Auto-Aligning Wireless Charger

FINAL REPORT

Team Number: 21
Client: Cheng Huang
Advisers: Cheng Huang

Team Members	**Roles**
Greg Matson	Tester, Researcher
Jack Welch	Tester, Prototype Designer
Jeremy Noesen	Software Designer, Scribe
Noah Pritchard	Hardware Designer, Client Interactor
Remington Greatline	Hardware Designer, Researcher
Malakhi Barkley	Software Designer, Prototype Designer

Team Email: sdmay23-21@iastate.edu
Team Website: https://sdmay23-21.sd.ece.iastate.edu/

Executive Summary

Development Standards & Practices Used

- IEEE 2405-2022 Standard for the Design of Chargers Used in Stationary Battery Applications
- IEEE 1657-2018 Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries

Summary of Requirements

- Able to detect when a phone is placed on the charger itself
- Able to scan the surface area of the charger to detect the location of the phone
- Able to automatically move the coils within the charger to the center of the phone
- Must be affordable and easy to use
- Needs to be large enough to be able to charge larger phones

Applicable Courses from Iowa State University Curriculum

- CprE 185
- CprE 308
- CprE 288
- EE 201
- EE 230

New Skills/Knowledge acquired that was not taught in courses

- How to make 3D models in Solidworks
- How wireless chargers work
- How to measure analog voltage from a charging coil
- Soldering

Table of Contents

1 Team

1.1 Team Members

Greg Matson, John Welch, Jeremy Noesen, Noah Pritchard, Remington Greatline, Malakhi Barkley

1.2 Required Skill Sets for Your Project

- Software design
- Software testing
- 3D modeling
- Mechanics
- Circuit synthesis and analysis
- Circuit design
- Organization

1.3 Skill Sets covered by the Team

Malakhi Barkley: Software Design, Software Testing, Mechanics

Remington Greatline: Circuit synthesis and analysis, Circuit design

John Welch: Software Design, Circuit synthesis and analysis, Organization

Noah Pritchard: Circuit synthesis and analysis, Circuit design

Greg Matson: 3D modeling, Software Design, Organization

Jeremy Noesen: Software design, Software testing, 3D modeling Organization

1.4 Project Management Style Adopted by the team

Electoral Consensus

1.5 Initial Project Management Roles

Jeremy Noesen: Software Designer, Scribe

Remington Greatline: Hardware Designer, Researcher

Malakhi Barkley: Software Designer, Prototype Designer

Greg Matson: Researcher, Tester

John Welch: Tester, Prototype Designer

Noah Pritchard: Client Interactor

2 Introduction

2.1 Problem Statement

Who cares? Consumers who own a phone with Qi wireless charging capabilities.

Who has the problem? Consumers who frequently use wireless chargers for their phones, or those who do not because of the frequent difficulties orienting their device to the charging coil.

What is the problem? Wireless charging pads are subject to user positioning error, which can negatively affect charging speeds.

Where is the problem occurring? Anywhere where a wireless charger is being used. (At home, in car rides, the office, etc.)

When is the problem occurring? When the device is not oriented on the charging pad in the optimal position.

Why is this problem important? In today's day and age, many people depend on their phone to get important information, communicate with others, navigate to their next destination, and much more. This makes having a fully charged phone each morning and throughout the day vital to many in order to have a productive day. On top of this, having a more efficient wireless charger can allow people to use their phones more efficiently and frequently.

How will this problem be solved? Develop a wireless charger that can orient the charging coil (Tx), on a 2D plane, with the internal coil within the device (Rx) using a current sensor.

When you place a phone on a wireless charger, sometimes the phone does not charge optimally/efficiently depending on where the phone is placed on the charger. Our goal is to construct a wireless charger that will charge the user's phone efficiently no matter where it is placed.

2.2 Intended Users and Uses

User	**Key Characteristics**	**Project Needs**	**Benefits?**
Frequent wireless charger users	• Can be anyone who owns a phone and wireless charger	• Optimize charging for user devices. • Offer a device that does not rely on phone software.	• In a day and age where our phones are becoming more of a necessity, it is essential that our phones

			are able to charge efficiently in order to make the most out of them.
Users with different phones from different manufacturers	• Can be anyone who owns a phone and lives/works with people who own different types of phones.	• Optimize charging for user devices • A "One size fits all" approach. Makes charging phones in one place simpler.	• It would remove the need for many different charging cables that differ slightly between phones.
Mrs. Huang	• Cheng Huang told us that his wife uses wireless chargers often, but often misplaces her phone on the charger, causing the phone to not charge efficiently or at times not at all.	• Improve convenience and efficiency of her wireless charger for her phone.	• Having a more efficient charger will allow her to be able to use it more often, as everyday our phones are becoming more of a necessity.

2.3 Requirements & Constraints

- Hardware:
    - 1 Arduino Uno
    - 1 Arduino Stepper Shield
    - 2 Stepper Motor

    - 1 Rubber belt
    - 2 IR sensors
    - 1 3d Printer
    - 1 Coil w/ PCB
    - Pulleys & Wheels
- Functional Requirements:
    - Able to detect when a phone is placed on the charger itself
    - Able to scan the surface area of the charger to detect the location of the phone
    - Able to automatically move the coils within the charger to the center of the phone
- Non-Functional Requirements:
    - Must be affordable and easy to use
    - Needs to be large enough to be able to charge larger phones
- Other technical constraints:
    - Power supply
    - 3D printing quality
    - 3D printing time
    - Solidworks learning curve

2.4 Engineering Standards

IEEE 2405-2022 Standard for the Design of Chargers Used in Stationary Battery Applications

> While this standard mainly refers to stationary chargers as opposed to wireless ones, we believe it still applies to our project. This standard deals with the potential battery charger performance and environmental considerations to take into account when constructing wireless chargers.

IEEE 1657-2018 Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries

> This standard deals with stationary battery installation and the recommended knowledge for maintaining stationary batteries. When it comes to building our wireless charger, we will need to be mindful of the correct installation procedures of setting up the charger itself, as well as maintaining it from a safety perspective.

3 Project Plan

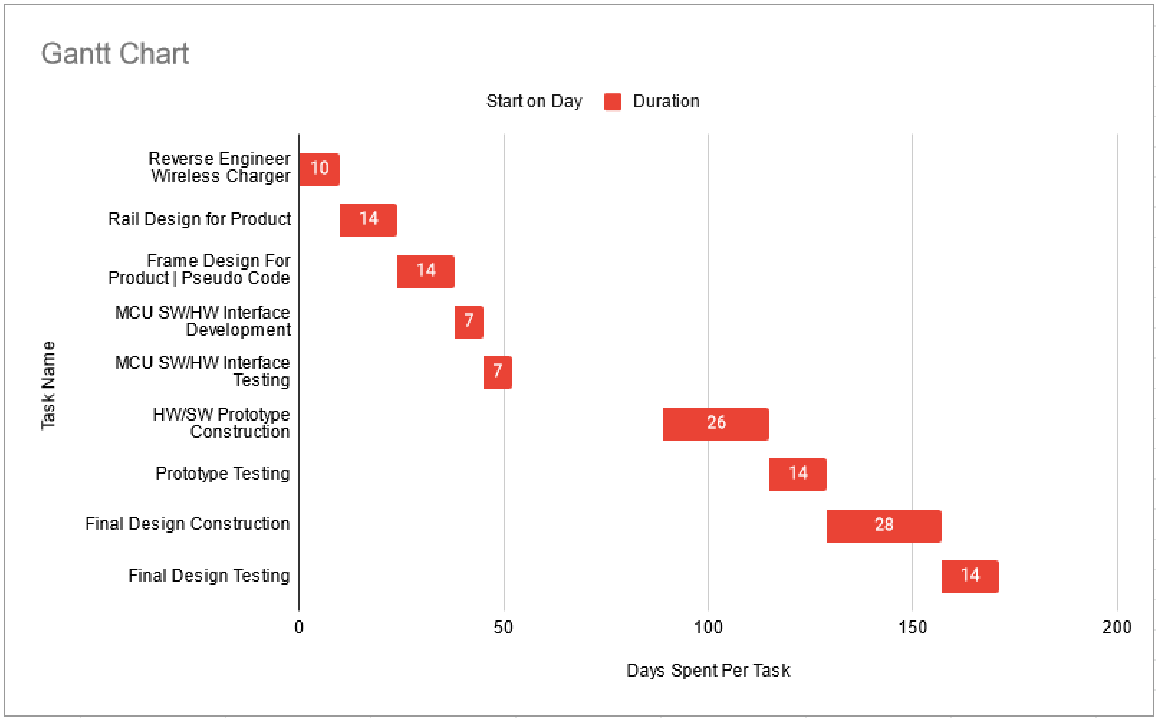
3.1 Project Management/Tracking Procedures

- Git for version control
- GitLab for a Git remote and for issue boards
- Discord for team communications and planning.

3.2 Task Decomposition

- Reverse engineer a wireless charger
  - Understand the inner workings
  - Connect current sensor to the output of the coil inside the charger
  - Is the maximum current output directly correlated with the alignment of the coil?
- Design a mechanical 2D plane such that the coil in the charger can move to any position on the charger
  - Use two stationary motors to move the inner coil
    - This will allow the coil to move with the least amount of resistance due to the light weight of the moving parts.
  - Ensure that the coil is able to move the entire range of the charger (i.e. it can optimize charging no matter the phone orientation)
    - Could be difficult to get the coil oriented all the way to the outer limits of the physical charger.
- Develop a software that can find the optimal location of the charging coil.
  - Scan the 2D plane
    - Find the optimum voltage/current output for the x-axis
    - Find the optimum voltage/current output for the y-axis
  - Ensure the scan time is as fast as possible.
  - Figure out a way to initiate the program
    - Could we use the current sensor to know when a phone is placed on the pad?
    - Also could use IR sensors if necessary.
- Design an attractive case for the charger.
  - Utilize a design that can inadvertently get the user to align the phone to the charger.
    - This could be a way to mitigate the risk of the charging coil not being able to reach the extreme values of the 2D plane
    - We could put small edges around the perimeter of the charging pad so the user will naturally place their phone within those boundaries.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria



3.4 Project Timeline/Schedule

1. Reverse Engineer Wireless Charger and Confirm Charging Current Measurability | 10/20/22
2. Rail Design For Product | 10/30/22
3. Frame Design and Pseudo Code | 11/13/22
4. MCU Software Interface Development | 11/27/22
5. MCU Software Interface Testing | 12/4/23
6. HW/SW Prototype Construction | 1/17/23
7. Prototype Testing | 2/12/23
8. Final Design Construction | 2/26/23
9. Final Design Testing | 3/26/23

3.5 Risks And Risk Management/Mitigation

1. Reverse Engineer Wireless Charger and Confirm Charging Current Measurability | Misreading current values | 0.8 | Mitigation: confirm measurements with partner and remeasure
2. Rail Design For Product | No real risks | 0.0
3. Frame Design and Pseudo Code | No real risks | 0.0
4. MCU Software Interface Development | Misunderstanding how components work | 0.1
5. MCU Software Interface Testing | Misunderstanding how components work from previous step | 0.1

6. HW/SW Prototype Construction | Damaged part while building | 0.4
7. Prototype Testing | Damaged part while testing | 0.3
8. Final Design Construction | Damaged part while building | 0.4
9. Final Design Testing | Damaged part while testing | 0.3

3.6 Personnel Effort Requirements

Task	**Average time per person (hours)**
Reverse Engineering Wireless Charger	3
Rail Design For Product	5
Frame Design and Pseudo Code	5
MCU Software Interface Development	4
MCU Software Interface Testing	4
Prototype Testing	5
Final Design Construction	4
Final Design Testing	5

3.7 Other Resource Requirements

- Testing materials
  - Wireless charger
  - Multimeter
  - A breadboard
  - Jumper cables
  - Resistors
- Design materials
  - Resistors
  - Qi charging coil
  - Arduino microcontroller
  - Wires
  - Solder
  - Motors (Servo or Stepper)
  - 3D printer to print
    - Frame
    - Rails

4 Design

4.1 Design Context

4.1.1 Broader Context

We are designing our wireless charger to appeal to the general household. A wide portion of the population has a phone that is compatible with the Qi wireless charging standard, and society depends on having some sort of Internet connection. Therefore, it's best to have a phone that is at full charge for most of the day, while simultaneously being able to use said phone. Our wireless charger aims to solve that problem.

Area	**Description**
Public health, safety, and welfare	We cannot think of any public health and safety risks with our wireless charger.
Global, cultural, and social	Our wireless charger will be in line with the IEEE Code of Ethics in every step of the design process.
Environmental	By designing a competitive wireless charger, we can diminish the improper disposal of old cables. Oftentimes it takes an extra step to dispose of electrical components, and most people may not take those additional steps.
Economic	Considering the additional technology we will implement inside our wireless charger, the price of it will be slightly higher than other wireless chargers on the market. Plus, considering that the wireless charger needs additional power to charge the phone and the motors inside the charger, overall energy consumption will increase and the energy bill of the household owner will increase slightly as a result. However, since the goal of the wireless charger is to charge the phone faster, it will need to be plugged in for less time, so we do not see this having a major impact on the overall energy consumption.

4.1.2 Prior Work/Solutions

INIU Wireless Charger

https://www.amazon.com/INIU-Wireless-Qi-Certified-Sleep-Friendly-Compatible/dp/B08LVSFN4X

Description:

- 15W super fast charging saves 45 mins off your waiting time.
- Superior compatibility for all Qi-certified devices.
- The FOD system for detecting foreign objects supports wireless charging with phone cases less than 5mm thick.

- Dual SuperConductivity coils ensure both landscape & portrait charging with power flowing.
- Dominant Temp°Guard controls heat smartly and silently to protect your phone battery.
- Self adaptive LED Indicator allows the most user-friendly power prompt.

Shortcomings:

- The alignment needs to be very precise to allow the phone to begin charging.
- The charger is small which makes it hard for larger phones to be aligned properly.
- Phone will not charge if the case is too thick.

JOYROOM Wireless Car Charger with Smart Alignment Charging

https://www.amazon.com/Wireless-JOYROOM-Alignment-Charging-Clamping/dp/B0B127NH3N

Description:

- 15W car charger that charges cars efficiently from inside the car
- Automatically clamps the phone into the optimal charging position
- Can charge through thicker cases (<= 4mm)
- Compatibility for Android and Apple devices

Shortcomings:

- Can only be placed vertically
- Has more moving parts, making it prone to manufacturing errors
- Only intended to be used in vehicles

Yoobao Wireless Charging Station Power Bank Charge Dock

https://www.amazon.com/Yoobao-Wireless-Charging-Compatible-Restaurant/dp/B07F1N9FPY

Description:

- Easy to use
- Visually appealing
- Compatibility for Android and Apple devices

- Dual coil configuration to ensure both landscape & portrait charging with power flowing

Shortcomings:

- The phone & case cannot be too thick otherwise they won't fit
- The charger is small which makes it awkward for larger phones to be aligned properly.

4.1.3 Technical Complexity

Our project will consist of a microcontroller unit (MCU), motors that provide the coil with two axes of movement using the belt/pulley system as the medium. A secondary coil will be used as a sensor to determine how well the charging coil is aligned to the charger. IR sensors will determine if a phone is placed upon the charger.

4.2 Design Exploration

4.2.1 Design Decisions

- Voltage Sensor
  - Measures the strength of the charging coil's changing magnetic field, converts the AC waveform into DC, then sends the analog signal to the Arduino for analysis.
- Proximity Sensor
  - Detects if a phone is placed on the device so it can start searching for an optimal charging position.
  - Utilizes IR sensors
- Rail-based Charger Coil
  - This was determined to be the most compact, efficient, and robust way to align the charger coil to the phone, has two axes of motion
- Arduino
  - Arduino is what we will be using to store our program to automatically move the sled based charger coil to the optimal charging position.

4.2.2 Ideation

Phone is secure in place	"Slider" alignment system	Easy to use	Easy to take with you on the go (flat)	High accuracy	Phone is elavated and safe from spills/tipping	User can choose level of accuracy needed	Low cost to manufacture after design	Easily Distributed
Very low possibiliy for user error	**Toaster**	Visually appealing	Most efficient charging	**Pad**	More internal room for movement	Easily updatable due to being software	**App**	Potentially usable with any wireless chargers
Charges multiple devices	Works with any Qi enabled device that is not too big	Partially automatic	Could charge multiple devices	Works with any Qi enabled device	Fully automatic	Works with any Qi enabled device that the software	Not automatic	
Phone is kept secure but still usable	Clip alignment system	Phone visible to driver	Toaster	Pad	App	Phone still usable while charging	Efficient use of space	Good ambient cooling due to surface area
Multi-purpose (car phone clip, charger)	**Car Clip**	Aligns phone quickly	Car Clip	Wireless Charger	Stand	More consistent phone placement	**Stand**	Easier view of phone while charging
Works with any Qi enabled device that is not too big	Fully automatic					Works with any Qi enabled device that is not too big	Partially automatic	

For the style of alignment, and ultimately the charger itself, we had five ideas, some of which were based on the products mentioned above, and others that were presented to us by our client. We used the above lotus blossom to identify the advantages of each style of charger.

4.2.3 Decision-Making and Trade-Off

Criteria	Weight	App (no movement)		Stand (1-axis movement)		Pad (2-axis movement)		Toaster	
		Score	Total	Score	Total	Score	Total	Score	Total
Alignment Accuracy	0.3	2	0.6	3	0.9	5	1.5	3	0.9
Autonomy	0.3	1	0.3	4	1.2	5	1.5	3	0.9
Cost	0.1	5	0.5	4	0.4	3	0.3	2	0.2
Size	0.1	5	0.5	4	0.4	3	0.4	1	0.1
Complexity	0.2	1	0.2	3	0.6	2	1.2	2	0.4
Total	1	2.1		3.5		4.9		2.5	

We chose to use the go with the Pad (2-axis movement) design. Due to being able to move along two axes, the pad can align itself precisely with the phone's charging coil. This design is also completely autonomous; a phone would be placed upon it, and it would find the phone with no user interference. It is one of the more complex and costly designs, but the other criteria were deemed more important in this case. This would be somewhat large, but not nearly as large as the Toaster style. The car clip style was not considered at all, since it can only be mounted in a car.

4.3 Proposed Design

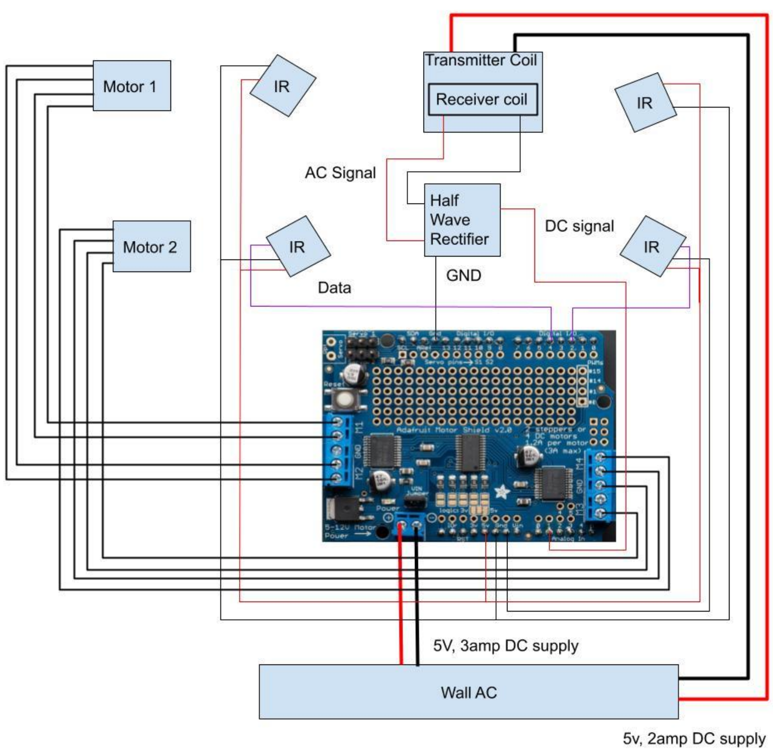
4.3.1 Overview

Our design will contain a two axis rail system. It will consist of two motors, both along one edge of our pad, with a belt system connecting them to the coil. To move the coil up or down, both motors move clockwise or counterclockwise respectively. To move the coil to the left, the top motor moves clockwise while the bottom motor moves counterclockwise. To move the coil to the right, the top motor moves counterclockwise while the bottom motor moves clockwise. The coil will be resting on top of a "sled" platform in the center of the belt system. The wireless charger will have an arduino microcontroller that will read the current of the coil as it looks for the phone on top of the wireless charger. When the DC voltage readings reach a calculated value, the microcontroller will then control the motors to move the coil to the optimal position to charge the phone.

4.3.2 Detailed Design and Visual(s)

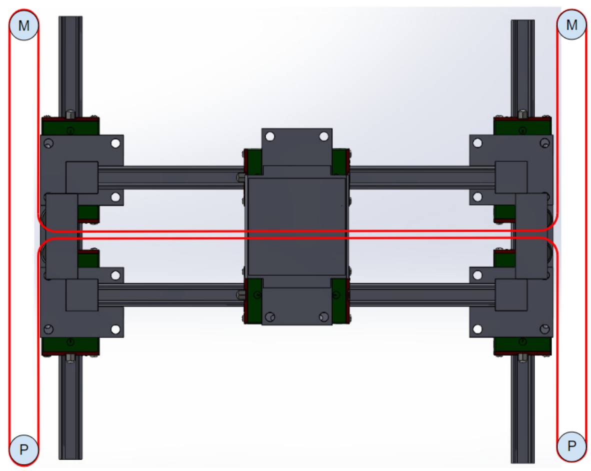
Electrical Components

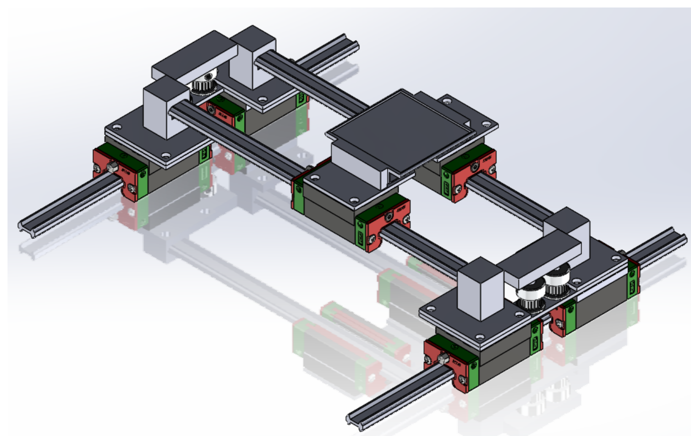
We will be using a stepper motor shield that will be soldered to the arduino board. This will give us ports to connect and drive the stepper motors. It will also allow us to connect the IR sensors and input from the measuring coil on one convenient platform.



Mechanical Components

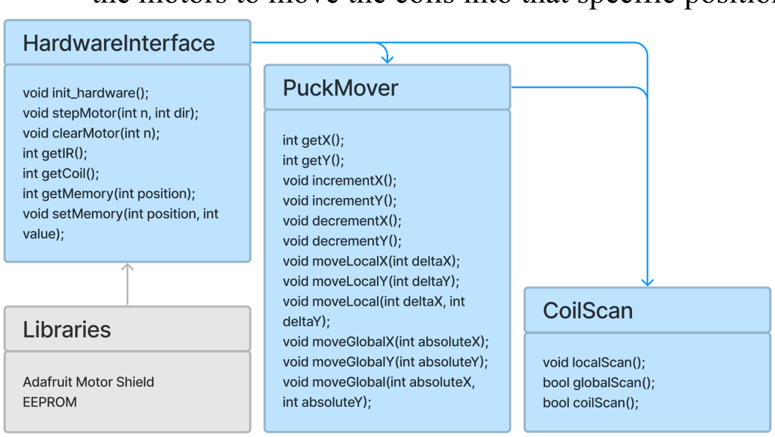
The mechanical components implemented in this design form a rail system that will allow our coil to move across a 2D plane. The charging coil will be automatically aligned by two stationary motors located at the left corners of the charger with a belt system connecting them to the coil (see image below). To move the coil up or down, both motors move clockwise or counterclockwise respectively. To move the coil to the left, the top motor moves clockwise while the bottom motor moves counterclockwise. To move the coil to the right, the top motor moves counterclockwise while the bottom motor moves clockwise.





Software Components

We plan to use an Arduino microcontroller to program our motors and current sensors. The microcontroller will first detect when the phone is placed on the wireless charger. Then, the sensors will scan the voltage readings from the coils, while simultaneously moving the coils across the charger. Once the microcontroller determines the optimal charging location, it will tell the motors to move the coils into that specific position.




```
if (getIR()) {
    if (!successful) {
        if (coilScan()) {
            successful = true
        } else {
            moveGlobal(0, 0);
            successful = false;
        }
    }
} else {
    stopScan();
    moveGlobal(0, 0);
    successful = false;
}
```

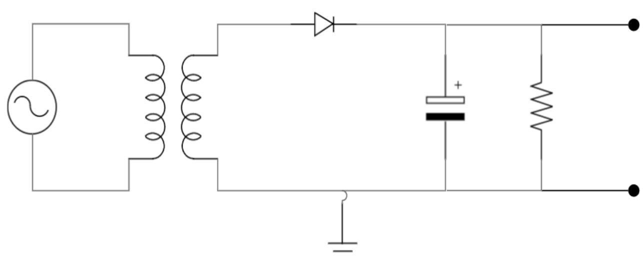
Design Components

- Twin motors
- Belt (Rubber)
- Small Pulleys
- Arduino MCU
- Charging coil
- Secondary coil(for measuring Charging coil)
- Tabletop Surface (Thin layer of plastic is most likely material)
- Various IR sensors

4.3.3 Design Changes from 491

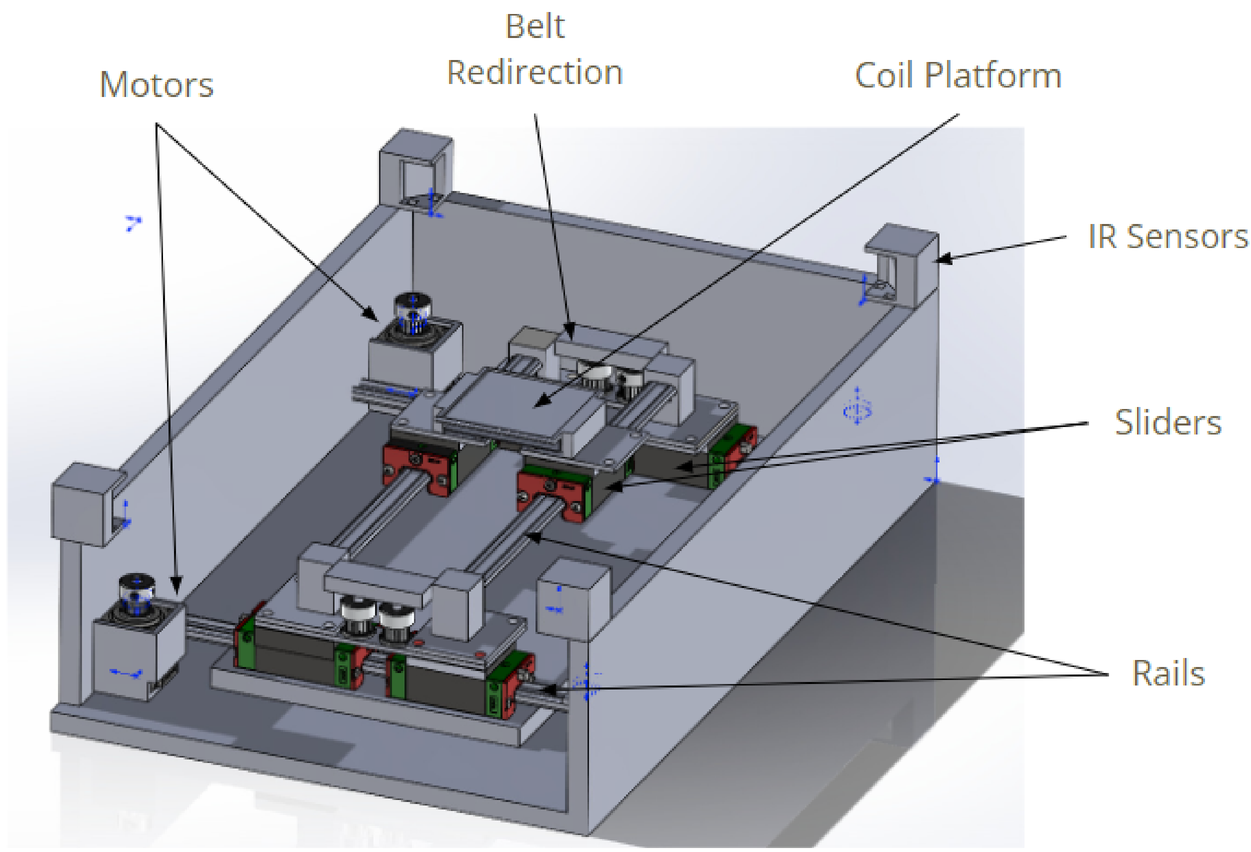
Electrical Component:

The main focus of the design is on the transmitting coil. The design needs to be able to charge a device, as well as determine the optimum charging position. Measuring the output voltage instead of current was one of the only design changes we encountered in 492. After much discussion with our advisor, we decided that it would be much easier and more efficient to measure the voltage of the charging coil rather than current. Determining an optimum position was a requirement, and due to the properties of inductors, if we decided to measure the current, it would prove to be very difficult to determine when the coil was charging efficiently. In order to measure voltage, we would need to connect our charger to a half-wave rectifier so the microcontroller could read the analog voltage output.



Half-Wave Rectifier

4.3.4 Functionality



A user will place their device on the wireless charger. Across the surface of the charging platform, IR sensors are able to detect that a user has placed their device on the charger. The charger contains a two axis rail system. It consists of two motors, both along one edge of our pad, with a belt system connecting them to the coil. The motors will be programmed to move the coil in any direction within the 2D plane. This allows the charging coil to move to the user's phone no matter the orientation. A secondary coil is constructed to measure the analog output voltage of the charging coil. This analog output is then sent through a half-wave rectifier which converts the AC signal into a DC signal, allowing the measuring coil to send data to the arduino. When the voltage readings reach its peak, the microcontroller will know the optimum charging position. The position will be saved in memory, and when the determination is made, the coil will move directly to that location.

4.3.5 Areas of Concern and Development

One of the major areas of concern for this project was the amount of power needed for all of the components. We needed power for the arduino to perform logic calculations, and power for the motors, IR sensors, and charging coil. The major concern is that our final design will have multiple power supplies, which is hardly convenient for the user. We are also concerned with the final design of our product.The sheer amount of expertise needed in order to draft and print the body of the charger was far more than expected. Not only was the workload alone a challenge but also, with the moving parts and increased capabilities, we want to make sure that we optimize the space such that our product is not too bulky. When it comes to a solution for the bulkiness of our design, we will try to use passive design methods to optimize the space. Things such as having stationary motors will allow us to use light, small moving pieces inside the charger. We are also going to need to fit an arduino inside the charger, so in order to keep the design attractive, we designed a plastic containment unit for the circuitry and coil.

4.4 Technology Considerations

Technology	**Strengths**	**Weaknesses**	**Alternatives**
Charging Coil	• Charging no matter the orientation. • Only one coil is necessary to charge a device oriented in either portrait or landscape. (As opposed to two coils in most current devices) • Having one coil could allow us to more efficiently allocate the power and could solve the problem of having a thicker charger.	• Charging may not be completely optimized due to volatile sensor readings • Depending on the coils' height relative to the phone or the case of the phone on the charger, the wireless charger may not charge efficiently or at all.	• Adjust size of wireless coils by adding loops and perhaps thicker wire • Use a thinner surface for phone to rest on • Design a larger charging coil if feasible.
Motors	• Can scan an entire 2D plan • Do not have to be one of the moving parts (Allows other, lighter parts	• Could wear down due to repeated use	• Could have an app that displays the orientation of the coil within the charger

	to be the only moving parts)		

4.5 Design Analysis

While the system itself was never completed, successively completing the separate components of the system yielded certain insights regarding this project's design. The Arduino based circuit design proved the MCU's adaptability making component interconnects an easy task. Power supply was not as straightforward initially, but was resolved once an additional power supply was acquired. Printing the various rail system components proved to be an inefficient process and therefore greatly delayed our progress. Making the 3D models was also tricky, as the measurements made in Solidworks were not very accurate in the final prints. Some of the parts that were attempted to be modeled required a higher level of mechanical engineering skills than initially thought. At the very end, the rail system was built, with some design flaws in accounting for the weight and a lack of an integrated timing belt.

Software Design was fairly straightforward and skeleton code was created early on. The only delay we ran into was waiting on hardware components to code around and test with.

5 Testing

5.1 Unit Testing

Unit	Testing Method	Testing Tools
The current/voltage of the coils	We will use a Half-wave Rectifier to measure the voltage of the coils when a phone is placed on the wireless charger. This will help determine the range of values our scanner should look for when finding the optimal location for the charger as well as patterns of behavior that may be useful.	Oscilloscope
Two-axis rail system mobility tests	We will manually set a position for the coils to move to in our software. Repeating this with different locations will allow us to try different positions and test the physical capabilities of the rail system.	Microcontroller, Rails, Motors
The microcontroller's functionality with our motors	We will test to see if the microcontroller can read the data given by the sensors, and convert that data into instructions for the motors. We will test a few different motors in order to determine connectivity and efficiency between the motors and microcontroller.	The microcontroller, motors, sensors and our software
The microcontroller's functionality with our sensors	We will test to see if the sensors can successfully send data to the microcontroller in a readable format. We plan to test with a few microcontrollers, microcontroller software, and sensors in order to ensure compatibility and efficiency between the two devices as well as respond to IR data.	Microcontrollers, sensors
Thermal conductivity of various surfaces	We will perform experiments on various materials to determine which material has ideal thermal conductivity. Material strength will also be considered.	Wireless charger shell, phone, coils

5.2 Interface Testing

Interface	Testing Method
The motors will interface with the microcontroller	We will program the motors via the microcontroller unit, and through trial and error, we will figure out how fast

unit to move the charger to the optimal position.	these motors move and in which direction. From there, we can use the information from the current sensor to determine where to move it to.
The infrared sensor will interface with the microcontroller unit to detect if a phone is on the charger.	We will configure the infrared sensor to determine when a phone is placed on the charger.
The voltmeter/current sensor will interface with the microcontroller unit to determine the maximum current flow between the charging coil and the phone.	We can make a graph of (distance between the phone and the current sensor) vs (current flow to the phone). We can find the maximum of this graph to optimize the charging power to the phone.

5.3 Integration Testing

Connectivity between the microcontroller and motors, and connectivity between the microcontroller and sensors are the two most critical integration paths in our design. If the microcontroller and the motors are improperly implemented, then the charger will be unable to move to the phone in order to charge it. If the microcontroller and the sensors are improperly implemented, then the charger will be unable to even locate the phone in the first place. These two integration paths will be thoroughly tested via Unit Tests 2 and 3, discussed in section 5.1 of this document.

5.4 System Testing

Our project will be comprised of four main components that will need to be individually tested before we can put them together and test the integration between them:

- Circuit Design
- Software Design
- Mechanical Design

Knowing all of our individual strengths we plan on splitting the testing up in groups such that the designers are the lead testers.

Circuit Designers

Our circuit design team initially tested the assembled half-wave rectifier circuit by soldering and connecting the half-wave rectifier to the Arduino's motor shield then measured and plotted the Arduino's readings. Testing the stepper motors consisted of the software team loading a motor testing program onto the Arduino board and testing various power supply configurations until a steady and consistent design outcome was achieved.

Software Designers

The software team was tasked with linking hardware outputs into software. This union's purpose is to collect analog data and analyze it to appropriately direct the motors to the correct position. The first test that was conducted by the software team was to confirm that the motors behaved in a predictable manner. Following tests primarily revolved around developing an algorithm for the charging coil that could find the local minimum of a twin peak voltage waveform, while successively tracking the coil's position. These tests proved to be successful despite delays due to reliance on hardware requirements prior to testing.

Mechanical Designers

The mechanical team was tasked with creating custom 3D models in Solidworks, so they can be utilized in the rail system design. In order to test these models in a timely manner, the team would create several copies of pieces of 3D models, and change the measurements and sizes slightly in order to make multiple tests in one print. The working measurements were then utilized in the final print.

5.5 Regression Testing

The old functionality was simply a wireless charger that the user had to properly orient, so our new additions only come with a moving, self-aligning charger.

We have been trying to set up our testing plan in such a way that it will ensure the components inter-functionality. We will test our hardware so that we know we are getting an accurate reading from the coil. We will have to make sure there is a clear maximum. This will be one of the critical features that will be vital for our project's success.

Another one of the critical features would be the mechanism that aligns the interior coil. We will need to make sure our device has the capability to power the two stationary motors. This could potentially allow us to later allocate the power to the charging coil. This will need to be tested, but it could potentially solve the issue of having a thick case. In order to prevent this mechanical component from breaking we will need to include buttons or switches at the limits of our scanning surface to ensure the motors know then to stop.

5.6 Acceptance Testing

- We will test that the device can detect a multitude of different cell phones
- We will measure the device to prove it fits within physical size constraints
- We will place and replace a phone and measure the noise produced by the motors to ensure it is acceptable
- We will measure the noise output of the electronics to ensure no discomfort is caused by electronics "whining"

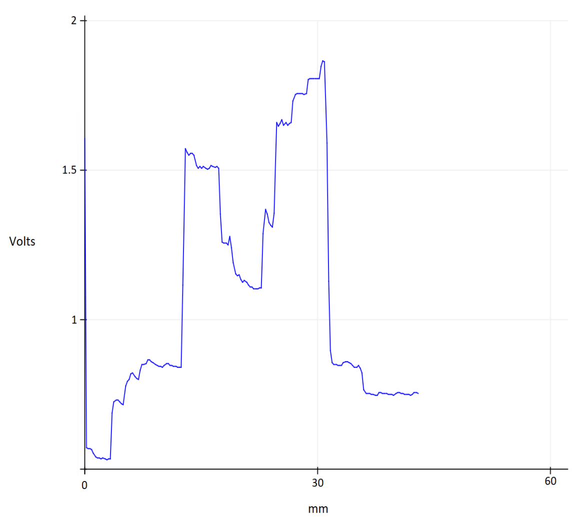
- We will write code to move the charging unit around continuously to ensure robustness
- We will charge multiple phones from 0% to 100% and compare it to a standard wireless charger
- We will measure the temperature of the device after consistent charging to ensure a safe temperature is maintained

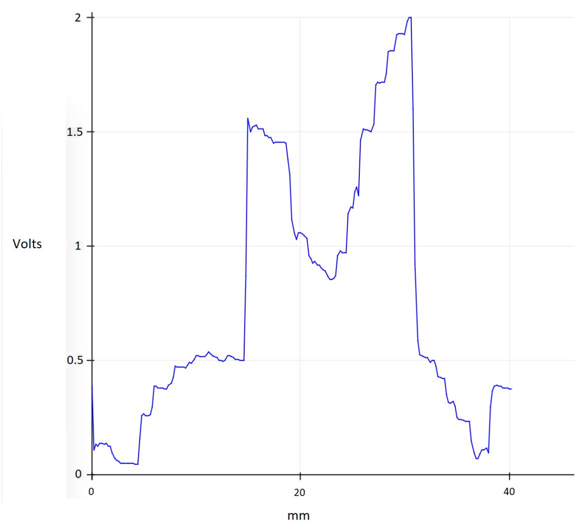
We will take the data we collected from the acceptance testing above, present it to our client, and inquire about any additional concerns/testing ideas he might have.

5.7 Results

While not all tests have been performed as of yet, our group has performed some preliminary testing before prototype construction, specifically the coil's voltage and current behavior. Unfortunately, our experiment's results were found to be flawed. Our semi regular client meetings proved to be useful however because if this error was not found early on, our group might have utilized flawed data for further

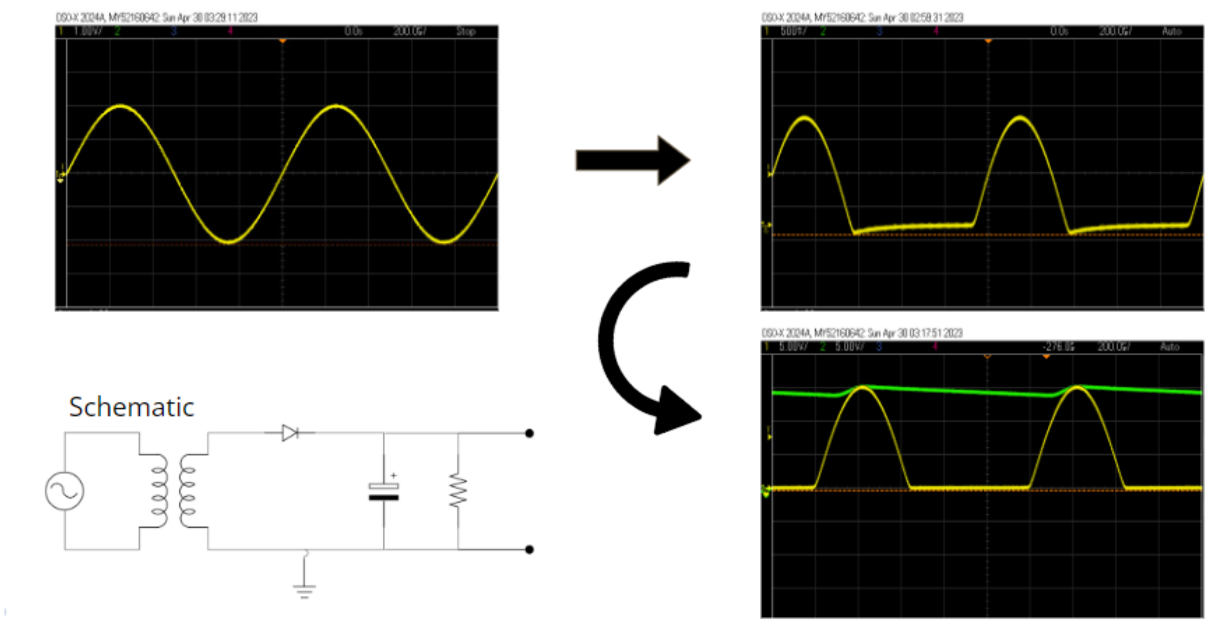
5.7.1 Software Results:





The software was easily able to detect proper alignment between the phone and transmitter coil (as shown above), motor manipulation was without errors, and reliable information was able to be gathered from the IR sensors (also proved through testing), though final testing of the software working with all hardware assembled was unable to be tested.

5.7.2 Electrical Results:



One of the biggest milestones for the hardware designing team was being able to successfully build and test a half-wave rectifier. The output voltage of the charging coil is displayed as the sinusoid on the top left. From there it is passed through a half-wave rectifier, as seen in the image on the top right. In order for the arduino to be able to read a certain value (of which determines the optimum charging position) a capacitor was added to the circuit to retain the maximum value of the sine waveform.

7 Professional Responsibility

7.1 Areas of Responsibility

Area of Responsibility	**Definition**	**NSPE Definition**	**IEEE Code of Ethics Definition**
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence	Perform services only in areas of their competence; Avoid deceptive acts.	To maintain and improve our technical competence, and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.	
Communication Honesty	Report work truthfully, without deception, and understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.	To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment.
Health, Safety, and Well-Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.	To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development

			practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment.
Property Ownership	Respect property ideas, and information of clients and others	Act for each employer as faithful agents or trustees.	To avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses
Sustainability	Protect environment natural resources locally and globally	N/A	To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment
Social Responsibility	Provide products and services that benefit society and communities.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession	To treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression

Work Competence: To only take on technological tasks that a person or yourself have experience in doing.

Financial Responsibility: Make/deliver a product at a reasonable cost and within budget.

Communication Honesty. Being open and honest about your work. Don't be deceptive and lie about what is going on with the project itself.

Health, Safety, and Well-Being: Minimize any safety risks and prioritize health and safety.

Property Ownership: Be respectful of other people's property, ideas, and information.

Sustainability: Respect the environment and help protect it and its natural resources

Social Responsibility: Make and deliver products that help benefit society as a whole.

The IEEE code of ethics is very similar to the NSPE versions in most areas. The only one I couldn't find in the IEEE version is regarding Financial Responsibility. Overall, they both may say some things differently, but they all tie back together to the topics in the first column.

7.2 Project Specific Professional Responsibility Areas

We assigned Property Ownership, Communication Honestly, and Social Responsibility as high because our product is a wireless phone charger, and we want to be sure that our charger can be a direct upgrade from what people currently use. We also want to do our best to respect people's phone's and not damage them. We also want to be open and honest with our customers about the charger's limitations and shortcomings, as no product is perfect.

We assigned Work Competence and Financial Responsibility as Medium because we want to ensure that everyone on our team is assigned to a task that fits their skill set the most. However, it isn't a bad idea to get a learning experience out of the project, and try a task that we aren't the most proficient in. We also want to ensure that our product can be made and delivered within our budget.

We assigned Sustainability and Health, Safety and Wellbeing as Low because even though our device is electrical, it does not pose a major threat to the environment or the customers safety when used properly. These are a couple of areas we are not particularly concerned about, as we plan on ensuring there are no loose/exposed electronics and exposed wires.

7.3 Most Applicable Professional Responsibility Area

We chose Social Responsibility as our most applicable professional responsibility area. Social Responsibility talks about providing products that help benefit society, and our project is about improving the quality of life of consumers who commonly use wireless chargers.

8 Closing Material

8.1 Discussion

Our requirements were:

- Be able to detect when a phone is placed on the charger itself
- Be able to scan the surface area of the charger to detect the location of the phone
- Be able to automatically move the coils within the charger to the center of the phone
- Must be affordable and easy to use
- Needs to be large enough to be able to charge larger phones

Although the individual components of our current design meets almost all of these requirements, we unfortunately ran into unexpected mechanical issues during integration that we do not have the experience to solve. The IR sensors will detect if a phone is placed on the charger, fulfilling requirement #1. We are unable to verify if our design can fulfill requirements #2 and #3, as our rail system is not fully constructed. The Arduino UNO is programmed to read voltage values from the center coils and is able to control its position via the motors. Requirement #5 is fulfilled, as our charger will be able to handle the Samsung Galaxy S22 Ultra, with dimensions of 7.17 x 3.74 inches. Requirement #4 is the only one not fully met, as our projected cost for this charger is $365.99, which is certainly more expensive than planned.

8.2 Conclusion

So far in our work, we have been able to measure the induced current through the secondary charging coil. We wanted to get a better understanding of how a typical QI fast charging coil works. We have also collected data that proves that self-alignment with a secondary coil is a feasible design. With our 2D rail system, we have designed an efficient way to move our coil across the entire surface of the charging plane. Lastly, we improved the overall design of the 3D model.Although we were unable to complete the system, our team was able to successively construct and compile the core components of the project and tests of these components showed that a charger that can automatically align itself has potential as a product.

Our goals are to:

- Develop a functioning circuit that will allow for the most efficient use of power
- Ensure that the rail system functions according to our design
- Make sure the phone begins charging quickly when the user places a phone down
- Make the charger appealing by optimizing the space necessary for the internal components

The best plan is to stay on track with our Gantt chart and communicate with both our client and each other, to ensure that each prototype we build meets our given requirements.

8.3 References

-, Amisha, et al. "Wireless Mobile Battery Charger Circuit." *Engineers Gallery*, 18 Dec. 2015, https://www.engineersgallery.com/wireless-mobile-battery-charger-circuit/.

"Choosing an Oscilloscope." *Nuts and Volts Magazine*, https://www.nutsvolts.com/?%2Fmagazine%2Farticle%2Faugust2013_Bates.

Hommer. "Wireless Charger Circuit- the Newest Charging Innovation." *OURPCB*, 11 Oct. 2021, https://www.ourpcb.com/wireless-charger-circuit.html.

IEEE Xplore, https://ieeexplore.ieee.org/Xplore/home.jsp.

Simões, Erick. "Ultrasonic." *Arduino Libraries*, 24 Oct. 2018, https://www.arduinolibraries.info/libraries/ultrasonic.

"Stepper." *Stepper - Arduino Reference*, https://www.arduino.cc/reference/en/libraries/stepper/.

"Trilateration." *Wikipedia*, Wikimedia Foundation, 24 Nov. 2022, https://en.wikipedia.org/wiki/Trilateration.

[Appendix]

IEEE 2405-2022 Standard for the Design of Chargers Used in Stationary Battery Applications

IEEE 1657-2018 Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries