HoverRail

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***Abstract*—A system capable of levitating and propelling a model magnetic levitation train (Maglev) for train hobbyists and beginner electromagnetics students. Current Maglev models are either expensive or require materials that would be hard to attain for the average person. Additionally, most Maglev models lack interactivity which hinders the learning experience. HoverRail aims to create an affordable, accessible, remote-controlled Maglev model for all.**

***Index Terms*— Maglev, Electromagnetics, CAD Design, Signal Processing, Train Models, Pulse Width Modulation**

I. Introduction

Magnetic Levitation Trains (MagLev Trains) utilize electromagnetism fundamentals in order to revolutionize travel by achieving levitation above magnetic surfaces, eliminating friction with the trackway, and enabling propulsion at remarkable speeds of around 310 miles per hour. It is such an advancement of transportation that currently, only three countries have operating MagLev Trains: China, Japan, and Korea. With the expectation for this product to reach a wider global range in the following years to come, the need to learn more about the product and the fundamentals regarding such product is only going to increase. To do that, we can look into MagLev train sets in the market today.

Many issues plague the MagLev Train set market today, and a change and introduction of our new product hopes to remove these issues. Firstly, when looking at the market, learning tools for MagLev trains are both expensive and inaccessible to train enthusiasts or beginners trying to learn more about MagLev Trains, electromagnetics, and other beginners alike. Costs are as high as $2,000 for a simple train set. Other train sets expect users to have open access to liquid nitrogen, a liquid that could cause harm to users. The market is flooded with expensive and inaccessible learning tools. Even if a train set that is both accessible and inexpensive is found, they lack interactivity, hindering the learning experience for the user since they don't have control over any component of the product. What our product ensures is an affordable, accessible, and remote-controlled MagLev Train to serve as an interactive educational tool to teach fundamental properties of electromagnetics and magnetic levitation for train enthusiasts and beginners alike.

II. USE-CASE REQUIREMENTS

As mentioned before, the current issues today facing the MagLev Train set market are that they are expensive, inaccessible, and lack any interactivity. Our affordable, accessible, and remote-controlled MagLev Train product hopes to serve as an interactive educational tool to learn more about MagLev Trains, electromagnetism, magnetic levitation, etc. But right now we're only stating the qualitative requirements we expect our product to meet. What specifications help define what our product must do to satisfy our desired qualities? Well first off, with any existing MagLev Train set, the carrier itself needs to levitate from the track. After doing some research on the current market for these trains, we found that the average levitation length from track to carrier varies from 0.8 to 1.2 inches. To be on the safer side, we would like our product to achieve 0.8 inches of levitation from the track to the carrier. When it comes to detecting objects blocking the track, we would like our carrier to detect objects as close as 2 cm from the carrier, and detect objects as far as one carrier length from the carrier. Also for detecting objects on the track, we would like our carrier to have a 75% accuracy at detecting objects on the track. We have come up with this number by looking into the types of tests train conductors are put through for their eyes. Two types of tests are conducted, the vision field test and color vision test. Looking at how 20/40 is acceptable for train locomotives [1], and there being multiple acceptable scores for color vision tests depending on the number of plates, we took the average of the "passing" scores (60% for vision field [2] and 88% for color vision [3]) and came out to 75% accuracy as a minimum reasonable accuracy percentage for our product to detect objects. For the remote control, we would like for the communication with the controller to the track and carrier to have a fast response time of under 3 seconds. We would like for the carrier to be stable enough in order to make a complete trip around the track without tipping or falling off. For the speed, we would like our carrier to properly function around the track at 2 miles per hour to account for components added to the carrier itself. As for making our product affordable, we have placed a benchmark of $450 as the maximum cost of this product, with an emphasis on trying to decrease the cost.

Plenty of factors played a role in identifying our use-case requirements. For economic factors, we intended our product to at most cost under $450. During our research in the market for the most similar MagLev Train set to our product, we found it to cost around that much. Of course we would like to use cheap and alternative components that can help drive our price down from the intended $450. We also anticipated that if our product were to be mass produced, then the cost would be significantly lower, which would help meet our goal of affordability. For other important factors such as public health, safety and welfare with our product, we wanted to avoid any harmful products or components that may be deemed as a risk for the user. For example, as mentioned before, current models rely on the user to have access to liquid nitrogen, which is something we took into consideration, and agreed to not include such harmful components. We also wanted to add a visual disclaimer, to warn people who may be wearing magnetic accessories. Such accessories could interfere with the circuit which could pose a safety risk, as well as interfere with the track and carrier since they utilize magnets. For global factors, we wanted to ensure that our remote control was simplistic enough for universal understanding.

III. Architecture and/or Principle of Operation

When designing our system we wanted to minimize complexity to create the best experience for our end users as much as possible. We want HoverRail to be used by train hobbyists and beginner electromagnetics students so we wanted a system that would allow us to abstract the more complicated aspects.

A. The Carrier
  a. We will be using a CAD design which will be 3D printed for the physical carrier
  b. The carrier will feature an ultrasonic sensor for detecting objects on the track and sending the appropriate signals to the Arduino Uno via Arduino Nano and HC05 Bluetooth Transceiver which in our design will be controlling the propelling of the carrier
  c. N42 magnets will be used to achieve levitation
  d. Start/Stop Subsystem
    i. Consists of the Linear Hall Effect, which allows for digital/analog outputs which allows for the most flexibility when it comes to algorithms for signal processing. The digital output will be streamed to Arduino Nano which will be physically attached to the carrier and communicate with Arduino Uno.
  e. Speed Detection
    i. There will be a set of Linear Hall Effect sensors specifically for detecting the circular magnets along the track. We will set up 2 Hall Effects for this purpose, one offset a certain distance from the first sensor. The goal is to have one sensor center above one magnet and the second in the space between the two magnets. This way when collecting the output from the Hall Effects we will have offset sinusoidal which will tell us not only the direction but also the speed as well (peak to peak distance).

B. Arduino Uno - connected to the track and has electrical connections to the speed-up coil. This is the main microcontroller.
  a. Obstruction Stop Module
    i. Once the Ultrasonic and Arduino Nano send serial output to the Arduino Uno microcontroller it will cut off the current to flow in the speed coils. The Arduino Uno will be connected to the track itself.
  b. Start/Stop Module
    i. Similarly, with the Linear Hall effect, the digital signals will prompt the Arduino to adjust the current in the track.

C. The Track
  a. The mechanical track will have a CAD design and be 3d printed
  b. N42 magnets will be embedded in the track to repel the magnets in the carrier.

D. Speed Up Coils
  a. In various spots along the track, there will be speed coils which are bolts with coiled copper wire around them. We expect the speed-up coils to have around 200 turns of wire.
  b. The speed-up coils will also be connected to high-current H-Bridges which will allow us to reverse the polarity of the current in the coil easily using Pulse Width Modulation (PWM). Additionally, PWM allows us to control how much current is flowing through the coil giving us control over how fast the carrier is moving.

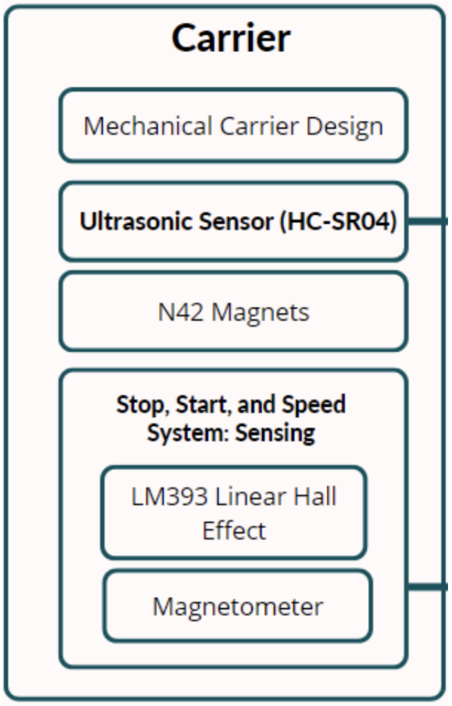

Figure 1. Maglev Carrier Composition

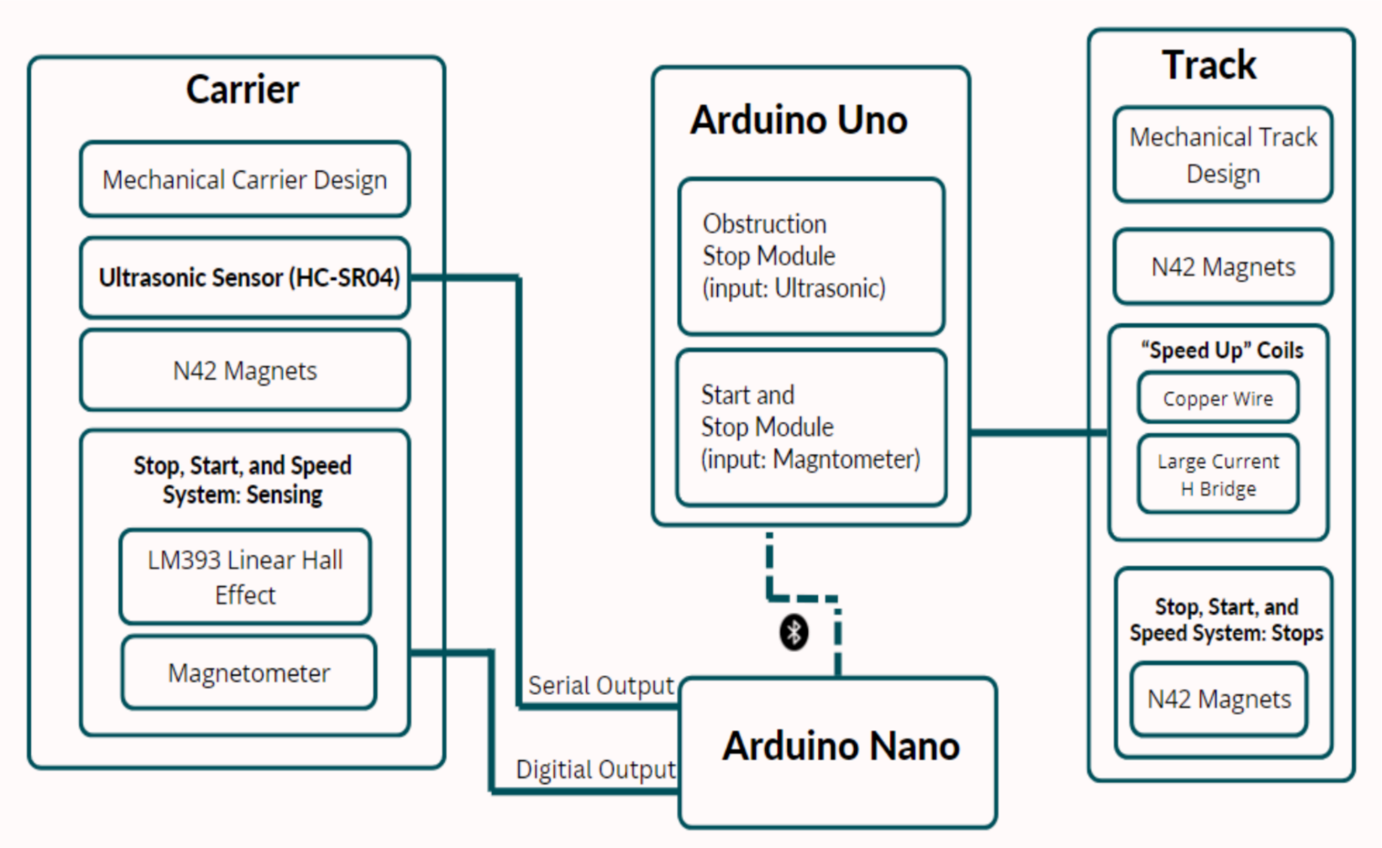

Figure 2 - Complete HoverRail Block Diagram

IV. DESIGN REQUIREMENTS

We’ve discussed what we expect out of our product to meet our goals. But what exactly from our design are we expecting? For our design requirements, we’ve broken them down into different subsections, to make it easier for comprehension while being descriptive about each component, and how they integrate with the entire product. The subsystems are the speed-up coil, the levitation system, object sensing system, and the stop, start, and speed system.

When it comes to the levitation system, we stated how we would like our product to have a levitation length of around 0.8 inches. This value was determined based on our needs for levitation and other examples of levitation we have seen in our research. In order to avoid friction, we need enough levitation from the carrier to which we would not worry about contact between the carrier and track, even if something were to make contact with the track. Upon our research, we consistently saw model maglevs with levitation heights of roughly 0.6-1.2 inches with no sign of friction on the track. This signified that this was a suitable range for our levitation to lie within. Upon further research on models we want to emulate, we landed on the value 0.8 inches.

When it comes to the speed-up coil system, we are looking at different components, the H-Bridge Chip and the copper wire. For the copper wire, we are hoping that the wire could achieve 200 turns while allowing for around 6 Amps to run through the coil while power is being supplied to the coil. We have come up with these specific numbers for turns and amount of current running through the coil from current models of MagLev Train sets that implement such coils. Such a coil would then allow for the carrier to achieve the 2 miles per hour as stated before. For the H-Bridge Chip, since we are allowed to change the polarity of the current going through the coil, we are hoping that whenever needed, the change in polarity operates in under 3 seconds, meaning the appropriate switches built in the chip will turn on/off depending on polarity within those 3 second; allowing for a smooth transition for the carrier to stop moving in one direction, and to start heading into the opposite direction.

When it comes to the object detection system, we will be relying on the ultrasonic sensor to detect objects. With this component, we are hoping that the sensor would be able to detect as close as 2 cm, and as far as 400 cm, which would allow us to say that our carrier can detect a minimum of 2 cm from the carrier, and as far as one carrier length.

For the stop, start, and speed system, we plan on using a linear hall effect sensor and hope that the sensor will be able to function properly and detect the change in magnetic field from the speed-up coil mentioned before while at speeds of 2 miles per hour. Once the sensor is able to detect the change in the magnetic field on the track, we would then want the carrier to slow down at a stop.

V. DESIGN TRADE STUDIES

To meet our use case requirements, we needed to create a magnetic levitation train that can levitate stably, can propel a carrier, and can detect objects within 2 centimeters of the track. In order to meet these requirements, we looked over various components and design styles to ensure that they meet our goals. This involved analyzing magnets of different strength, going over multiple designs for our speed up coils and their ability to create a suitable magnet field, and researching different ways to implement a start and stop system that would interact with our track and carrier.

Design trade-offs for our projects were split into categories based on the portion of the train they applied to. These categories included:

- Magnets
- Speed Up Coils
- Start/Stop System

A. Magnets

Several factors were considered when determining the magnets that would be used. One major factor was whether to use super-cooled magnets. Many maglevs, including the current systems used in countries in Eastern Asia, use supercooled magnets because of their ability to withstand overheating in magnets, creating a stronger magnetic field due to energy not dissipating from the heat. While this would highly increase the strength and effectiveness of the magnets, they require access to liquid nitrogen. Not only is this inaccessible, but direct physical contact with liquid nitrogen is dangerous for the assembler of the track and participants that may want to use the model maglev. Given this risks, we decided to not attempt to create supercooled magnets

Determining the proper magnets was something that took extensive research. To determine the strength of the magnet, maximum energy product (BHmax), residual induction (Br), cost, and maximum operating temperature needed to be considered. Maximum energy product (measured in Gauss-Oersteds) measures the “ volume of magnetic martial required to project a given level of magnetic flux” [4] . Put simply, the higher the maximum energy product, the higher the surface magnetism of the material [5]. Residual induction (measured in Gauss), also known as magnetic flux density, tells users the intensity of magnetic fields.

While looking over existing magnetic levitation model trains, we found that most models used ceramic magnets or neodymium magnets. Ceramic Grade 5 magnets–the strongest grade in ceramics–are widely used in industry in products ranging from motors, automotive sensors, and speakers [6]. A significant reason for their wide use is their high maximum operating temperature as shown in table 1. However, their low BHmax and Br value would make it difficult to levitate a carrier as desired. The neodymium magnets have higher BHmax and Br values, making them extremely strong in comparison to most magnets in use. While they have a low operating temperature, this can be managed through regulating the current that makes contact with the magnets.

Samarium Cobalt magnets were another form of magnets that were used in projects relating to magnetic levitation. This magnet has high Br, high BHmax values, and a high operating temperature. However, the cost of the magnets was out of scope for our current project.

Following an analysis of the three magnets, neodymium n42 magnets were determined to be the best fit due to their applicability for our project. Though they had a low maximum operating temperature, their strength, shown through their high BHmax and Br values, combined with their low cost made them the best magnet for a model remote control magnetic levitation train.

Table I - Strength of Magnets Relative to Cost [7] [8] [9] [10]

Magnet Type	**Qualities of Magnet**			
	BHmax -> Maximum Energy Product (MGOe)	***Residual Induction (Gauss)***	***Max Operating Temp (Celsius)***	***Cost per magnet (Dollar USD)***
Neodymium 42	42	13,050	150	0.70
Ceramic 5 (ferrite)	3.6	3,950	300	1.42
Samarium Cobalt 26	26	10,500	350	5.34

B. Speed Up Coils (Wire and Transistor)

Multiple considerations were taken when determining the setup of our speed coils. The considerations included determining how to manipulate the current flow into the speed up coil and the materials for the coils.

In order for the current flow to meet our needs, the direction and intensity of the current needed to be able to be manipulated. This manipulation would allow us to control when the carrier moves and the speed at which it moves. Our initial design is shown in Figure 11. The transistor in the circuit acts as a switch for the current flowing into the “speed up” coils. The diode to the right of the coils protects the components of the circuit from any damage if a high current suddenly enters the circuit. While this allows us to manipulate the current going into the coils, it limits the intensity of the current in the fields given the options are just “on” or “off”.

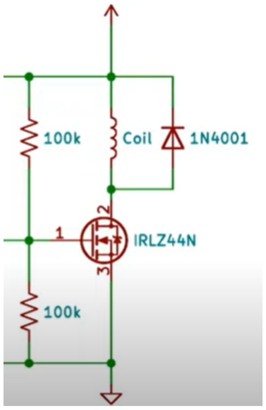

Fig.3. Initial Speed Up Coil Circuit

An alternative to this system is the H-Bridge. This pre-built circuit component has built in flyback diodes and switches that control the movement of current flow in two different directions. Depending on the switches that are turned on, current flows in different directions, allowing the user to manipulate the current and further the magnetic field in the speed up coils. This allows us to gradually increase, decrease, start, and stop the magnetic field in our circuit, meeting our use case requirements.

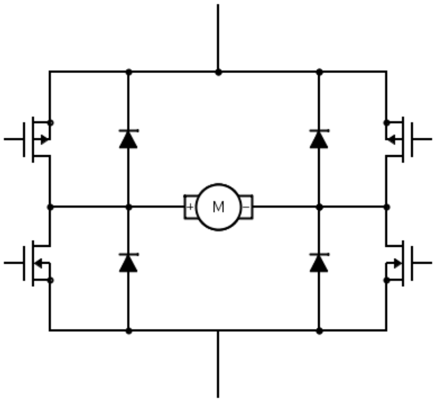

Fig.4. H-Bridge. Note: M represents the placement of the coils

When determining which wire was the best fit for the project, we exclusively saw copper wires being used in similar designs. Copper wires are highly conductive and affordable, making them a good option for our project. As a result, we did not consider any other conductive material for the design of the coils in the speed-up coils.

II. Start and Stop System

Multiple considerations were taken when determining how to implement the start and stop system for the carrier. To meet use case requirements, the stop and start system needs to be able to sense a stop and then send a signal to the track to slow down the speed up coils. The key to this system working properly is sensing when the carrier is approaching a stop. We considered using an ultrasonic sensor or a linear hall effect with a magnetometer.

In the ultrasonic system, when a particular stop was selected, a step motor would drop a divider in the middle of the track. As the carrier with the ultrasonic sensor approaches the stop, the divider would be detected. This would result in the ultrasonic sensor sending a signal to the speed-up coils to slow down the carrier. While this system works effectively, the addition of a step motor and a divider would involve building various mechanical components. Also, there is a possibility that the step motor would malfunction due to being near the track magnets or track magnets would be attracted to materials in the step motor, resulting in us having to build extra safety measures than what is in our original design. Additionally, such a system deviates from the model maglev systems we have seen in the past.

In the linear hall effect with a magnetometer system, each stop has a unique amount of magnets elevated along the track. As the carrier with the linear hall effect with a magnetometer approaches the stop, the sensor detects the unique magnetic field produced by the stop. If this field matches the expected field of the desired stop, a signal will be sent to the speed-up coils to slow down the system. This system depends on the arduino being able to differentiate between the magnetic field of the track and carrier and the magnetic field of the track, carrier, and stop along the track. Additionally, a strong material must be used to elevate the magnets on the stop to ensure that they do not attach to the track magnets despite their attraction. However, this system depends on electromagnetic principles. Given that a major goal of our project is to further educate on principles of electromagnetic principles, this implementation meets a major goal.

After analyzing both systems, the linear hall effect with a magnetometer system was the best option. Given that we will use the ultrasonic sensor to stop the train if there are obstructions, this will be available as a backup system.

VI. System Implementation

The remote control magnetic levitation is implemented through a magnetic track, a carrier that looks over details in the track, and an arduino managing the relationship between the track and the carrier.

The magnetic track is responsible for helping the system levitate and propel. The magnets along the track work with the magnets on the carrier to levitate the carrier. Additionally, speed up coils throughout the track control the speed at which the track moves. The carrier, along with assisting in levitation, uses ultrasonic sensors to detect an obstruction and a linear hall effect with a magnetometer to detect designated stops along the track. An arduino attached to the carrier (Arduino Nano) communicates with an arduino connected to the track (Arduino Uno) to allow the track and the sensors on the carrier to communicate to implement the stop, start, and speed system along with dealing with obstructions.

A. Magnetic Track

The magnetic track consists of a 3D printed track, N42 magnets, and “speed up” coils. The track is designed to have cut outs along the top in the shape of N42 magnets. These magnets are key to creating a magnetic field that will produce levitation and propulsion. The strength and spacing of the magnets along the track determine the strength and consistency of the magnetic field. While a strong magnetic field will ensure that our carrier will levitate, too strong of a magnetic field can create an unstable carrier. N42s are a magnet we consistently saw in designs similar to our goal, which is what led us to choose these magnets. In terms of spacing, we plan to have multiple prototypes to determine how to best placement for magnets along the track to optimize levitation while maintaining stability.

N42 magnets will also be used as stops along the track. These magnets will be placed on elevated surfaces along the track. Sensors in the carrier will detect a different magnetic field than the usual produced by the track and carrier, resulting in a series of software commands that will slow the current in the “speed up” coils, stopping the carrier. Each stop will have a different amount of magnets, creating a unique magnetic field that the system can distinguish. These magnets will be elevated by strong, not magnetic material that can keep the stop magnets from attaching to the track magnets despite their attraction. Details relating to the sensors and the software commands will be further explained in the carrier and software subsection.

Lastly, the track contains “speed up” coils that will be used to control propulsion. This system includes copper wires that are tightly wound attached to a H-Bridge which is attached to an Arduino Uno and a power source. A H-Bridge, as shown in figure 4, is an electronic component that has transistors along the sides (they create a “H”-shape”) that act as switches for current. These switches often work in pairs of diagonals, creating a current flow that looks like an S (or an S reflected along the y-axis) depending on which switches are activated. If these switches are not activated in pairs, they will not effectively pass current through the system, something we plan to use as the “speed up” coils off state. Though many H-Bridges exist, our team made the decision to use a H-Bridge with fly-back diodes to prevent any damage to the components in case we have a spike in current unexpectedly. At the center of the H-Bridge (in the middle of the “H”), a wound coil will be attached. By Lenz Law, the current passing through these coils will create a perpendicular magnetic field which will result in the propulsion of the system.

The H-Bridge and power source–the direction and strength of the current–are controlled by an Arduinio Uno. Depending on what is provided from the user interface and the carrier, the arduino will appropriately responded by regulating the current that goes into the system through the power source and regulating the direction of propulsion through manipulating the switches on the H-Bridge program that interfaces with both the track and the carrier.

B. Magnetic Carrier

The carrier consists of a 3D printed track, N42 magnets, an ultrasonic sensor, a linear hall effect with a magnetometer and an Arduino Nano. The track is designed to be long and to have lengthened sides. In our research, we have seen that longer carriers are more stable. Additionally, the lengthed sides ensure the train will not flip over, another way of maintaining stability. N42 magnets will be placed at the bottom of the outside of the carrier to ensure the track will levitate. We plan to add insulating material along the inside to ensure any electrical components inside the carrier will not be damaged by the magnets or magnetic fields that will be produced as the carrier propels.

The linear hall effect and the Arduino Nano along with the user interface will implement the train stops. Once the user has selected a stop, the carrier will propel. Propulsion of the carrier is a result of the magnetic field created by the track magnets, carrier magnets, and “speed up” coils. Due to stops having magnets on an elevated surface, a different magnetic field is created once the carrier approaches these magnets. The linear hall effect with a magnetometer produces a serial output when connected to an arduino that shows the intensity of the magnetic field. If plotted, this will appear as a sinusoidal. The stops will cause spikes or changes in amplitude in the comparison to the sinusoidal of the carrier, track, and speed up coils. The Arduino Nano will determine if the current magnetic field is consistent with the original sinusoidal. If not, this is an indication that we are approaching a stop. The Arduino Nano will communicate via bluetooth to the Arduino Uno, notifying the speed up coils to reduce their magnetic field, further reducing the speed of the carrier. The peak-to-peak distance along the sinusoidal will also be used to determine the speed at which the carrier is going.

The ultrasonic sensor and Arduino Nano will be used to stop the carrier if there is a sudden obstruction. If the ultrasonic sensor detects an object within 2 centimeters of the front of the carrier, the Arduino Nano will communicate via bluetooth to the Arduino Uno to reduce the magnetic field being generated, slowing down the carrier as it approaches the stop. Additionally, this system will work as a backup for the linear hall effect with a magnetometer if that system were to fail. In this case, step motors with dividers will be placed along the track to signify stop. If a stop is selected, the divider will lower. The carrier will interpret this as an obstruction and send a message to speed up the coils to reduce current, further slowing down the carrier.

C. Software and User Interface

The user interface for our project will allow the user to interact with the carrier and the track. Different user interfaces will be used depending on the prototype. Our minimal viable product involves a straight track in which the carrier moves from one side to the other, meaning it has two stops. This will be controlled by a joystick. The direction the joystick is moved will determine which pair of switches in the H-Bridge will be activated, changing the direction the carrier moves. Our final prototype (a full oval track) will use a remote or a series of buttons to symbolize the different stops along the track. Both options will involve pressing a button associated with a particular stop which will send a signal to the Arduino Uno. If the linear hall effect on the carrier finds the magnets associated with this stop, the Arduino Nano attached to the carrier will communicate via bluetooth to the Ardunio Uno to reduce the current going into the coils, bringing the carrier to a stop.

The Arduino Nano's main job is to take in data from the environment of the carrier. For the ultrasonic sensor, the sensor is designed to provide a serial output of the distance of objects directly in front of the sensor. We plan to filter out any objects associated with the track and carrier to ensure we do not trigger any false stops. If there is an unaccounted for object within 10 cm of the carrier, the Arduino Nano will send a signal to the Arduino Uno to stop the "speed up" coils. For the linear hall effect with the magnetometer, the sensor is also designed to provide a serial output of the current intensity of the magnetic field. Given that that track does not have a constant stream of magnets, when plotted, this will appear as a sinusoidal. Through signal processing, we will establish a baseline sinusoid for the magnetic field created from the track magnets, carrier magnets, and "speed up coils". This baseline sinusoid will be used for a few different applications. This sinusoid will be measured from peak-to-peak to determine the speed at which the track is moving. The sinusoid can also be analyzed to determine if there is a stop. If there are any sudden peaks in the sinusoidal, the Arduino Nano will communicate via bluetooth to the Ardunio Uno to reduce current in the "speed up" coils.

The Arduino Uno's main job is to manipulate the "speed up" coils depending on its inputs to change the speed of the carrier. This was done through working with the H-Bridge. The H-Bridge's switches can be turned on and off through using them as PINs in the Arduino program. Turning on the 1st and 3rd Switch will result in current flowing in the left direction in the coil, creating a magnetic field in the copper coils that will move the carrier forward. Turning on the 2nd and 4th switches will result in current flowing in the copper coils in the right direction, creating a magnetic field in the copper coils that will move the carrier backward. If these switches are not turned on in these pairs, current will not effectively move through the copper coils at the center of the H-Bridge. Therefore, the "speed up" coils would be considered "off" if the H-Bridge switches are turned on in this manner. Taking advantage of this "off" state will be an alternative to reducing the current in the "speed up" coils if we are unable to manipulate the current coming in and out of the power source.

VII. TEST, VERIFICATION AND VALIDATION

The following sections discuss our testing plans for each of our subsystems.

A. Tests for Speed-Up Coil System

We will use the speed detector granted to us by the readings from the linear hall effects. The sensors can be double-checked with manual time and distance measurements. We want to achieve a speed of 2mph to satisfy the design requirements along with the use-case requirements. Speed will be measured along the straight sections of the track. For the prototype, the entire design is a straight track, for the second the track will have sections that are straightaways.

B. Tests for Levitation System

We will be manually verifying the height of our carrier above the track with physical measurements. We will have met our design and use case requirements if we can achieve a levitation of 0.8 inches. The levitation distance will be measured from the top of the track to the bottom of the carrier.

C. Tests for Object Obstruction Module

We will manually set up instructions on the track and measure the distance at which the carrier stops before the obstacle. We ideally want the carrier to stop at least one carrier length before the obstacle at a minimum of 2 centimeters before the obstacle given the limitations of our ultrasonic sensors. Overall we want our carrier to be 75% accurate when detecting obstacles.

D. Tests for Start/Stop/Speed Up System

Once there is a signal trigger that tells the Arduino Uno to change the current in the track, we would like there to be a fast response of around 2 seconds as mentioned in the use-case requirements. We will measure the time it takes from signal dispatch to the actual stopping by logging in to the Arduino terminal.

VIII. PROJECT MANAGEMENT

A. Schedule

Our schedule is split into 3 main milestones, the first two having to do with the physical design of the track and the last being more focussed on final aesthetic touches. Our first milestone is where we achieve MVP with a straight track and in the second milestone, we will add more complexity with a curved, circular track. Finally, the third milestone will be to add the finishing touches with sensor integration and make it more aesthetically pleasing. Refer to Table 1 at the end of the document for the schedule.

B. Team Member Responsibilities

All team members will be involved with CAD design for the track and carrier. Angel and Emanuel will be working on the circuit design for the speed-up coils and attaching the coils to the track. Angel will specifically be working on the initial prototypes, designed from cardboard, of the track and carrier. Emanuel and Myles will be working on the Arduino scripting and manipulating the PWM and current flowing through the H-Bridges. Myles will be tasked with the signal processing of the outputs of the ultrasonic and Hall Effect sensors. Emanuel will also be heading the user interface components and integrating a mechanism for remote control and user input. Roles were determined based on interest and prior course experience.

C. Bill of Materials and Budget

Please refer to Table 2 at the end of this document for the Bill of Materials.

D. Risk Mitigation Plans

The most critical risk is that we aren't able to achieve levitation. In this case, we will default to having a setup with mechanical wheels which will still be propelled by the speed-up coils. Another critical risk is the complexity of the signal processing with the Hall Effect sensors when it comes to detecting stops and speed-up coils. In the case, we cannot use the Hall Effects to detect stops, we will default to an IR sensor configuration in which the carrier passing the IR sensor will trigger the change in current in the speed-up coils.

IX. RELATED WORK

As mentioned in our introduction, there are numerous Maglev model trains on the market. Some models have achieved magnetic propulsion and suspension using mechanisms found in real-life Maglevs. The models which have realistic propulsion and suspension systems are usually very expensive or are not in production anymore. Otherwise, in the development of interactive, affordable Maglev trains there are not many related projects or products.

X. SUMMARY

We are creating a remote control magnetic levitation train for train enthusiasts and to further education about magnetic levitation technology and electromagnetics. Our goals in designing this project is to have a carrier that levitates stably, has the ability to start and stop, and can stop if there is an obstruction in track. In meeting this goal, various factors were considered including the type of magnets, the implementation of "speed up" coils, and how to go about implementing our stop and start system. In the end, we decided to build a magnetic levitation train using N42 magnet, a H-Bridge for our speed up coils, and a linear hall effect with a magnetometer for our stop and start system–with an ultrasonic sensor available if this fails. We plan to test the effectiveness of each system through manually testing levitation, the obstruction system, and the linear hall effect. The stop and start system will be tested through sending signal triggers and checking to see if the system appropriately responds.

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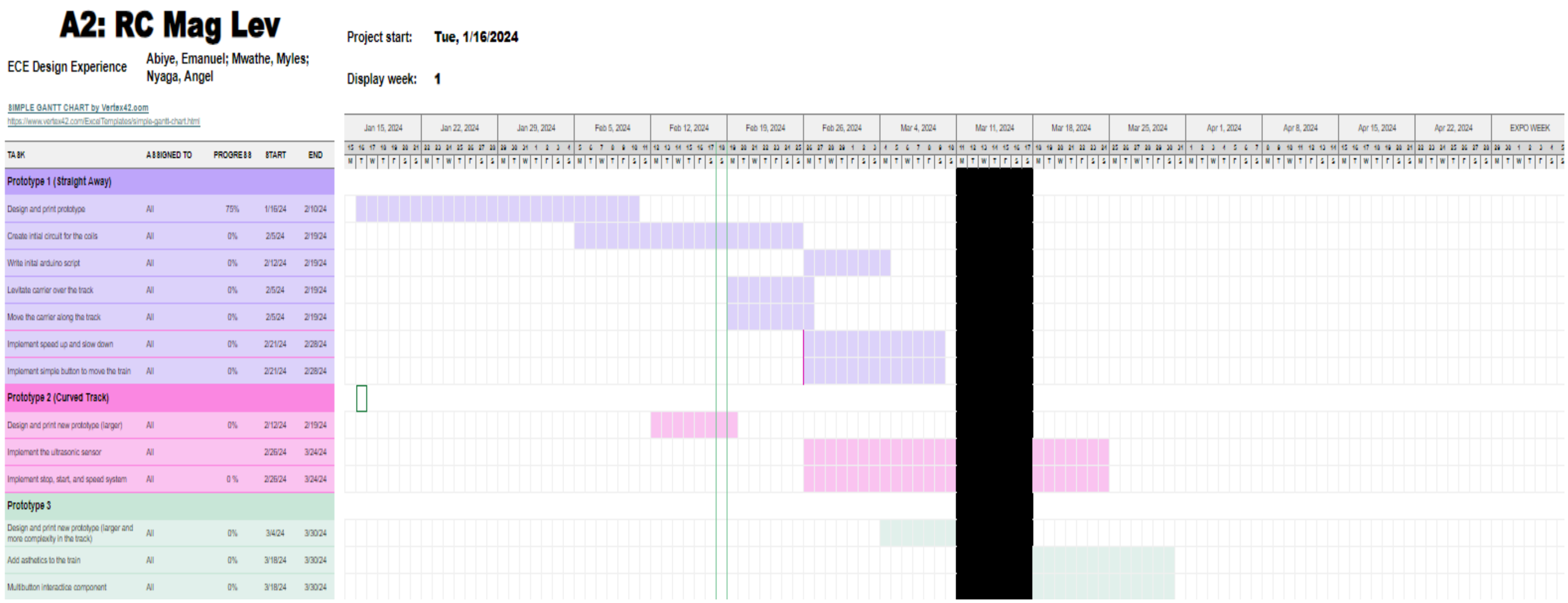


A2: RC Mag Lev

ECE Design Experience

Abiye, Emanuel; Mwathe, Myles; Nyaga, Angel

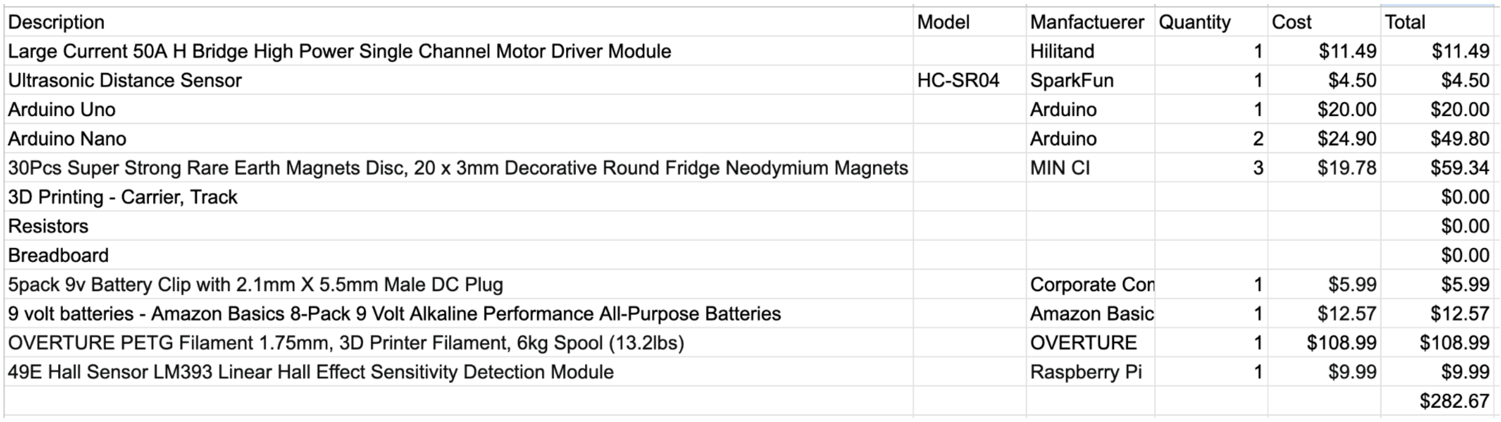
SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project start: **Tue, 1/16/2024**

Display week: **1**

TASK	ASSIGNED TO	PROGRESS	START	END
Prototype 1 (Straight Away)				
Design and print prototype	All	75%	1/16/24	2/10/24
Create intial circuit for the coils	All	0%	2/5/24	2/19/24
Write inital arduino script	All	0%	2/12/24	2/19/24
Levitate carrier over the track	All	0%	2/5/24	2/19/24
Move the carrier along the track	All	0%	2/5/24	2/19/24
Implement speed up and slow down	All	0%	2/21/24	2/28/24
Implement simple button to move the train	All	0%	2/21/24	2/28/24
Prototype 2 (Curved Track)				
Design and print new prototype (larger)	All	0%	2/12/24	2/19/24
Implement the ultrasonic sensor	All		2/26/24	3/24/24
Implement stop, start, and speed system	All	0 %	2/26/24	3/24/24
Prototype 3				
Design and print new prototype (larger and more complexity in the track)	All	0%	3/4/24	3/30/24
Add asthetics to the train	All	0%	3/18/24	3/30/24
Multibutton interactice component	All	0%	3/18/24	3/30/24

Table II - Gantt Chart



Description	Model	Manfactuerer	Quantity	Cost	Total
Large Current 50A H Bridge High Power Single Channel Motor Driver Module		Hilitand	1	$11.49	$11.49
Ultrasonic Distance Sensor	HC-SR04	SparkFun	1	$4.50	$4.50
Arduino Uno		Arduino	1	$20.00	$20.00
Arduino Nano		Arduino	2	$24.90	$49.80
30Pcs Super Strong Rare Earth Magnets Disc, 20 x 3mm Decorative Round Fridge Neodymium Magnets		MIN CI	3	$19.78	$59.34
3D Printing - Carrier, Track					$0.00
Resistors					$0.00
Breadboard					$0.00
5pack 9v Battery Clip with 2.1mm X 5.5mm Male DC Plug		Corporate Con	1	$5.99	$5.99
9 volt batteries - Amazon Basics 8-Pack 9 Volt Alkaline Performance All-Purpose Batteries		Amazon Basic	1	$12.57	$12.57
OVERTURE PETG Filament 1.75mm, 3D Printer Filament, 6kg Spool (13.2lbs)		OVERTURE	1	$108.99	$108.99
49E Hall Sensor LM393 Linear Hall Effect Sensitivity Detection Module		Raspberry Pi	1	$9.99	$9.99
					$282.67

Table III - Bill of Materials