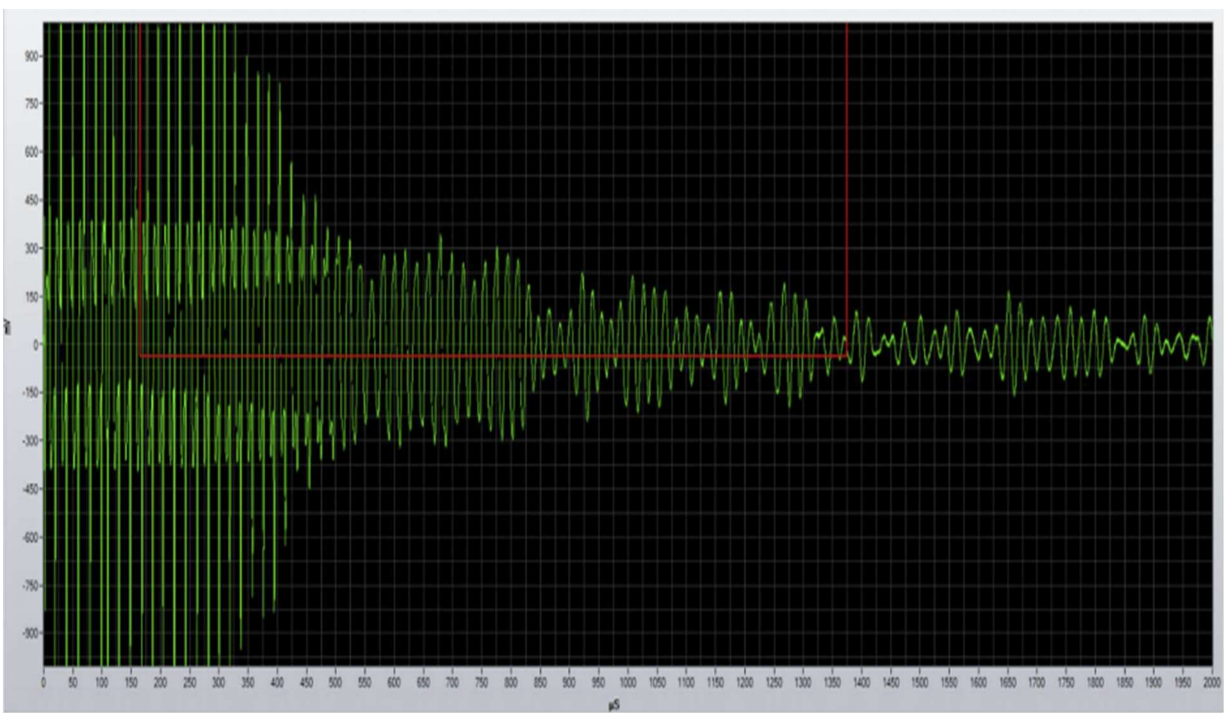
Picture 29: Through-transmission flaw detection signals

For our application it is appropriate to record and access multiple measurements and parameters. The measurement categories of time and attenuation domain will provide accurate results for identification and defect characterization. Time domain parameters include time-of-flight and velocity measurements for longitudinal waves. Attenuation domain provides data on fluctuations from reflected and transmitted signals (Bhardwai, 2002).

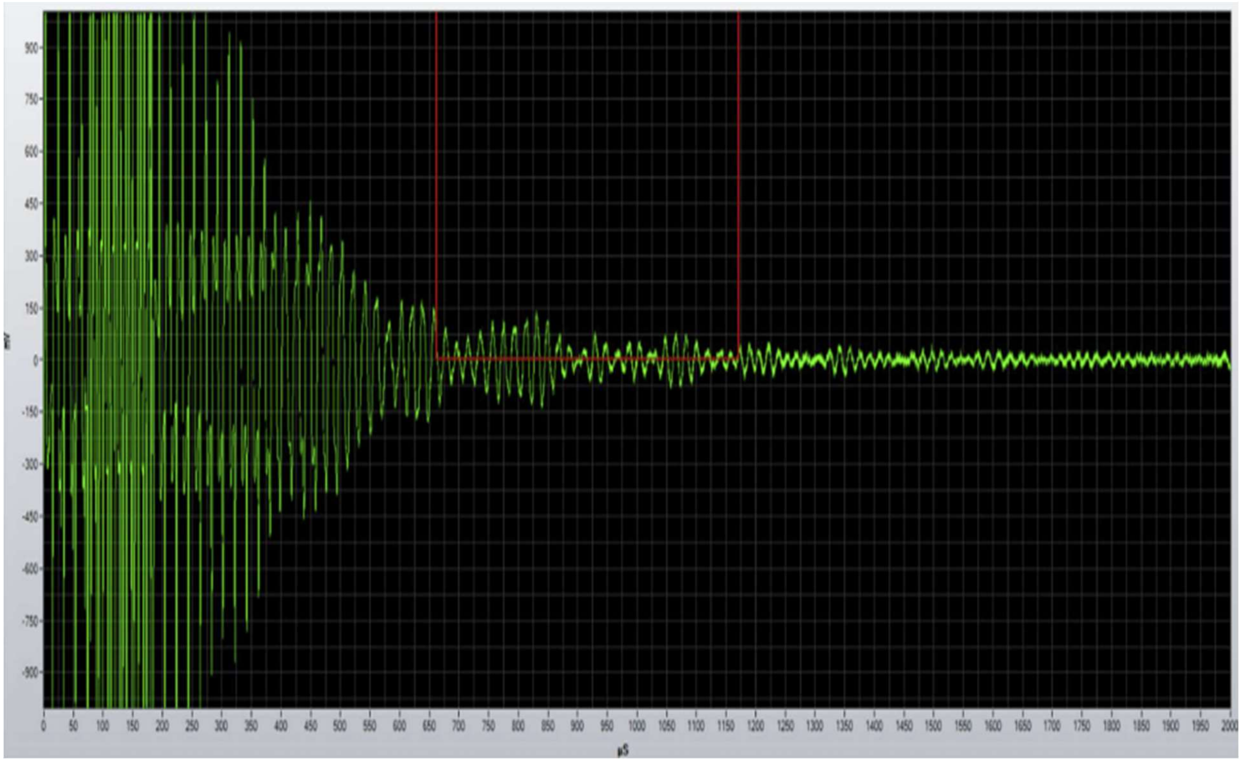
Careful consideration must be given to the type of transducer selected as characteristics of a specific frequency, pulse shape, and pulse width of ultrasound propagation vary with material type. For example, a frequency of 50kHz may easily propagate through Material A, while making no impact on Material B. Furthermore, a frequency of 2MHz may have no problem propagating through both Materials A and B, but the pulse width would be too large for Material A to produce any meaningful results (Bhardwaj, 1987).

Informal testing was conducted on a wooden utility pole by The Ultran Group, Inc. They attempted to test for successful propagation using a planar/unfocused NCG50-D50 and S50 transducers that used 50kHz, 100kHz, and 200kHz frequencies with a standard pulser and a high-voltage pulser. Successful propagation through the pole was noted by the 50kHz frequency with increased gain to 84Db from the receiving transducer. The 84dB gain from the receiving transducer produced enough noise to dampen the signal completely so averaging was applied. Although the 50kHz frequency was able to transmit through the pole, it was noted that a larger diameter transducer would produce more profound results for NDE applications on the large diameter pole. The 100kHz and 200kHz frequencies for this experiment were proved to be unsuccessful, but further modifications to signal processing could possibly produce effective results with these frequencies. The test setup is noted in figures 30, 31, and 32 below (Whetzel, 2021).

Picture 30: Field Test Setup

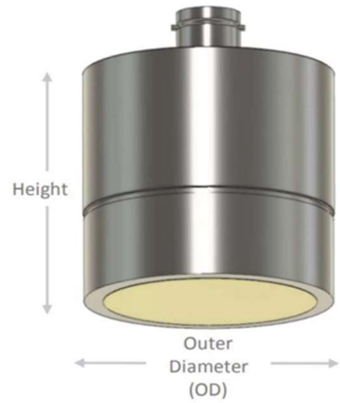


Picture 31: Received Signal (averaged) from 50KHz Frequency High Voltage Pulser.



Picture 32: Received Signal (averaged) from 50KHz Frequency Standard Pulser.

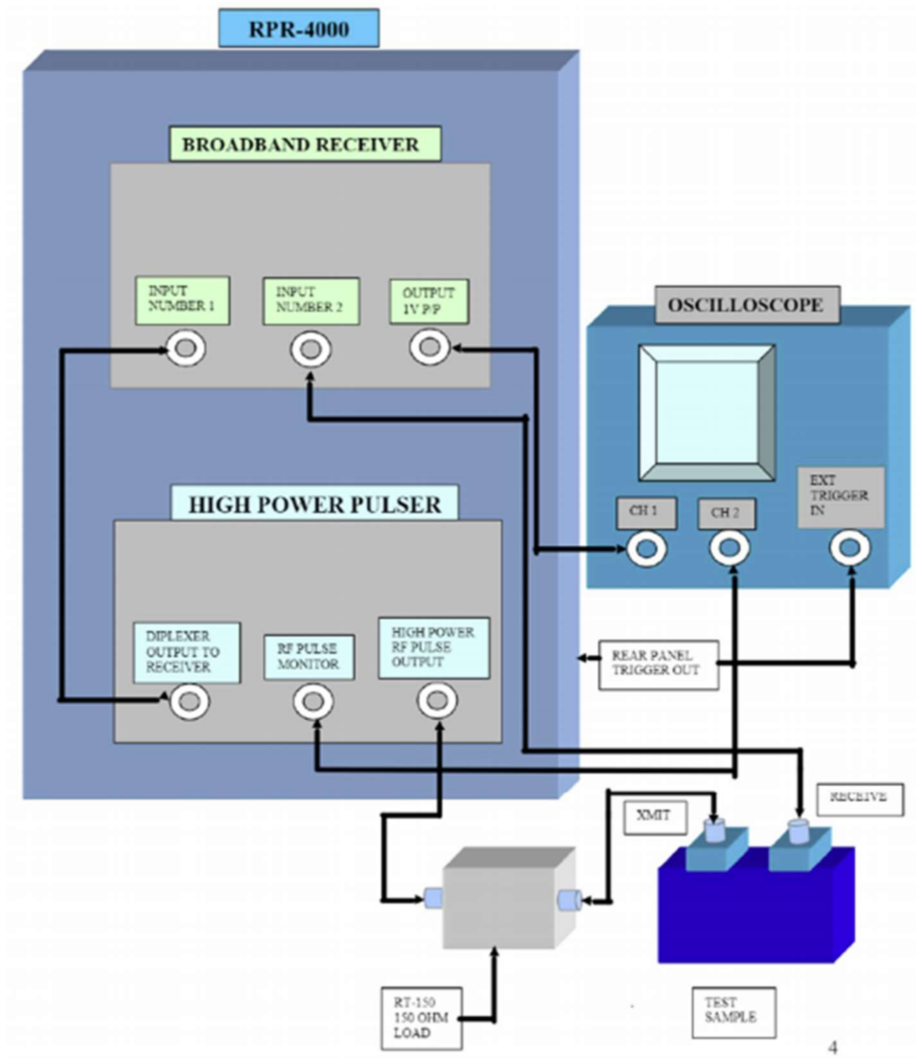
After careful consideration and thorough research, the NCG50-D63 and NCG50- D50 from The Ultran Group, Inc. would be an ideal choice for our application. The NCG50-D63 and NCG50-D50 are high-performance piezocomposite non-contact ultrasonic transducers, with nominal frequencies of 50kHz and 63mm & 50mm face diameters. Since successful yet weakened propagation through the utility pole was achieved by two D50s', to ensure increased sensitivity and stronger signal impression we will use the D63 for the transmitting receiver and the D50 for the receiving transducer. Figure 33 below shows the basic structure of the NCG series transducers.



Picture 33: NCG500-D19 Ultrasonic Transducer

The testing separation between the transmitter and wooden pole will initially be set to 210 mm while the receiving transducer's separation width will be 55 mm. A 390V tone burst will be used to excite the transmitting transducer and the receiving transducer's gain will initially be set to 84dB. Needed adjustments in these initial configurations may need to be made to produce optimum propagation and signal analysis through the full diameter of the pole.

The RPR-4000 High Power Pulser/Receiver from RITEC, Inc. will be used to excite, drive, and receive the signals from the transducers. The transmitting transducer will be connected to the RT-150 Termination via BNC cable before being connected to the high power pulser. The RT-150 reduces reflections that can affect the shape of the toneburst as well as provide more control of the voltage amplitude. The receiving transducer will be connected to the broadband receiver which contains a microprocessor that controls the receiver gain, filter settings, and receiver input. The RPR-4000 has a front panel keypad and menu screens for controlling all the functions of the high-power pulser. The output of the broadband receiver and the RF pulse monitor will be connected to the TDS2012C Oscilloscope from Tektronix, Inc. Except for the Duplexer (not needed), the following configuration is pictured in figure 34 below.

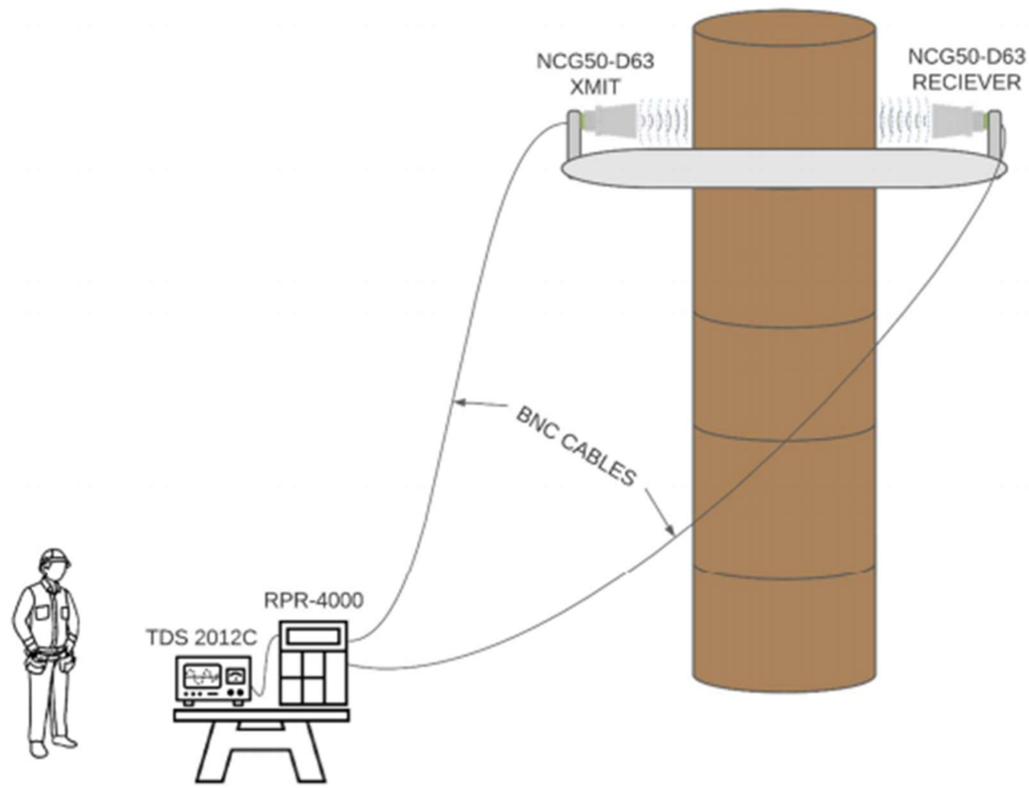


Picture 34: The RPR-4000, Transducer, and Oscilloscope Configuration.

5. <u>Limitations and Future Considerations:</u>

Due to the specialized equipment needed to excite the transmitting transducer, amplify the receiving transducer, and display the processed signals, limitations will be enacted on the RUPICs functionality. In order for the RUPIC to fulfill the project's mechanical and functional requirements, the complete ultrasonic sensor subsystem will need to be joined together and mounted on the RUPIC. Because of the extremely high voltage requirements of the pulser/receiver, it is unlikely we will be able to find a battery capable of delivering the power and be light enough to not weigh down the RUPIC.

In a more realistic scenario, the transducers will be the only portion of the subsystem that will be mounted to the collar while the rest of the equipment remains at the base of the pole, on the ground. The connection between the transducers and the pulser/receiver will be maintained by BNC cables measuring approximately 100 ft in length, picture 35 below illustrates this proposed setup.



Picture 35: Proposed Field Application Setup

Although meeting the full requirement and functionality specifications are not possible at this time, future development, optimization, and enhancement will be made on the prototype. Prioritization will be given to identification or production of a battery or mobile power source capable of driving and sustaining the ACUT sensor system. In addition to being able to power the system, it would need to be able to be supported by the strength of the collar so the collar can stay secured to the pole.

Another area of enhancement and functionality would be improvements in the data and signal processing. Added features such as being able to transmit the data (signals) wirelessly to a trained operator on the ground. This will provide real-time signal measurement to the operator enabling him to make a judgement on the status of the pole. Still, the technician would need to be trained in the procedures and methods used for operating an oscilloscope in addition to being able to make the correct judgements in identifying defects. A step forward from human judgements, the implementation of an artificial neural network to make statistically accurate decisions on the condition of the pole would greatly improve the functionality of the collar. Not only would it make decisions faster and more accurately than a human, but it would also negate the need for an operator who is trained to read signals and operate an oscilloscope.

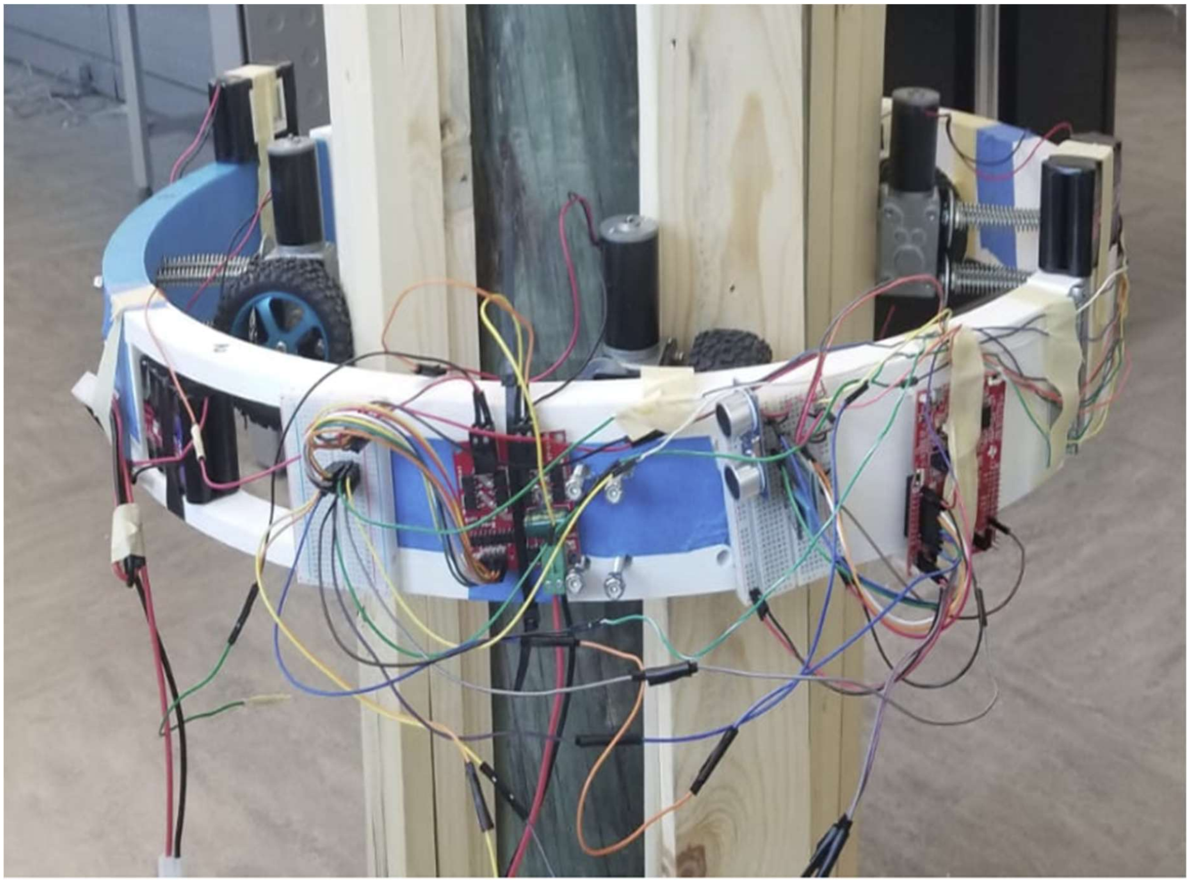
Although oscilloscope signal readings would suffice for defect detection, the transducers also contain the ability to perform C-Scan imaging. A C-Scan image could provide a more clear and definitive approach towards visually recognizing defects that would otherwise be distorted by signal analysis.

6. Conclusion:

There are many methods when considering non-destructive evaluation and defect detection of various materials. Ultrasonic propagation provides a means to efficiently evaluate the serviceability of wooden utility poles by detecting defects that otherwise would not be found through visual inspection. Unlike traditional ultrasonic transducers, Air-coupled ultrasonic transducers can be applied to fulfill the functional requirements of the RUPIC.

D. Testing and Calibration Results

When testing out the prototype there were some stuff that functioned correctly and other areas that needed to be changed or looked into to make the effectiveness of the overall design better. The 4 motors that were being powered by 4 batteries provided enough torque to lift the collar off the ground furthermore when combined with the springs they provided enough pressure on the pole to stay suspended in the air. The springs did compress to fit to different pole diameters but they might provide too much force and maybe some weaker springs might work better. The distance sensor and the humidity and temperature sensor were both tested and they returned accurate reading to the microprocessor. Furthermore the bluetooth device was able to receive and transmit data to the phones in real time. The 3D printed collar had to be printed in pieces, but when the pieces were glued together they managed to withstand the stress that was put on them due to the springs of the ascending subsystem. Due to unforeseen circumstances we did not have a collar that was the accurate diameter to test out the system. Therefore we had to make adjustments to the pole to increase the diameter and furthermore test the system. The lock and hinge mechanism that was used for the collar worked as expected and allowed for the collar to open up and close so that it can fit different pole diameter sizes. Due to time and budget constraints the group was not able to to acquire the Ultrasonic Transducer sensor so we could not test or calibrate it to work on utility poles but this does not mean that it wont function as we have gather and received data that states that the ultrasonic transducer sensor can function for the purpose of testing wooden poles. Since we could not mount the ultrasonic transducer or the power system for them to the collar we are not sure if the motors would be strong enough to lift everything, but if 4 motors are not strong enough more motors can be added.



Picture 36: RUPIC Prototype 2 Testing

E. Discussion on Lessons Learned

The creation of RUPIC helped lead to a better understanding of the time and amount of work that goes into developing a working system for a company. There are a lot of steps that you have to go through from the start where you get assigned a task with certain requirements, till you reach the end where you have a working prototype. Even when you managed to get to the prototype part and feel like you are almost done you look back and realize that now that you have a better understanding of how certain systems work that you can make changes to make the overall system better. To reach the end one of the most important things is to remember that you are not doing this alone, that this is a team effort. Being in a team means that everyone has to put in an adequate amount of work, that tasks assigned to a group member should be accomplished on the expected days, that there has to be constant communication within the team and that if you need help or get stuck you can always ask your team for assistance. If a team member is not putting in the amount of work they should be doing or not completing their task it can lead to the whole project being delayed. If the communication through the team is not consistent and clear then there can be design problems that arise when integrating the systems and this can lead to the project being delayed. If there is a problem that arises or someone gets stuck on a task then ask the group for help because it's a group assignment and we need to lean on each other for assistance.

V. Conclusions

Through the research and development of the overall solution based on the sponsor's requirements, it was possible to determine that the application of RUPIC is tangible from an engineering perspective. Nevertheless, further development and monetary funding is required in order to complete the development and make it operate as truly intended. Moreover, this project demonstrated the ability to implement the idea of a strappable, lightweight robotic collar capable of conducting decay testing procedures on wooden utility poles. It exemplified the capacity of engineering a complex system that can be safely carried, set up, and easily manipulated through a user friendly application accessible through a server on the internet. Overall, It is necessary to mention that RUPIC is a tool designed with the intention to not only guarantee the safety of the operator, but also expedite the whole testing process. Therefore, helping the technicians become less concerned with the testing of the wooden utility pole and more concerned with the maintenance that needs to be conducted on the pole.

VI. References

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VII. Organization Chart

Carlos Gross-Martinez

Project Manager

Communications Subsystem Design and Engineering

Kyle Mason

Main Application Subsystem Design and Engineering

Matthew Maggio

Ultrasonic Transduction Inspection Subsystem Design and Engineering

Miguel Barragan

Mobility Subsystem Design and Engineering

William Medina

Collar Design Development and Engineering

VIII. Appendices

A. Detailed Component-wise Schematics with Pin Connections

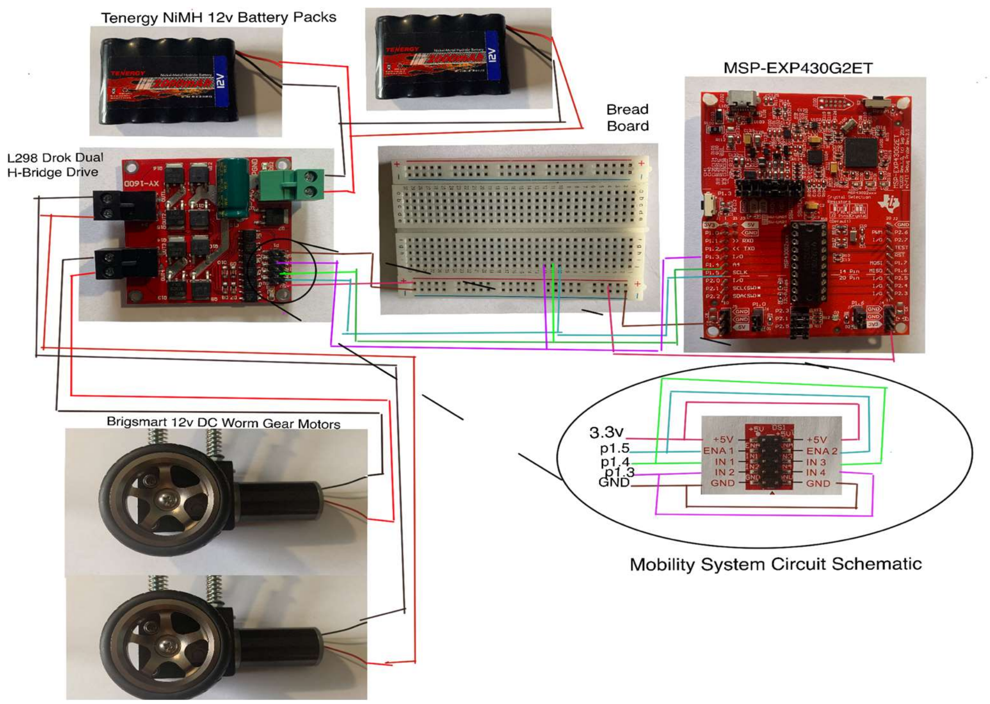

Figure: Mobility (Ascending) Subsystem Schematic

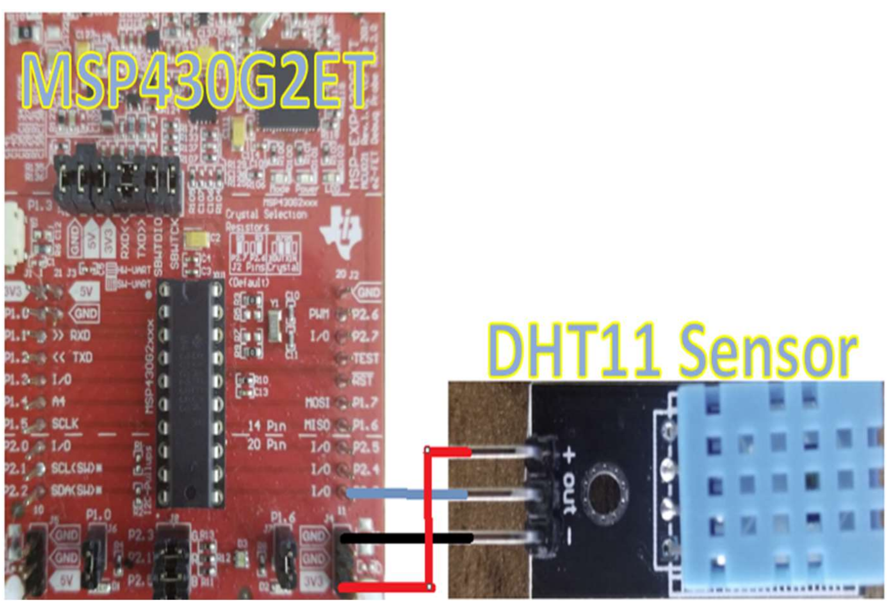

Figure : Humidity and Temperature Sensor Wiring

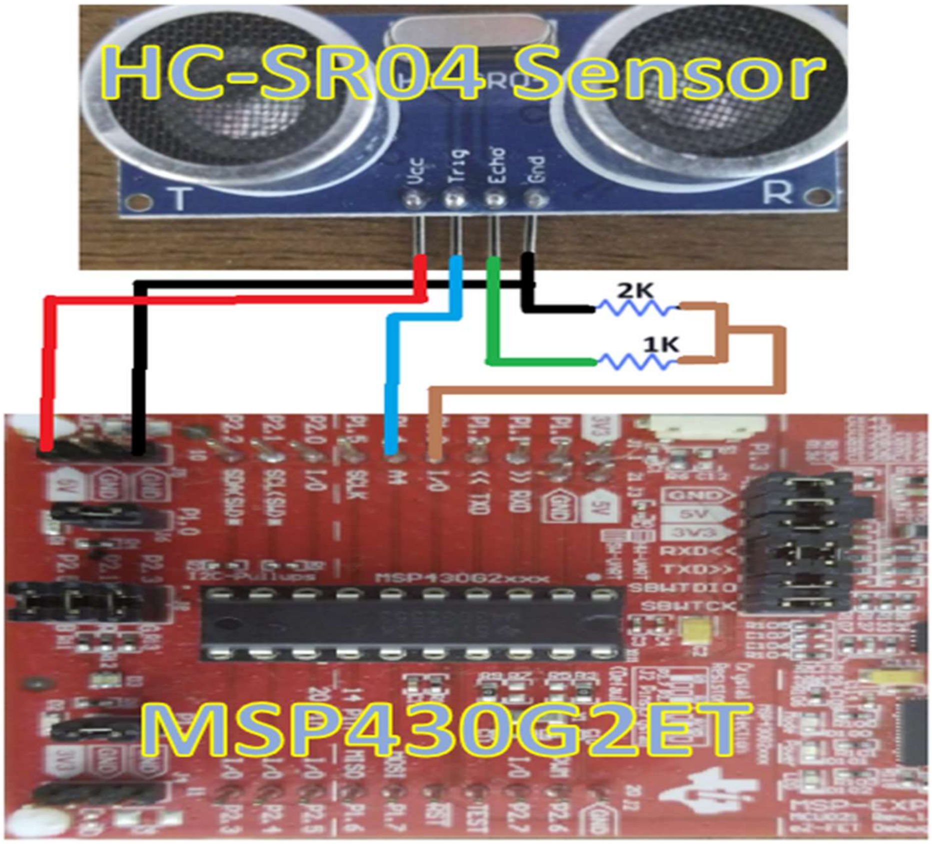

Figure: Ranging Detector Mod Distance Sensor Wiring

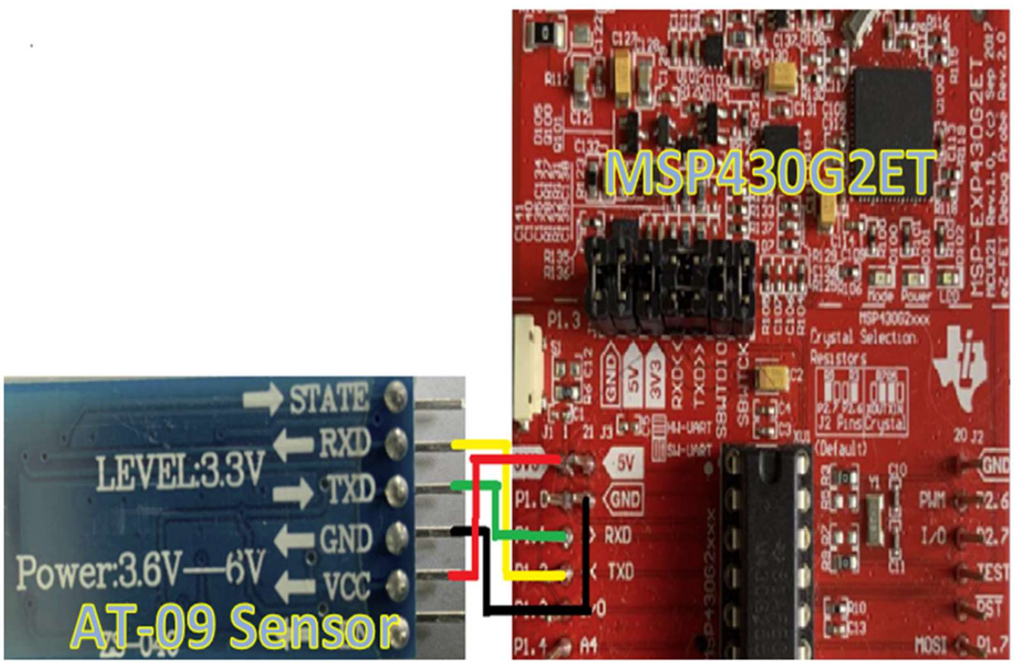

Figure : AT-09 Sensor Wiring

B. Programs

Mobility Subsystem Code

```
#define LED RED_LED
int motorpin1 = 5;
int motorpin2 = 6;
int enable = 7;
int distance = 1000;

void setup() {
  Serial.begin(9600);
  pinMode(2, OUTPUT);
  pinMode(motorpin1, OUTPUT);
  pinMode(motorpin2, OUTPUT);
  pinMode(enable, OUTPUT);
}

void loop() {
    if (Serial.available())
    {
      char data_received;
      data_received = Serial.read();
      //if (data_received == '1')
       if (data_received == '1')
      {
        digitalWrite(LED, HIGH);
        Serial.write("LED turned ON\n");

        delay(250);
        analogWrite(enable, 255);
        Serial.println("ascending");// prints that button 1 is high
        digitalWrite(motorpin1, HIGH);
        digitalWrite(motorpin2, LOW);
        delay(distance);
      }

       if (data_received == '2')
       {

         digitalWrite(LED, HIGH);
         Serial.write("LED turned ON\n");


         delay(250);
         analogWrite(enable, 255);
         Serial.println("descending");// prints that button 1 is high
         digitalWrite(motorpin1, LOW);
         digitalWrite(motorpin2, HIGH);
         delay(distance);
       }
       if(data_received == '0')
       {
         digitalWrite(LED, LOW);
         Serial.write("LED turned OFF\n");

         Serial.println("Stopping");
         digitalWrite(motorpin1, LOW);
         digitalWrite(motorpin2, LOW);
         analogWrite(enable, 0);

        }
     }
 }
```

Communication Subsystem Code

```
//Communication Subsystem Driver Code
//By: Carlos Gross-Martinez
//Description: This driver program for communication subsystem

//libraries
#include <dht.h>
#include <hcrs04.h>
//collar current state light indicator
#define LED RED_LED

//pin definition for HC-S sensor
#define PINECHO 5
#define PINTRIG 6

//pin definition for DHT
#define DHT11_PIN 11

//constructor call from data structres libraries for sensors
dht DHT;
hcrs04 mySensor(PINTRIG, PINECHO);

void setup() {

  //set communication baud rate
  Serial.begin(9600);

  //set specified pins as outpus
  pinMode(2, OUTPUT);

  //initializes HC-SR04 sensor
  mySensor.begin(); /* Initialize the sensor */

  //checking DHT11 sensor functionality
  int chk = DHT.read11(DHT11_PIN);
  if(chk == DHTLIB_OK)
  {
    Serial.print("OK,\t");
  }
  else
  {
    Serial.print("Temp Sensor Error,\t");
  }
}
```

```
void loop() {

  //condition checking if data is being transmitted by application
  if (Serial.available())
  {

    //obtaining distance from HC-SR04 sensor
    float DISTANCE = mySensor.read();

    //print distance to application
    Serial.print("Distance : ");
    Serial.print(DISTANCE);
    Serial.println(" cm");
    delay(200);

    //obtaining and priting to application humidity and temperature from DHT11 sensor
    Serial.print(DHT.humidity, 1);
    Serial.print(",\t");
    Serial.println(DHT.temperature, 1);

    //obtaining directive from application
    char data_received = Serial.read();

    //conditional statement to control mobility subsystem based on received aplication directive
    if (data_received == '1')
    {
      //update current state light indicator and print state
      digitalWrite(LED, HIGH);
      Serial.println("Ascending");
    }

    //conditional statement to control mobility subsystem based on received aplication directive
    if (data_received == '2')
    {
      //update current state light indicator and print state
      digitalWrite(LED, HIGH);
      Serial.println("Descending");
    }

    //conditional statement to control mobility subsystem based on received aplication directive
    if(data_received == '0')
    {
      //update current state light indicator and print state
      digitalWrite(LED, LOW);
      Serial.println("Stopping");
    }
  }
}
```

RUPIC Driver Program

RUPICDriverProgram §

```
//RUPIC Microprocessor Driver Code
//By: Carlos Gross-Marinez and Miguel Barragan
//Description: This driver program integratates code from the mobility and communication subsystems

//libraries
#include <dht.h>
#include <hcrs04.h>

//collar current state light indicator
#define LED RED_LED

//pin definition for HC-S sensor
#define PINECHO 5
#define PINTRIG 6

//pin definition for DHT
#define DHT11_PIN 11

//constructor call from data structres libraries for sensors
dht DHT;
hcrs04 mySensor(PINTRIG, PINECHO);

//pin definition for mobility subsystem
int motorpin1 = 7;
int motorpin2 = 8;
int enable = 9;
int distance = 1000;

void setup() {

  //set communication baud rate
  Serial.begin(9600);

  //set specified pins as outpus
  pinMode(motorpin1, OUTPUT);
  pinMode(motorpin2, OUTPUT);
  pinMode(enable, OUTPUT);

  //initializes HC-SR04 sensor
  mySensor.begin(); /* Initialize the sensor */

  //checking DHT11 sensor functionality
  int chk = DHT.read11(DHT11_PIN);
  if(chk == DHTLIB_OK)
  {
    Serial.print("OK,\t");
  }
```

```
  else
  {
    Serial.print("Temp Sensor Error,\t");
  }

}

void loop() {

  //condition checking if data is being transmitted by application
  if (Serial.available())
  {

    //obtaining distance from HC-SR04 sensor
    float DISTANCE = mySensor.read();

    //print distance to application
    Serial.print("Distance : ");
    Serial.print(DISTANCE);
    Serial.println(" cm");
    delay(200);

    //obtaining and priting to application humidity and temperature from DHT11 sensor
    Serial.print(DHT.humidity, 1);
    Serial.print(",\t");
    Serial.println(DHT.temperature, 1);

    //obtaining directive from application
    char data_received = Serial.read();

    //conditional statement to control mobility subsystem based on received aplication directive
    if (data_received == '1')
    {
      //update current state light indicator
      digitalWrite(LED, HIGH);

      //update pins in mobility susbsystem to move rotate tires in forward direction
      delay(250);
      analogWrite(enable, 255);
      Serial.println("Ascending");// prints that button 1 is high
      digitalWrite(motorpin1, HIGH);
      digitalWrite(motorpin2, LOW);
      delay(distance);
    }
```

```
    //conditional statement to control mobility subsystem based on received aplication directive
    if (data_received == '2')
    {
      //update current state light indicator
      digitalWrite(LED, HIGH);

      //update pins in mobility susbsystem to move rotate tires in backward direction
      delay(250);
      analogWrite(enable, 255);
      Serial.println("Descending");// prints that button 1 is high
      digitalWrite(motorpin1, LOW);
      digitalWrite(motorpin2, HIGH);
      delay(distance);
    }

    //conditional statement to control mobility subsystem based on received aplication directive
    if(data_received == '0')
    {
      //update current state light indicator
      digitalWrite(LED, LOW);

      //update pins in mobility susbsystem to stop rotating tires
      Serial.println("Stopping");
      digitalWrite(motorpin1, LOW);
      digitalWrite(motorpin2, LOW);
      analogWrite(enable, 0);
    }
  }
}
```