



PROJECT: HYPERLOOP PROTOTYPE

MOTORDRIVE & CONTROL SYSTEM

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ABSTRACT

This project aims to design an approach to the Hyperloop Alpha Proposal (open-source concept) and develop a new approach on a miniature scale exploring the feasibility, implications and factors affecting the Hyperloop system. The concept inspiration was taken from Hyperloop One and Space X's competition for students to create and propose their own version which is the goal of this project.

The project will explore the appropriate mechanical system such as the motor system needed to achieve levitation and propulsion through either Air bearings or electromagnetic levitation develop in conjunction to a control system which should be able to regulate or control the motor system with a control panel/program communicating with the capsule via both Serial Communications and wireless communications (TCP).

At the end of the project a discussion about the real-world application or reflection of the larger scale counterpart based on the developed system on the feasibility, implications, efficiency and effectiveness of the proposed Hyperloop System. A glimpse or brief introduction to indicate if the Hyperloop or any of its variation would an appropriate alternative or new mode of transportation in the future.

A miniaturized prototype of the Hyperloop Alpha Proposal (open-source concept) is developing a new approach on a miniature scale exploring the feasibility, implications and factors pertaining the Hyperloop system. The initial engineering interests are inspired by Hyperloop One and Space X's competition for students to design and propose their respective approaches to the project. The project explores three main aspects deemed crucial to the development of the desired system, using basic power electronics and electrical machinery principles to design a feasible and efficient compressor system. Therefore, an H-Bridge based DC Motor drive and a three-phase AC Motor drive are being utilized to investigate the optimal levitation and propulsion conditions for minimum resistance and frictionless means of transportation.

In addition to the main motor drive system, two variations of the control systems (Umbilical & Wireless Network) were designed in conjunction with a control software that communicates with the onboard microcontroller system regulating the Motor drive, levitation and propulsion systems (via solenoid valves). Finally, this project specification considers the implementation under Thailand's geographical conditions as design constraints hoping to encourage the possibility of dispersing population and development within Bangkok throughout the country due to ease, speed and reasonably lower maintenance/capital/travel costs than existing or proposing solutions. As the project approaches a conclusion, the developed system will reveal a glimpse of the possible solution or a variation appropriate as an alternative or a new mode of transportation in the future bringing Thailand forward and possibly becoming the center of Asean.

*This Project has been through many variations and prototype. To comply with the requirement of the submission contents has been reduce to streamline this report.

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SECTION 1

INTRODUCTION:

Humanity has excelled in the development of civilization for hundreds and thousands of years due to advancements in technologies, these advancements especially in the introduction of different transport systems had allowed humanity to travel, connect and share knowledge starting from the wheel in the stone age to the steam-engine locomotive and automobile during the industrial revolution to the aircrafts by the Wright brothers. These are concept and ideas made into reality by dreamers who'd dared to defy and experiment with groundbreaking concepts.

In the 21st century it may seem that there are new ideas and concepts being realized everyday but are we rehashing old ideas one too many times? Or does our comfort and trust in the modern transport system technology made us too reliant on existing technologies instead of inventing new reality defining ideas? Either way, there no deny that we have the capacity to dream more and pursue incredible new ways of connecting and commuting.

A great example would be the magnetic levitation trains or also known as the bullet train in japan. This concept of a levitation has been in used for over 40 years and have been considered and used in many contourites around the world. The very same concept is considered for the California Rail project between San Francisco and Los Angeles or the Chinese proposed rail project running from China through Southeast Asian connect Asean Countries. However, the implementation has proven to be quite costly in many cases with an estimated cost of at least \$51 Billion for the distance of 286 km. Instead of rehashing existing ideas that are exhausting our resources working against the force of nature, why not explore new ideas that make would make those forces work for us. That idea is Elon Musk's Hyperloop Alpha concept.

The Hyperloop is an open idea presented by Musk as an alternative solution to the mentioned California Rail project in which the concept presents a potentially more innovatively efficient and cheaper mode of transportation. Instead of attempting to implement to reduce friction and by magnetic levitation and air resistance by design, the hyperloop uses the air resistance working against the capsule to aid with the levitation and propulsion of the hyperloop inside a low-pressure tube to achieve a high speed and resistance free method of transportation implemented with lower amount of resources.

Using Knowledge and experiences from three years of this Electronic and Electrical Engineering Degree a prototype concept is explore and investigate this idea in an attempt to build a student designed version of the hyperloop exploring the motor drive system and simple control system. This project is very much a challenge to myself as budding futurist as well as an engineering student attempting to reflect his own ideas, knowledge and practical skills to the test and measure the success of development of this ambitious concept.

MOTIVATION BEHIND PROJECT:

As partly described in the background of the project above my motivation and desire to work and accomplish this project and relevant objective extends to my background as an engineering student and a budding futurist. From a perspective of an enthused engineering student, tinker who consistently work on projects, it is believed that almost if not all of technology have the ability benefit society as well as a destructive manner like two sides of a coin. In this case, the hyper loop has potential to revolutionize the transportation as we know it bring two destination drastically closer to each other.

Reflecting to back Thailand. The Capital Bangkok has truly symbolized the center of the country as intend. However, because Bangkok is the Centre of everything in the country the Metropolitan area itself have become over populated causing traffic congestion and widening the gap between each developing region within the country. As the country operates the gaps between the region will only widen unless a private entity if not the government intervene and develop the remaining regions to catch up to the capital standard.

Thailand is much smaller than the West coast of the united states alone perhaps not even half size which in comparison for the initial proposal for inner California travel time from San Francisco to Los Angeles (559km) in 30 minutes, the conceived idea was to connect the Northern and southern region of Thailand i.e (Chiang Mai (688) and Phuket (840km)) to the capital which shouldn't take much more than the estimated time for the California version.

Thus, people would incline to work out of Bangkok even if they prefer to live there and will eventually help sparing out the dense capital and distribute the people outwards into other areas allowing the country to develop more organically. Moreover, without getting political Thailand is Central to ASEAN as the country is geographically advantageous to all its enharbouring ASEAN countries which could benefit from faster and cheaper transportation for easier flow of communication, travel and development in south-east Asia.

It is not denied that this Hyperloop project is incredibly ambitious in terms of it's motivating factor in my case and the reasoning above can only be prove/disprove in due time as technology development and if the Hyperloop system has been implemented in other parts of the world as the world will slowly see the development of this technological concept. As in the scope of this project, I will explore the Electronics/Electrical and mechanical aspect of the Hyperloop with these background motivations in mind and will factor the country's condition when modelling the system reflecting the extensive subject attached to this project from Material Sciences to Civil Engineering. However, this project will solely focus on the aspect of building the Motor Drive and Control system regarding the Hyperloop.

I hope anyone who reads this report include the examiner finds this project insightful and fins my motivating slightly moving or inspirational. As initially, this project is an opening idea. This Report is open for educational and development purposes and I am willing to open or collaborate on future version of this project.

AIM & OBJECTIVES

The Aim of this project is to design and build a miniature hyperloop prototype with a Motor drive and a software control system using previous skills and knowledge accumulated from this degree to aid the learning and designing process of the motor drive based on the power electronics and electrical machinery principles to form and explore the hyperloop as a self-contained project.

The objectives required or planned to meet are:

- Design a physical hyperloop Capsule design using CAD software
- Fabricate Hyperloop Capsule using 3D printing
- Design Motor drive for Brushless DC Motor and brushed DC motor using H-bridges.
- Explore the implementation between a Brushless DC motor and a brushed DC motor.
- Design a Control Software on PC to control the system with a simple interface as would be used on an actual system
- Communication between control software should be able to communicate by a serial USB cable or through a network connection.
- All physical design aspect will be fit inside the hyperloop capsule
- Evaluation of the concluded prototype.
- Reflection of the final prototype and discuss on the implementation of this version for real world use

Even though the hyperloop system can be viewed as a self-contained project, the concept requires other fields of engineering (Mechanical & Civil) which their respective knowledge areas or concepts will be explored and mentioned in this project but not essential to the core topics are:

- Hyperloop containment tube & possible compressor system
- Battery type and usage
- BLDC Motor Design
- Tube Supporting structures
- Exploring suitable material for printing and real world manufacturing.
- Air flow & fluid mechanics

The secondary aim of this project is to explore how different areas of engineering and converge and collaborate to form and develop a new idea/concept looking for areas where each field intersect and how one aspect communicates with the other. This will allow this student to understand to collaborative process in an actual engineering project for future references as part of his engineering or developing experience.

WHAT IS THE HYPERLOOP

What is the hyperloop system, as briefly mentioned in a couple pages prior to the aims & objectives. The Hyperloop is a new form or concept of transportation proposed by Elon Musk as an open-idea for any company or anyone who wishes to develop the concept. The easy way to grasp the idea of the concept is to imagine a magnetic levitation train running through a tube instead of a track. This was an idea that was conceived back in 2012 and since then multiple companies, divisions and student teams have been formed to peruse this novelty idea and revolutionize the transportations around the world.

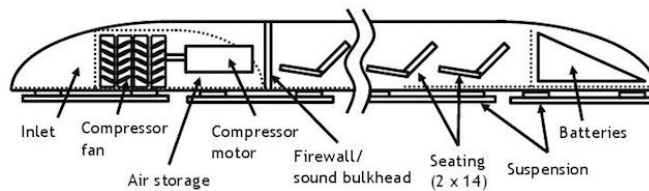


Figure1: Hyperloop Capsule System Diagram

The Hyperloop consist of two main aspect which is the hyperloop capsule itself where the passengers and cargo will be placed. In this Capsule, the system consists of the compressor motor itself at the front of the tube, the control system and motor drive just to the rear, the passenger or cargo pod in the mid-section of the hyper loop and the battery at the end of the capsule. The second aspect is the compressor tube tracks, these tubes in the actual application of the hyperloop would stretch in a straight line with slight or minimal turn to the destination avoiding the most amount of G-force the passengers could potentially experience during transit since the Hyperloop as mentioned in the proposal could go up to 1118km/h based on the distance between San Francisco and Los Angeles and the estimated time given.

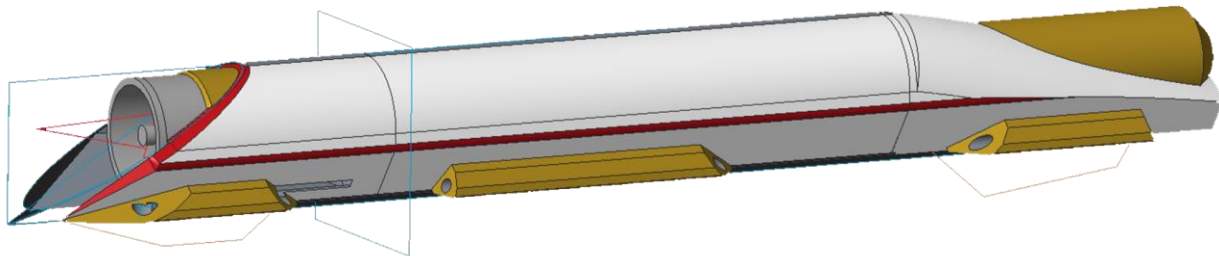


Figure2: Hyperloop Prototype 4 Render

This project will be focusing mostly on the capsule aspect of the hyperloop system especially the motor drive, control system and capsule design. However, other aspect will be present within this project as each aspect very much embodies the hyperloop concept.

APPROACH

The project in which the project will be taken is in the form of a miniature scaled version of the hyperloop using the realistic condition and requirements that needs to be considering when designing the hyperloop system. The project scopes and parameters in which considering on the feasibility of this project are listed in this section (Project Feasibility and consideration).

The miniature version of the hyperloop should consider producing the following as part of the approach to this project:

- 3D Printed CAPSULE with Miniature Motors & battery (Air Bearing Version)
- Wifi Enabled Microcontroller for wireless control
- 2-meter flexible tubing determining this diameter of the capsule
- Modelling the potential system that could exist in the real world
- Safety
- Component efficiency
- Reflect and evaluate real-world use.
- Miniature environmental factors
- Cost consideration

The Inspiration for this miniature was initially based on the representation of the system and to presented similar to a miniature trainset as the hyperloop is basically a new form transportation which is closest the rail system. With skills as an engineering student and hobbyist delving into robotics, RC systems and drones the approach model will be a hybrid of how an engineering student would plan out and organize a project but with the methodology used to develop other external projects starting from a proof of concept, different prototypes exploring different aspect of the project and converging the different design to form and development the latest prototype or as far as this report is concern the concluding prototype.

Another reason this project is being explore on a miniature scale rather than half or quarter scaled version is due to the obvious fact that developing such a system and design would require diverse facility in engineering ranging from Electrical to mechanical, the cost to produce all the parts, the time frame available as the larger or complex that parts are the longer fabrication and experimentation time would occupy and lastly due to the complexity of the concept and goal approaching this project on a miniature scale as a third year student is extremely challenging on its own, if this project were to be implemented on a larger scale a team of engineering students from different fields will have to collaborate based on their respective specialty and skillset.

FEASIBILITY

A reality check or at least the feasibility of the project is quite crucial before approaching this project as to attempt to design and build a hyperloop system as a student does not only seem but actually is extremely ambitious and to consider the real feasibility factor, the project will be judge by the following factors and should remain within the constraints mentioned:

- Cost under £200 (Agreed with Supervisor)
- Appropriate approach.
- Self-contained design.
- Time to build no more than 6 Month (With the time range of both semester)
- Demonstration Simplicity & Convenience
- Student Knowledge field
- Student Skill set
- Ability to learn new knowledge area

The feasibility factor is listed based on experience in project work and other relative skillset in the process of producing the deliverables (i.e Time to Model, design and fabricate the systems sued in this project). However, the margin of the feasibility may change with in a small range with access to more funding by the Supervisor and University or access to equipment such as access to a 3D printer and training which initially was not available at the beginning of the project but now is helps reducing the printing cost, time and number of prints in terms of the prototyping process. (Details can be found in the fabrication section).

TIME FRAME

Although this project may seem to be quite demanding in terms of time due to the complex structure of the project which includes different feeds of engineering for different aspect of the project. However, it is not impossible to proceed with this project with a 10-month limit. Since the interim report embodies the end of the initial stages of the project the amount of objective accomplish or actual work done has demonstrated that most the side properties which feeds in from the other fields has been completed to the point of modification are not needed further and is ready to support the main field of the project which focuses on the motor drive and control system.

COST ESTIMATION & BREAK DOWN

The table below demonstrate the expenses and cost relating to this project which includes the estimated cost from the beginning of the project at the time of the interim report compared to the actual expenses use to develop this project. The factor of cost and expenses was keep to a minimal throughout the project to remain relevant with the objective pertaining the hyperloop being a cheaper but efficient system. For individual components break down please check the implementation section.

Cost Analysis				
	Model	Motor	Controller s	Overall
Customer Activity:				
Cheapest Option	Model 2.5	DC Motor	Arduino Nano	GBP 59.00
Appropriate Option	Model 3.0	EDM 1	Particle Photon	GBP 101.00
Motors	Voltage	Size	Power	Cost
DC Motor	6V	40mm	500kv	GBP 10.00
EDM 1	5-7V	33-36mm	11000kv	GBP 19.00
3D Printing Analysis	Syste m	Volu me	Mate rial	C o st
Model 1.0	Air Bearing	121.7598cm	White Plastic	GBP 49.00
Model 2.0	Maglev	53.5569cm	White Plastic	GBP 45.00
Model 2.0	Airbearing	42.3514cm	White Plastic	GBP 34.00
Model 2.5	Airbearin g	45.2154cm	White Plastic	GBP 30.00
Model 3.0	Airbearin g	395.6140cm3	White Plastic	GBP 63.00

Pipe	Inner Diameter(mm)	Outer Diameter(mm)	Length	Cost
Clear Acrylic	36	40	2m	GBP 10.00
Clear Acrylic	40	45	2m	GBP 14.00
Clear Acrylic	46	50	2m	GBP 15.00
Clear Acrylic	50	55	2m	GBP 16.00
Clear Acrylic	56	60	2m	GBP 17.00
Controllers	WiFi	Bluetooth	Suitable size	Cost
Arduino Uno	External	External	NO	GBP 15.00
Arduino Micro	External	External	Yes	GBP 26.00
Arduino Nano	External	External	Yes	GBP 19.00
Particle Photon	Internal	External	Yes	GBP 21.00
Lilypad	External	External	Yes	GBP 26.00
Tinyduino	External	External	Yes	GBP 50.00

PROJECT MILE STONES & COMPLETION

The table below shows and demonstrate the completion and time progression throughout the project. Each section display estimated and recorded starting and duration time for each section follow by the progress completed in each section. The amount of testing, design and implementation reduced from this report are shown in the table below as well.

Hyperloop Project Planner						
	PLA N	PLAN	ACT UAL	ACTU AL	PERCEN T	
ACTIVITY	STA RT	DURA TION	STA RT	DURA TION	COMPLE TE	
Objectives	1	5	1	4	100%	
Aim	1	6	1	6	100%	
Specifications	2	4	2	5	100%	
Research #1	4	8	4	6	100%	
Brainstorm	4	2	4	8	100%	
GUI Programing	6	3	4	6	100%	
Network Programming	5	4	5	3	100%	
Control System Programing	5	2	5	5	100%	
Modeling Session 1 (CAD)	3	2	5	6	100%	
Proof of Concept	4	1	4	2	100%	
Motor Testing	4	1	4	2	100%	
Battery testing	4	1	4	2	100%	
3D Printing 1	1	5	6	7	100%	
Assembling 1	6	1	5	8	100%	
Experiemntation 1	9	3	9	3	100%	
Evaluation 1	9	6	9	7	100%	
Modeling Session 2 (CAD)	9	3	9	1	100%	
3D Printing 2	9	4	8	5	100%	
Assembling 2	10	5	10	3	100%	
Experiemntation 2	11	2	11	5	100%	

Evaluation 2	12	6	12	7	100%	
Motor Drive 2	12	1	12	5	100%	
Modeling Session 3 (CAD)	14	3	14	6	100%	
3D Printing 3	14	4	14	2	100%	
Assembling 3	14	5	14	3	100%	
Experiemntation 3	15	2	15	8	100%	
Evaluation 3	15	6	15	3	100%	
Motor Drive 3	15	1	15	5	100%	
Modeling Session 4 (CAD)	16	3	16	3	100%	
3D Printing 4	16	4	16	8	100%	
Assembling 4	16	5	16	3	100%	
Experiemntation 4	16	2	16	5	100%	
Evaluation 4	16	6	16	3	100%	
Motor Drive 4	16	1	16	8	100%	
Modeling Session Final (CAD)	17	3	17	-	100%	
3D Printing Final	17	4	17	-	100%	
Assembling Final	17	5	17	-	100%	
Experimentation Final	17	2	17	-	100%	
Evaluation Final	17	6	-	-	100%	
Motor Drive Final	17	1	-	-	100%	
Pipe Assembly	18	5	-	-	100%	
Subsystem - Capsule Test 1	18	8	-	-	100%	
Subsystem - Tube Test 1	18	7	-	-	100%	
Full System Test	20	4	-	-	100%	
Full System - Evaluation	20	5	-	-	100%	
Presentation & Demo	20	8	-	-	0%	
Demonstration	23	28	-	-	0%	
Report	24	28	-	-	100%	

SECTION 2 RESEARCH

PRIMARY RESEARCH**MOTOR SYSTEM**

Motors are very common day objects used in our lives from our washing machines to modern electric cars. This project will utilize a motor like the ones use in model airplanes. To create levitation and propulsion we need a substantial amount of air channeling through the hyperloop capsule and that requires a lot of thrust and speed. These Brushless EDF Motors are used to thrust massive airplanes model that would simulate the use of motors for jet engines. Same perspective applies to this project we are simulating a bigger scale transportation mode.

These brushless motors are more powerful motor system available for use compared to the small DC motors used in children's toys. However, these brushless motors are used on a larger scale like in electric cars which uses a 3 phases input and a motor drives. The motor drive must convert the power from the battery which is a dc signal to an AC signal using a three-phase converter in conjunction with a Pulse width modulation signal to feed the motor with right signal. Reason for using this signal is that the pulse width modulation pulse aid in the control of the speed of the motor since if the signal is constant the motor will spin at full speed depending on the current a voltage. Therefore, the PWM signal helps to regulate the desired speed. The reasons for using 3 phase input for these motors is to always feed in peak of signal to keep the motor spin efficient and consistently.

Brushless DC motor or BLDC hence the name is brushless and does create less friction internally allowing for faster spin instead of torque since internally the magnets, stator and rotors are not in contact and allow the motor to drive more frictionless.

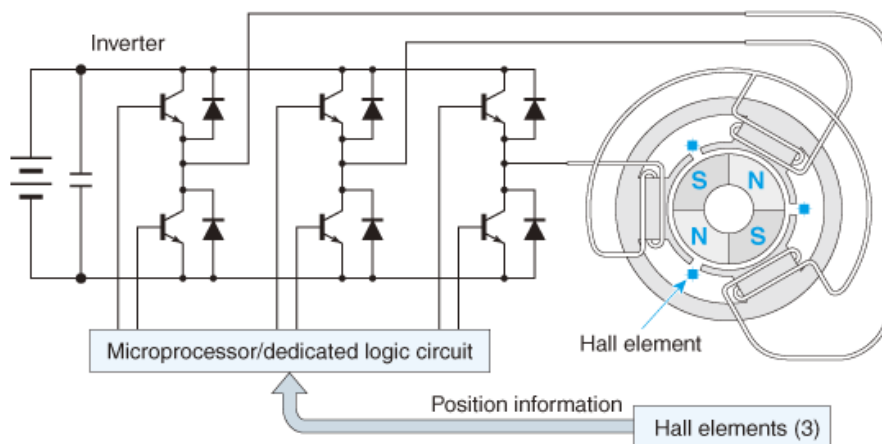


Figure 3: BLDC Motor System

HALF BRIDGE MOTOR DRIVE

To operate a motor on a basic level, a straight connection with the power source will suffice for a dc motor in toys. However, in proper engineering a H-bridge or a half bridge is implemented for a brushed type DC Motor. A H-bridge circuit usually consists of four switches made from two half bridges with two switches on either side. The load

or in the case of a motor should be connected between the two set of half-bridges. The switches used within a h-bridge are mostly bipolar transistors or power MOSFET but sometimes they are drawn or refer to in the form of mechanical switches.

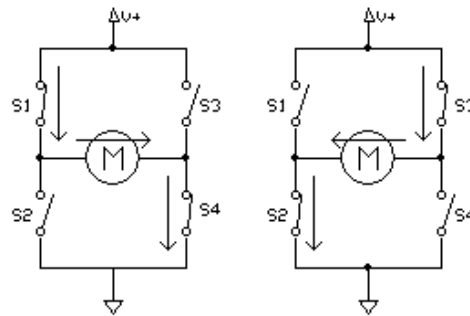


Figure 4: basic H-bridge configurations

The operation of the H-bridge and the direction in which the Brushed DC motor depends on the configuration of the switches. These configurations are usually operating in pairs. For example, if S1 and S4 are switched on the current will be forced to flow or be driven through the only path available which is the motor and down through the switch s4 spinning the motor in a direction. However, if the switch is reverse the other way with S3 and S2 Closing the circuit the current will be force to flow in the opposite direction following the only path available for the current to flow.

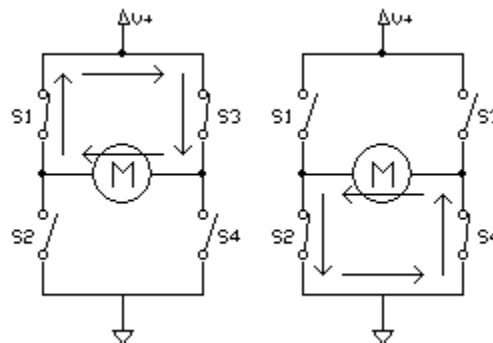


Figure 5: basic H-bridge configurations

Moreover, the configuration where the upper or lower set of switches can be active at once, this will allow the current to circulate through the motor freely. And during the PWM Cycle the back EMF of the spinning motor will causes the current to flow in such a way that the circuit will brake the motor and stop. This process within this configuration is called dynamic braking.

THREE PHASE HALF BRIDGE MOTOR DRIVE

In terms of the brushless DC motor, the three-phase motor drive must energize at least two of the three coils inside the BLDC motor to reposition and spin the rotor before repeating the same process with different coils. A 3-phase Motor drive circuit consist of 6 power transistors which are controlled by the different Pulse Width Modulation which determines which transistors should be powered or not. The Phases are meant to be active at different time, each phase will be 120 digress out of phase to ensure that the correct numbers of coils are energize during operation. (Refer to both signal diagram below or the design section)

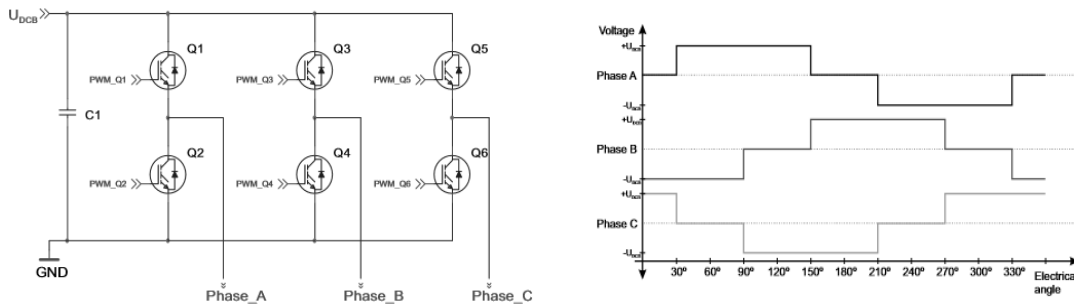


Figure 6: Basic 3-Phase Switching Circuit and PHASE A,B,C output

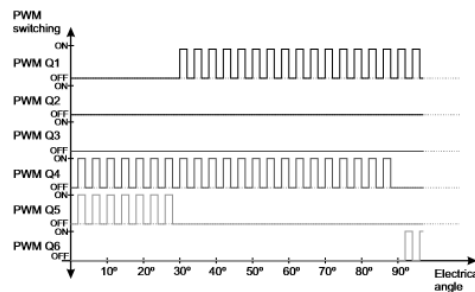


Figure 7: Basic 3-Phase Switching Circuit and PHASE A,B,C output

In terms of switch of the Power Transistors there are also two methods of switching, these two methods are:

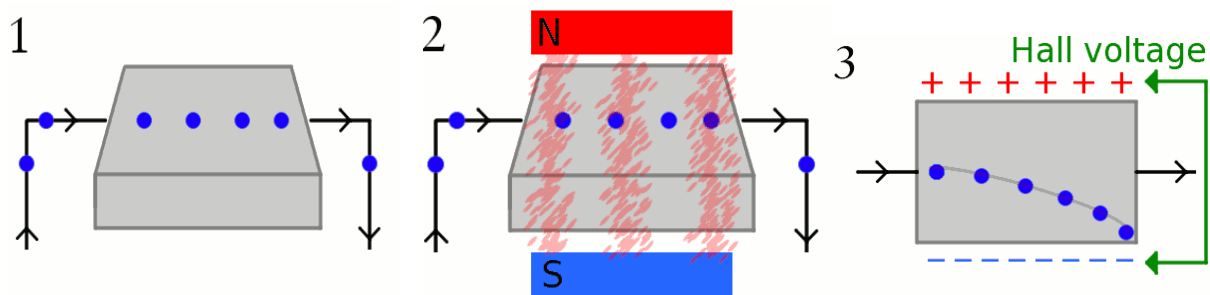
Independent switching: In the process of independent switching for the power transistor, during operation only two of the transistors would be switched on and active when powering or supplying the phases to the BLDC. In a phase only the transistor or top will be switched on, for the second phase the bottom transistor will be switched on and active and for the third phase, both transistors will be off as the driver only needs to energize two signals once. The motor will also be free wheeling when all the transistors are off.

Complementary Switching: In the process of Complementary switching of the transistors two transistors will be switched on active during the power supply to the BLDC similar to the independent switching. However, during the freewheeling state the complementary transistors are switched on allowing current to flow in the opposite direction after the current goes through the freewheeling diode and drops to 0.

HALL EFFECT

The Hall effect is the effect use to aid the measurement of a magnetic field discovered by Edwin Hall in 1879. In this case use to detect the field produced permanent magnets within the Brushless Motor when they are active. The Hall effect usually depends on the nature of a conductor and its current based on the moment of electrons, holes and ions and how they are effected by external magnetic forces.

For example, when a magnetic field is generated and present the charge in this field will experience the Lorentz force which will make the charges deviate from the straight path across the conductive material and instead to either side of the material. Once this effect occurs a potential difference proportional to the size of the strength of the magnetic field present and current would be produce and from this Hall Voltage we can use that to measure the magnitude of the magnetic field around the coil inside the motor.



www.explainthatstuff.com

Figure 8 – Hall Effect:

HALL EFFECT SENSORS & PROBES

These all Effect Sensors are of course sensor operating based on the hall effect hence the name. Most common hall effect sensors are semiconductors and operate through measuring the Hall voltage across the two sides of the sensor once they are place them with in a magnetic field. The simplest use or the us in the case of this project is to detect the position of the of the BLDC motor inside the capsule system

These Sensors are usually very affordable cheap and quite robust for their uses in everyday gadgets from keyboard to industrial robots in factories. In addition, the hall

effect sensors are extremely useful and reliable

compared to older reed switches which are mostly mechanical in its operation due to the

dependents of conductive contacts. The hall sensor is completely electronic and can

representation the data with several degrees instead of detecting the two states of on-off on the reed switches.

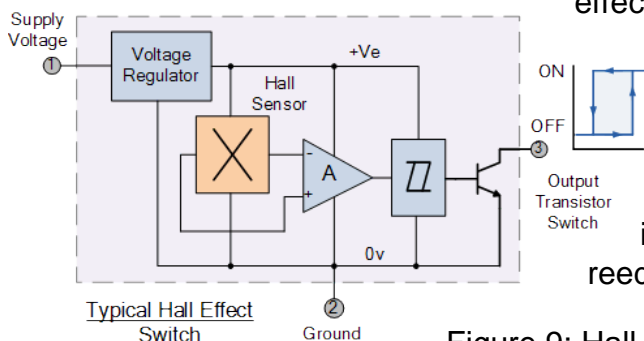


Figure 9: Hall sensor Internals

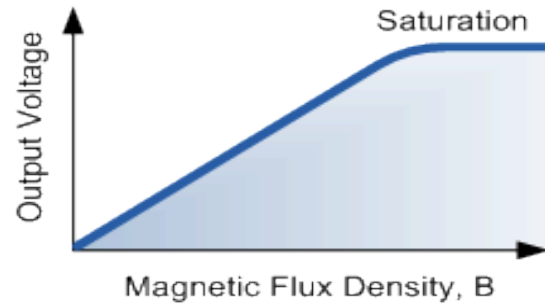


Figure10: Hall Voltage Characteristics

As seen above the characteristic of the Hall effect sensor and its output voltage is proportional to the amount of flux experienced until the saturated voltage is met.

The Output or Hall Voltage are based on:

V_H is the Hall Voltage in volts

R_H is the Hall Effect co-efficient

I is the current flow through the sensor in amps

t is the thickness of the sensor in mm

B is the Magnetic Flux density in Teslas

$$V_H = R_H \left(\frac{I}{t} \times B \right)$$

HALL SENSOR DETECTION

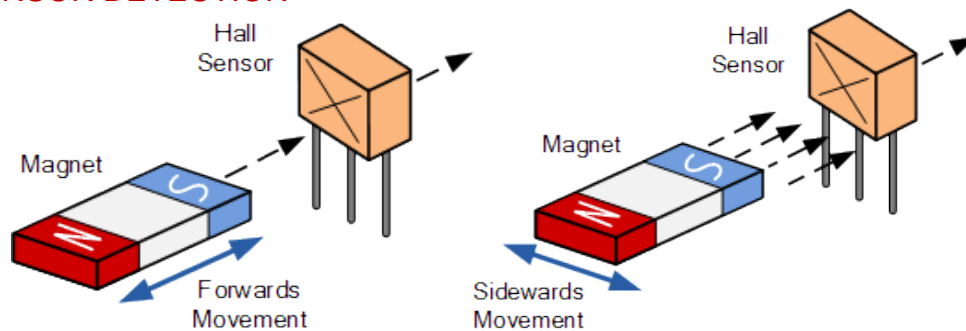


Figure11: Hall sensor detection

For a Hall Sensor, there are two ways of detecting magnetic flux the sensor is interacting with. The first way is the head-on detection, this detection is a linear method of detecting the magnetic flux depending on how close and strong (based on proximity) the flux is linearly producing a higher Hall voltage (V_H) when the flux is higher and closer. The second method of detection is side way detection, this method of detection is based on the sideward moment both horizontally and vertically and will base the produce the Hall voltage based on the movement in respective to the center of the sensor or the center of the zero-field center line of the sensor. This method of detection is ideal and more appropriate for this project as this will aid the count of the speed of rotation of our BLDC Motor.

MICROCONTROLLER

A Microcontroller is an integrated device, which performs a specific task per the instructions stored in its memory. They are “computer on a chip”. Microcontrollers performed a sophisticated and critical role in this project as all the analogue inputs received from all the subsystems were processed by them. In this project, we have chosen to use the Arduino Microcontroller for testing and prototyping purposes and finally we transferred to the Particle Photon. Although the great number of resources available for the Arduino influenced the solutions investigated in the first phase of the project, the outcome of our research confirmed that the Particle Photon was the right fit.

THE ARDUINO:

The Arduino is an extremely efficient Microcontroller with an open source platform. It consists of both a physical programmable circuit board and an IDE (Integrated Development Environment) that runs on the computer. Figure 5.2.1.i shows an Arduino Uno which has been used in this project.

The whole concept of using the Arduino platform was to allow for easy and fast prototyping. It gives a lot of pre-wiring and free code libraries, and an advantage of this was that we could concentrate on testing our ideas instead of spending time on building supporting circuitry or writing tons of low level codes. In addition, the I/O pins of the microcontroller are typically already fed out to sockets/headers for easy access (This may vary a bit with the specific model).

On the software side, Arduino provides several libraries to make programming the microcontroller easier. The simplest of these are functions to control and read the I/O pins rather than having to fiddle with the bus/bit masks normally used. More useful are things such as being able to set I/O pins to PWM at a certain duty cycle using a single command or doing Serial communication.

THE PHOTON

The Photon is not just powerful but also easy to use. It has the same capabilities as the Arduino (i.e the I/O ports, libraries) with additional components like the Broadcom Wi-Fi. It also has an open cloud services where the user can store collect data over the internet. Figure 5.2.1.ii shows the Photon. The photon is used in this project due to its, size, portability and power consumption. Therefore, it can be easily integrated into the capsule. The data can be transmitted wirelessly using the Broadcom Wi-Fi and so no excess wiring is required on the capsule or tube.

NETWORK SYSTEM

TCP – PC SERVER

The TCP server code consist of 4 parts which includes Import References, connection establishment, send and receive. First the System.Net and System.Net.Socket is imported to declare the TCPServer as a Socket and a TCP Listener to listen for multiple incoming messages. The connection establishment is accomplished by clicking on the connect button which will start the TCP listener with the Host device IP address and the port number given in textbox. Once it is connected the picturebox will light green and you will be able to proceed to receive or send messages. To send messages just enter a value into the Server_send textbox which will be sent by the TCP Server.

Send command taking the text box value as the argument to the Client. When Receiving messages from the clients the TCPserver.receive will keep listen to for messages constant as the function/event is called every timer interval which is set to 100ms and will allow the datastream to constantly take in data and sort through the data filter mention previously.

When Communicating between the Server and Client in this Network. We only need to start and stop the clock and photon when either timer is up or false start/fault is detected. To start the clock, the integer '1' is send over to the photon but when we need to stop the clock or any process a '0' will be send over to photon in which either case will comply. These was both implement into an initiate() and stop() function or into a switch case when the TCPServer.send function/event was called which the integer will take into the cases and sends out the intended command integer.

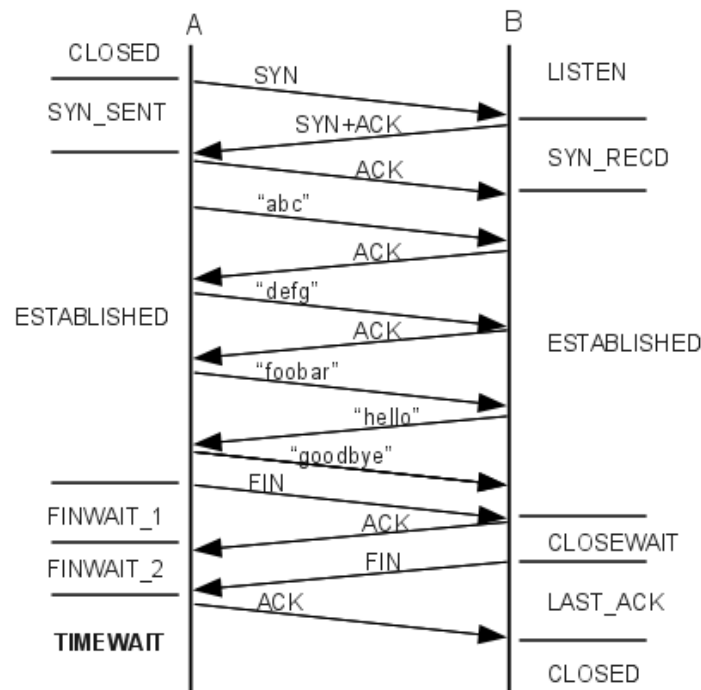


Figure12: TCP Connection

CONTROL SYSTEMS

The BLDC EDF Motors that is mentioned in the previous section requires a 3-phase input which in this case we couldn't simply plug in a microcontroller and a power source like a plug and play device. These brushless motors do require a special controller, which is the motor drive. These motor drives are feeding in the 3 phases signal and converting the current from the power source to the current type needed in this case. Then it feed the current signal in to the motor. As the motor spins a sensor feedback is feed back into the controller to determine the speed in which the motor is spinning and once the input is taken in a process in a form an of closed loop feedback system. The circuit of the motor drive itself will regulate the motor speed constantly allowing the motor to spin efficiently and accurately as intended. The diagram below demonstrates the process of the motor:

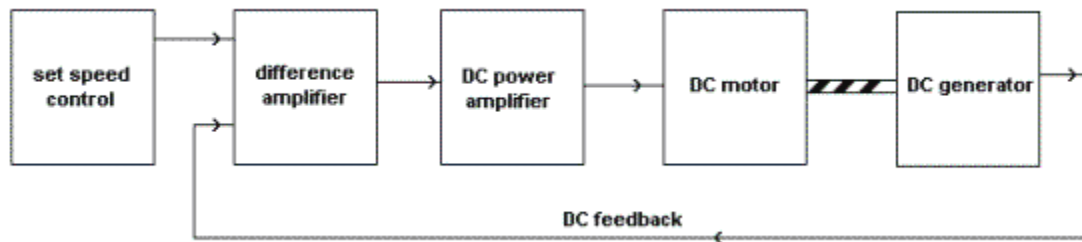


Figure13Motor Drive system:

http://www.hobbyprojects.com/block_diagrams/images/dcspeed.gif

ESC RESEARCH

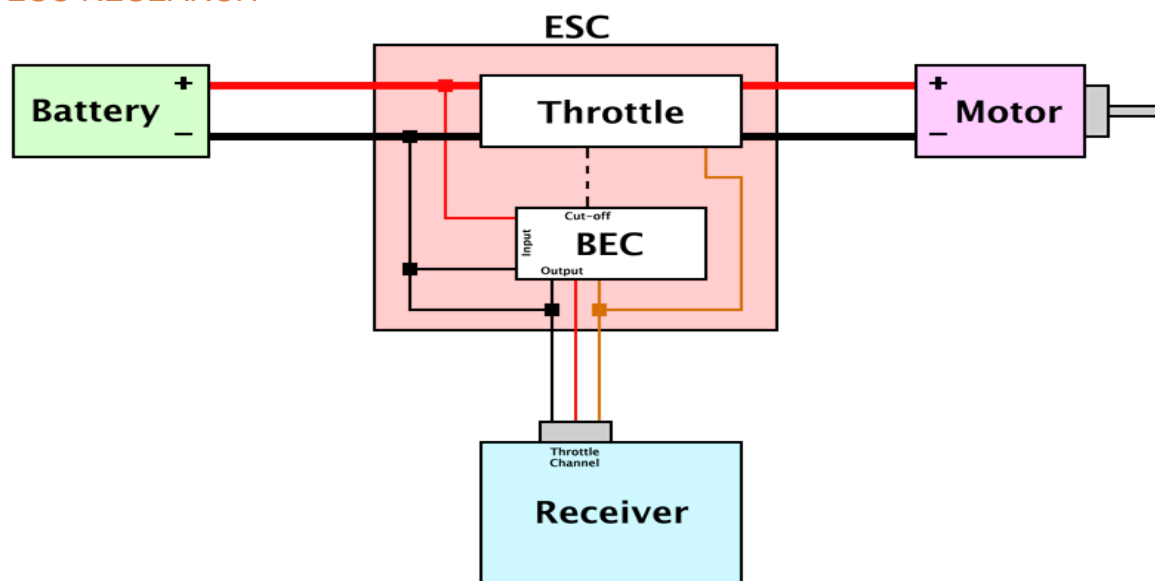


Figure14: BLDC EDF System

BATTERY/POWER SOURCE

For this project, the power source will power the capsule which includes the microcontroller and the motor. The motor requires a certain amount and kind of input in which most alkali batteries would not be able to properly supply. In this case, a lithium-ion batteries is considered instead. Lithium-ion batteries are layers of sheets which makes up a chemical process between Lithium and a secondary element such as

nickel, carbon or aluminum. Inside the batteries both of the element acts as an electrode (Cathode and anode) with a separator in between the two within a electrolyte solution which in this case would be the Ether. Once the battery is charged the lithium ion molecules will move to the negative anode which is the electrode that is lithium. When the battery is discharging the lithium ion molecules move along the solution to the positive electrode. However, the use of lithium ion batteries is quite dangerous, if there was an overheating issue or a breach in the separator causing the electrodes to come in to contact that will cause the battery to short cause an explosion or smoke. The use of lithium ion batteries for BLDC EDF motors are recommended as the table below.

Li-Po Cell	KV Range
3	3000-4500kv
4	2300-3400kv
6	1500-2300kv
8	1150-1700Kv
10	940-1350kv
12	770-1120kv

Batteries usage recommended for BLDC Motor for hobby use.

RELEVANT REDUCED TOPIC

The topics below are also recached thoroughly and utilized throughout the project. however, as they are less relevant than the topic above these topics have been removed to reduce and regulate the amount of content in this report

3D Printing – methods and design

- Material Sciences
- Supporting structure designs
- Aerodynamics in automobile and transportation designs
- Tube Compression system
- Integrated Circuit Design - Motor drive system
- Braking Circuit & Back EMF
- Synchronous and Asynchronous speed

*You will still find work relating to the mentioned fields within this report

Section 3: Design Capsule Concept

CAPSULE DESIGN

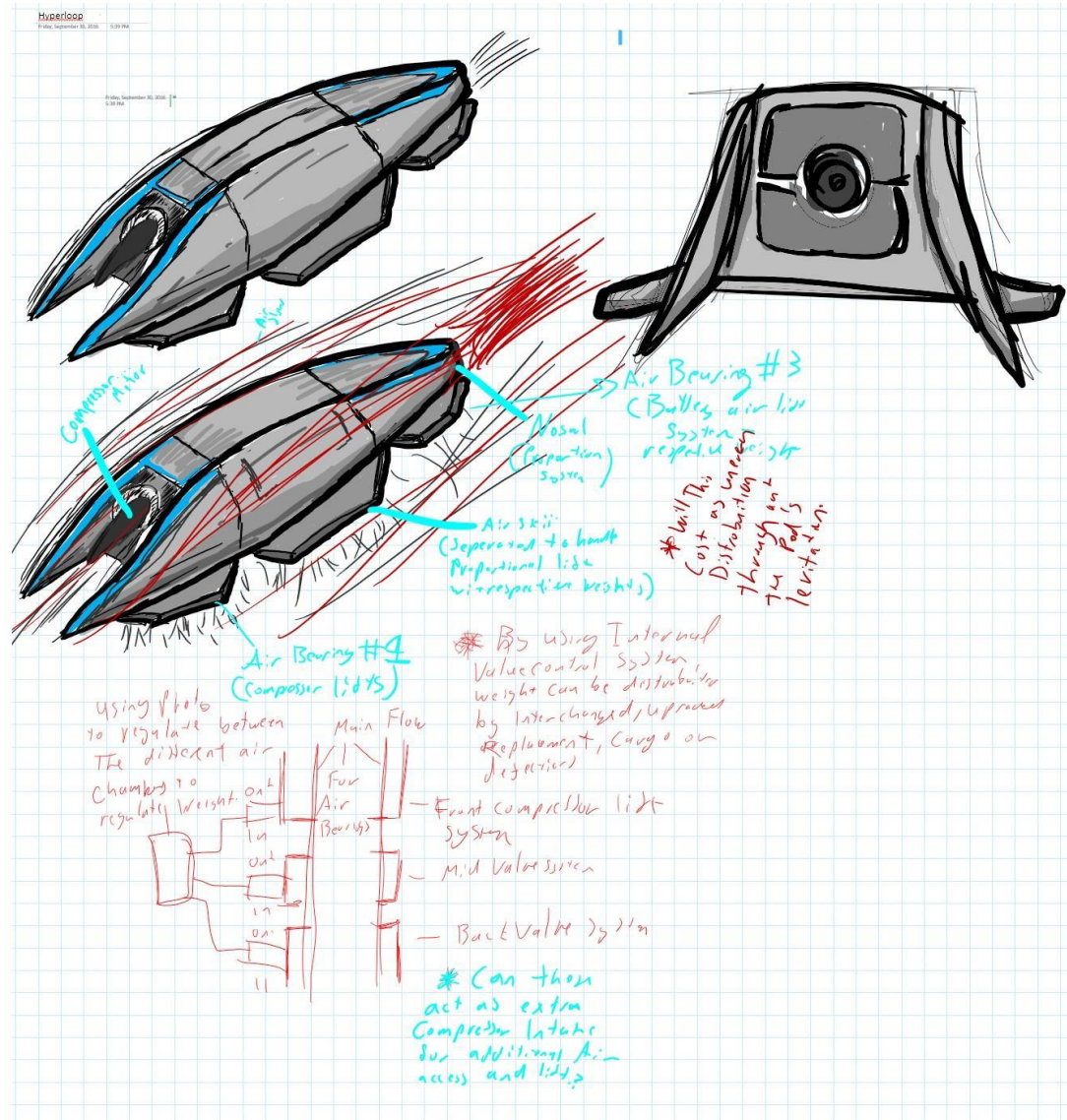


Figure15: Hyperloop Capsule Concept Sketch

Design Notes:

The Design attached above is the initial design for this version of the hyperloop capsules. The Design is split into three section which is the front, mid and rear section which houses different components. The Front section is designed to be the housing for the motor and motor drive system. The Mid section houses the microcontroller attached to motor in the front and the battery in the rear section. However, underneath the capsule a is a propulsion air track and the levitation system depending on the variation (Air Bearings or mag lev).

Initial System Design

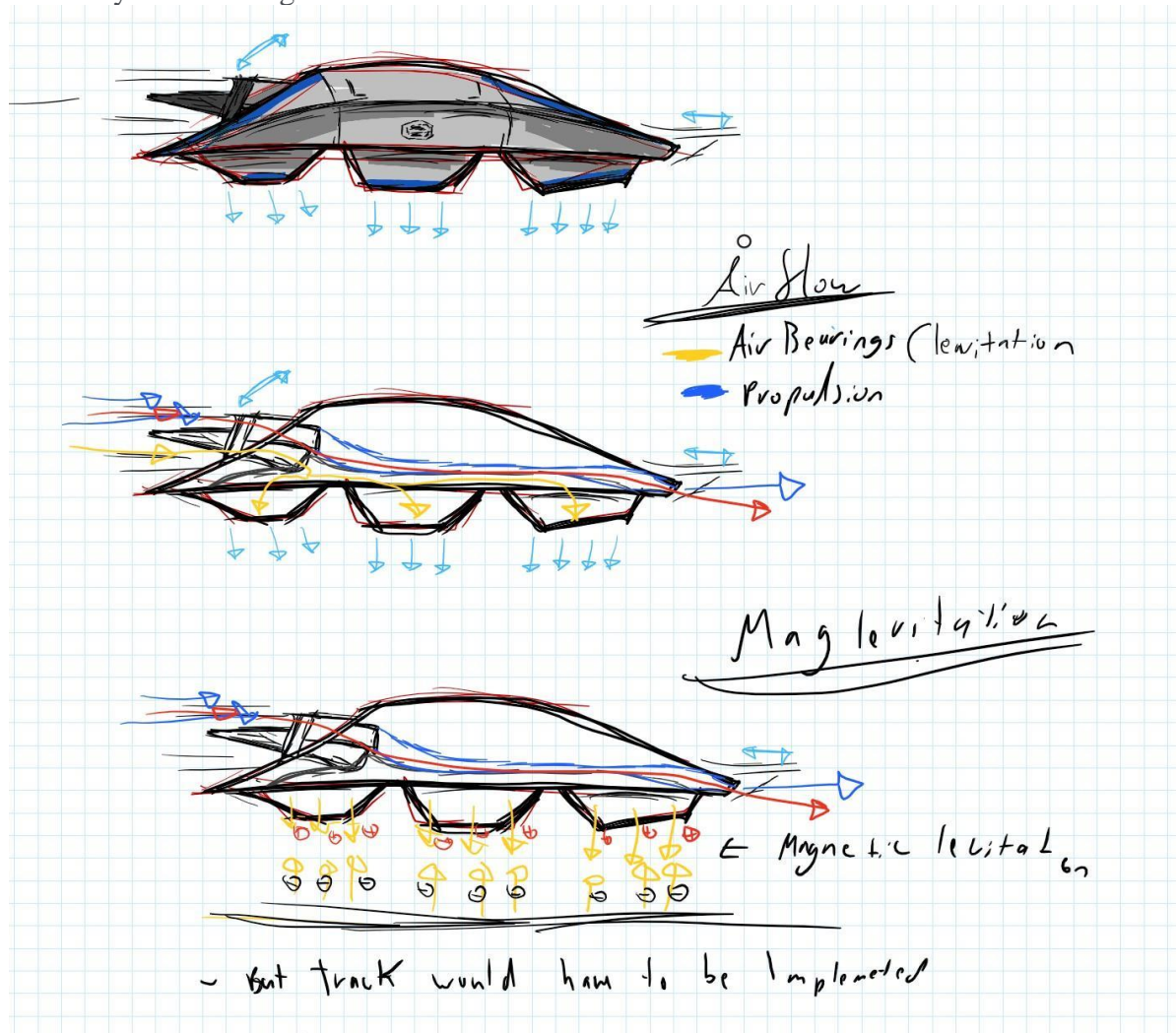


Figure1:6 Hyperloop Levitation System Concept Sketch

Design Notes:

The later incarnation of the Hyperloop concept was explored by many teams, company and universities and some of the variations have diverted back to using magnetic levitation instead of air bearings. This was possibility due to the implementation or design reasons. As a secondary design the design above shows how this version of the Hyperloop capsule can be adapted to either system. Even though the air bearing system is what is primary focuses on in this project, the concept of magnetic levitation are explore to investigate if air bearing is truly better or preferred method to magnetic levitation as mag lev trains are not a new or very innovative ideas and in terms of implementation would requires the project to design an additional rail systems and an electromagnetic suspension circuit which will increase the cost of implementation for this project.

Initial Tube System Sketch

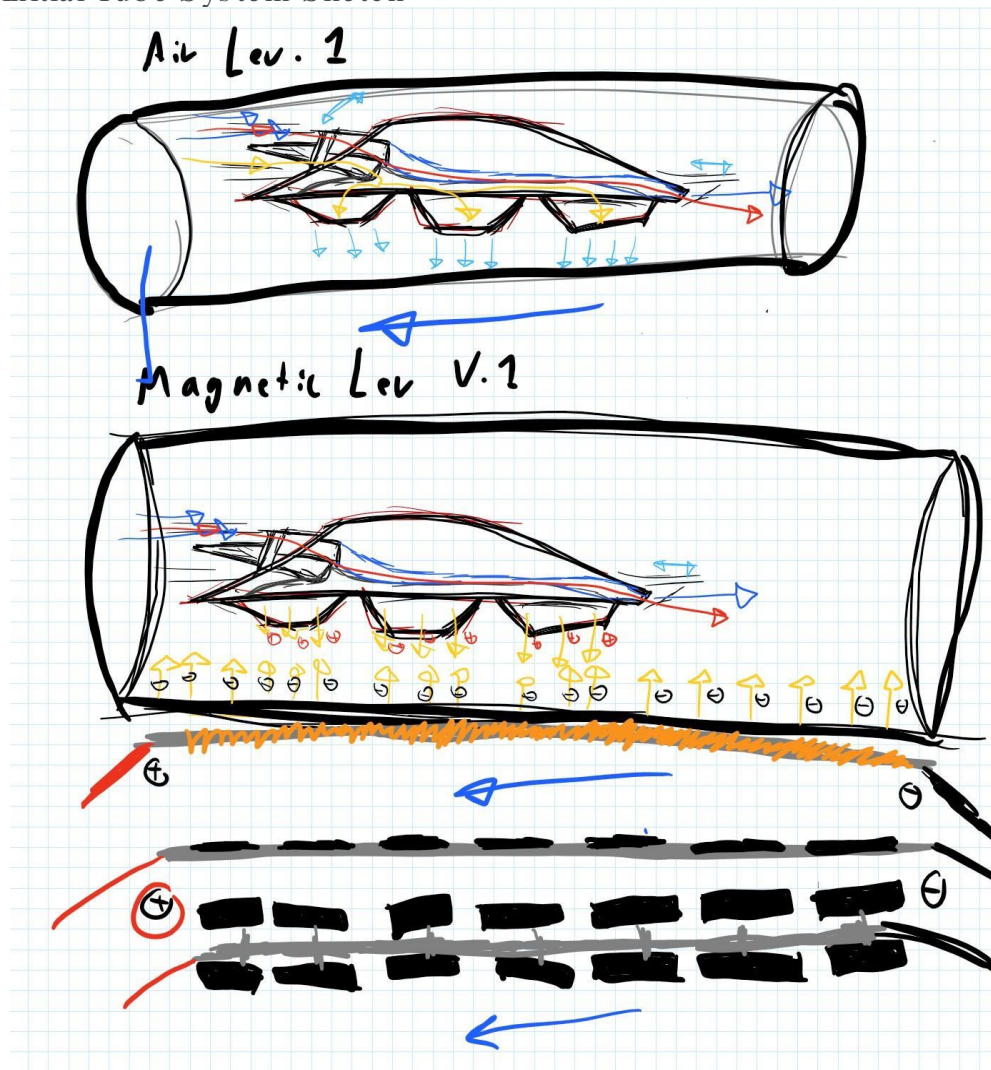


Figure17: Hyperloop Tube Systems Variation Concept Sketch

Design Notes:

The Tube which houses the hyperloop is one of the crucial component of what makes the hyper loop so especially since the air bearing version was inspired by the air pressure mailing system used in buildings by sending capsule in a tube. It is fair that the mag lev version would not need to be in a tube but to fulfil the requirement of being weather prove and attempt to make it an innovative solution when the magnetic levitation version did not anything new to the table and the fact that as a final year university project does not prevent the project to mature into a more innovative solution. The Idea solution and implementation of this Project would be the simpler Air Levitation V.1 shown above.

MOTOR PERFORMANCE REQUIREMENT:

To determine how fast the motor needs to spin at a minimum speed, we need to work out the overall weight of and air needed to channel to lift and levitation the hyperloop prototype. This will set a baseline for us as a goal to design and simulate towards. The requirement of the motor will be based on edf motors used in most hobby airplanes since this project is focusing on the miniature model of the hyperloop

In this case, the approximate break down of the weight of the hyperloop is:

Capsule Casing: 300g

Circuit: 200g

Microcontroller :100g

Motor: 300g

Solenoid value $100\text{g} \times 4 = 400\text{g}$

Total Weight is 1300g or 1.3 kg

For this project, ideally a 10mm levitation from the surface is sufficient. Therefore, the motor needs to be able to lift 1.3kg.cm.

Now a 1 kg unit of mass is equals to 9.8 m/s/s or approximately 10 Newtons (need 13 Newtons) and motor are measure in Watts:

Power in Watts is approximately the kg.m.torque x RPM

Therefore, we will need:

$1.3 \text{ kg.cm} = 0.013 \text{ kg.m}$ (converted to meters)

Power = $0.013 \times \text{RPM}$ Watts

So, the motor will need to be around 13 Watts spinning at 1000rpm to lift 1.3kg.cm

However, the brushless motor of the BLDC brushless motor gives a flexible amount of power depending on the type and level of voltage/current the battery is used. To determine a motor speed in rpm in this case of the BLDC EDF motor use in hobby sets the rpm is represented by:

$$\text{RPM} = \text{kv of motor (not kilovolt)} \times \text{battery voltage}$$

In this case, the selected motor is 4500kv x 7 volts which gives the motor the rpm of around 31,500 rpm. To accommodate this, we can adjust the requirements with a high rpm and lower watt but since the levitation can be regulated using the solenoid valve the motor will not need to be operating at 100% (31,500 rpm) and at 50% will still be suffice to support the levitation process. Therefore the overall propagation speed can be dependent on the speed of the motor over the minimum rpm requirement suing the solenoid valve to restrict the airflow as the speed increase to maintain a consistent level of levitation.

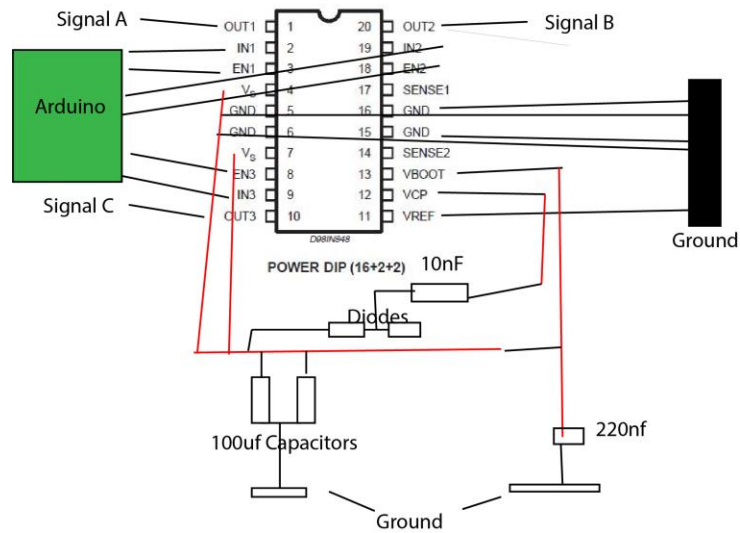
CIRCUIT DESIGN**BLDC THREE-PHASE DESIGN FINAL DESIGN**

Figure 18: main circuit design

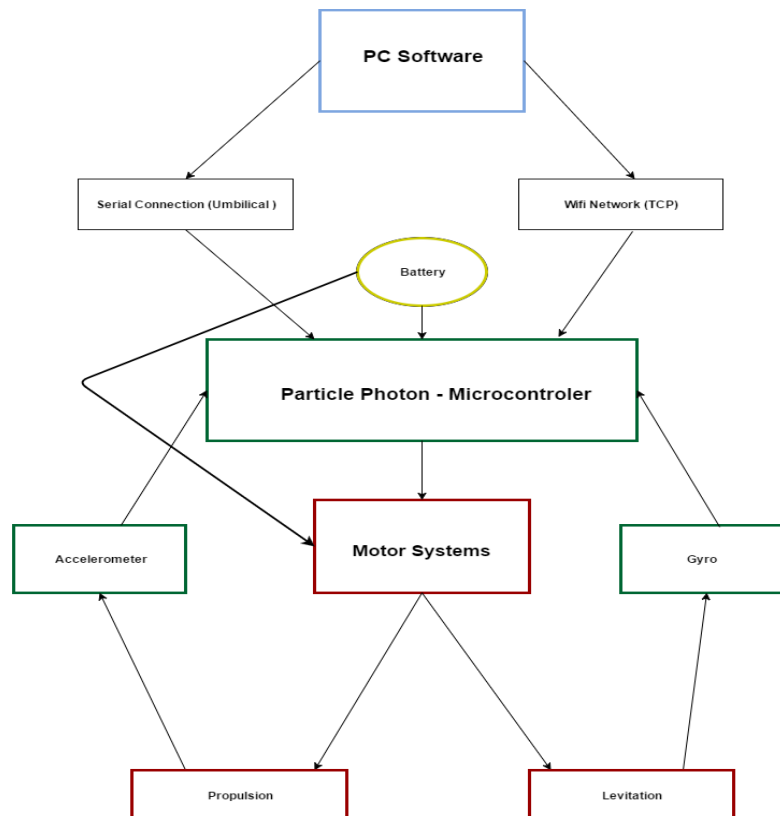
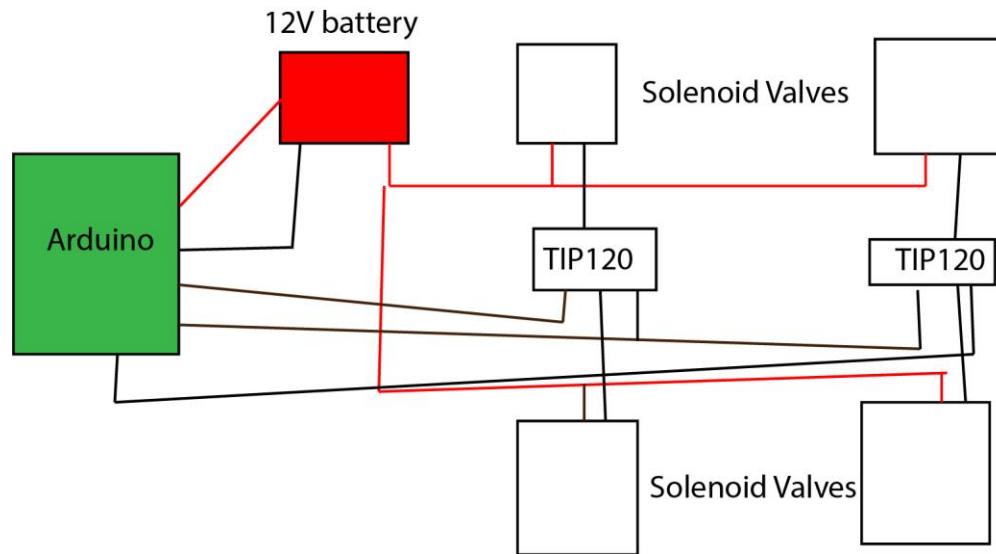
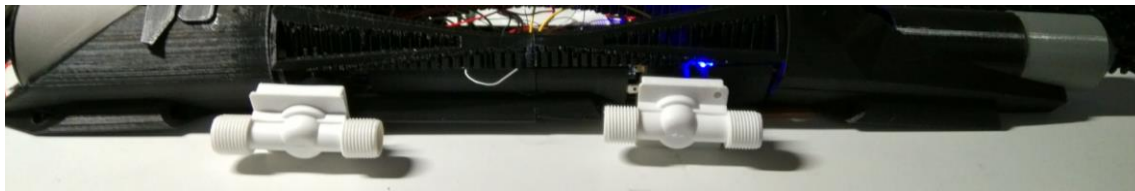


Figure 19: System flow diagram

SIMPLE VALVE REGULATION CIRCUIT**Figure 20: Valve control Circuit example**

The solenoid valves are implemented to help regulate the airflow throughout the hyperloop. Four of the $\frac{1}{2}$ inch solenoid valves are mounted around the mid-section of the capsule to help distribute the right amount of air between the front and the rear section of the modular capsule prototype (See design section). The rating of the solenoid valve may be rate 12V but does start operating 6 volts and would operate with either the 7-volt lithium ion battery in the wireless configuration or the 12volt lead acid battery in the wired configuration. The consist comprised with a connection to a Darlington TIP120 transistor to allow the valve to operate off the battery with a connection to the Arduino or photon (depending on the configuration in use) to control the intake level of the valve which a dc motor as well.

VALVE HARDWARE**Specifications**

- Working Voltage: 12 DC
- Max Current 470mA
- Operating mode (Normally open
- Inlet size = $\frac{1}{2}$ inch
- Material: nylon Stainless Steel/polyethylene
- Valve type: servo operated
- Filter stainless steel
- Max operating temperature 120 degrees

Figure 21:

SECTION 4: SIMULATIONS

MATLAB SIMULATION

The purpose of these simulation are to demonstrate and prove that either motor drive could reach the minimum required rpm in theory. The simulation circuit are down early in the project to prove that either concept would work, though out the course of studying power electronics and electrical and system the Matlab work done on this project has been refined and explored based on the modelling skills gained from lab work which are used to update this simulation section.

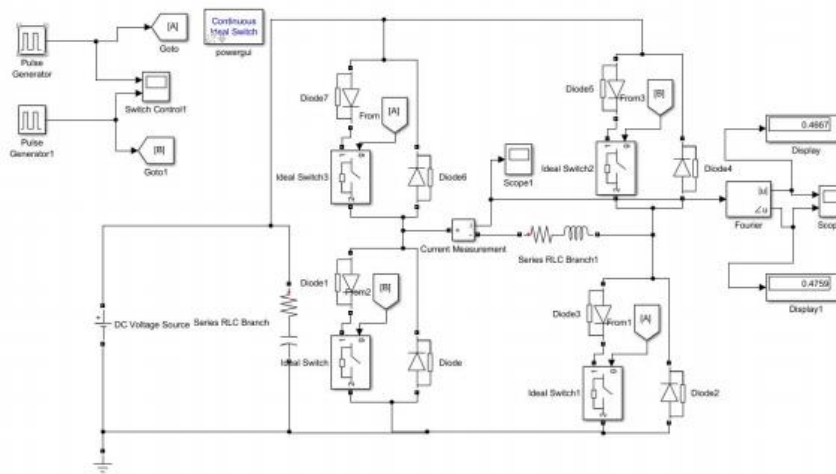
BDC H-BRIDGE MOTOR DRIVE SIM

Figure 22.1: h-Bridge Motor Drive Design

In this H-bridge circuit simulation a signal pwm square wave input is input into a multiplexer to switch the different sides of the half-bridges. The figure below shows the signal going into the switches in turn. As a radobesult in theory, the h-bridge motor drive does allow the dc motor to reach the required rpm running with a 50Hz pwm input.

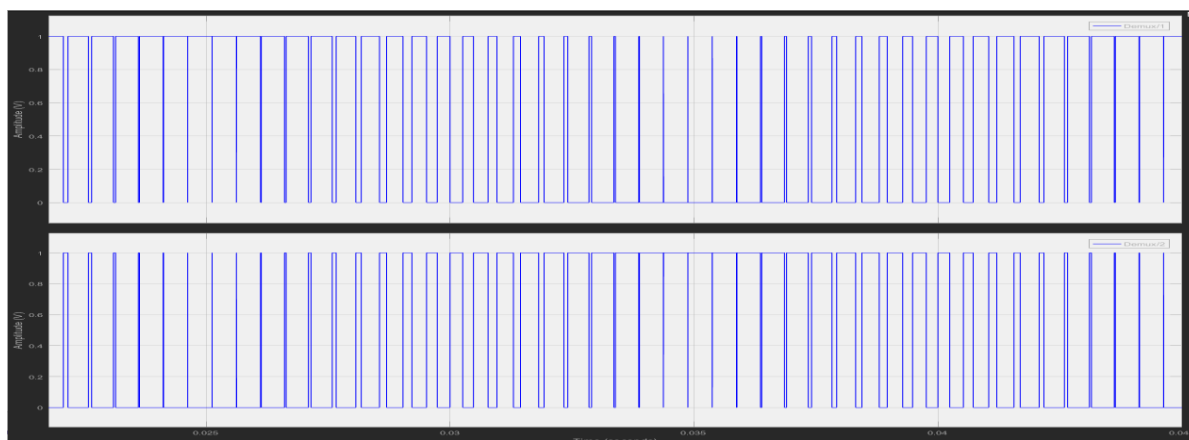


Figure 22: h-Bridge PWM input signal

BLDC THREE-PHASE HALF BRIDGE SIM

The Three Phase Motor drive have been adapted into simulation form in matlab starting with 3 sets of PWM signals multiplexing in pairs into the six different transistors which is then switching the signal going into the BLDC motor. As a result from this simulation this configuration is sufficient to support the minimum amount of rpm (13W at 1000RPM or adjusted equivalent the motor needs to spin) needed to accommodate the levitation process.

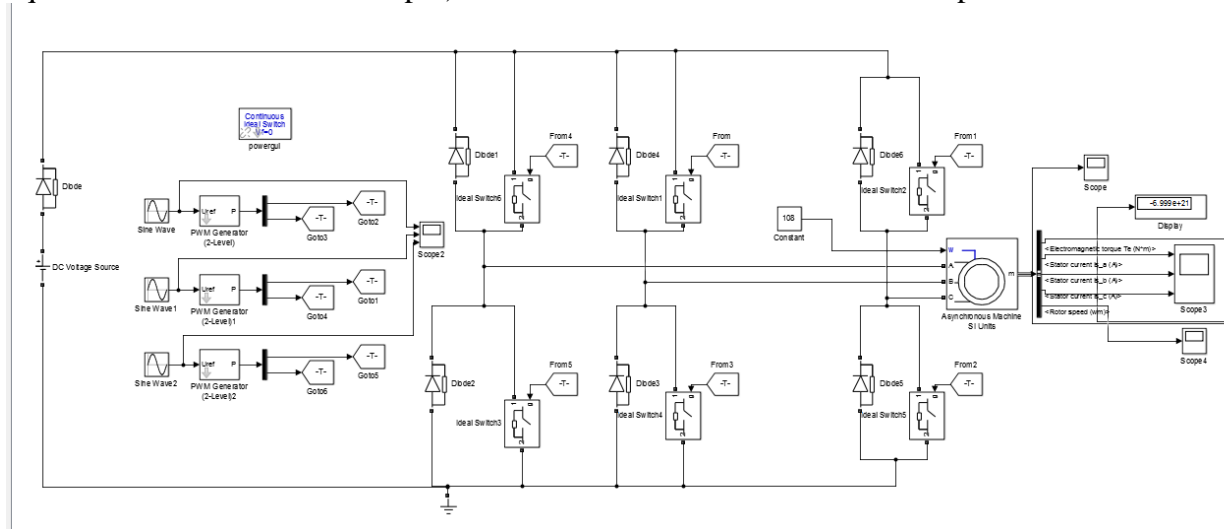


Figure 23: h-Bridge 3-phase Motor Drive Simulation

As can be observe from the signal graph to the left, these are pwm signal using sinwaves. Square waves are also use to simulate in this circuit since the Arduino can only generate digital pwm or basically square wave pulses. In this Simulation, the signal generator has been set to 50 Hz with each of them being 120 degrees out of phase. These signals can be labeled as signal A, B, C. Signal A will be lagging at -120 degrees, signal be can be kept in phase at 0 degree and signal C will be leading at 120 degree.

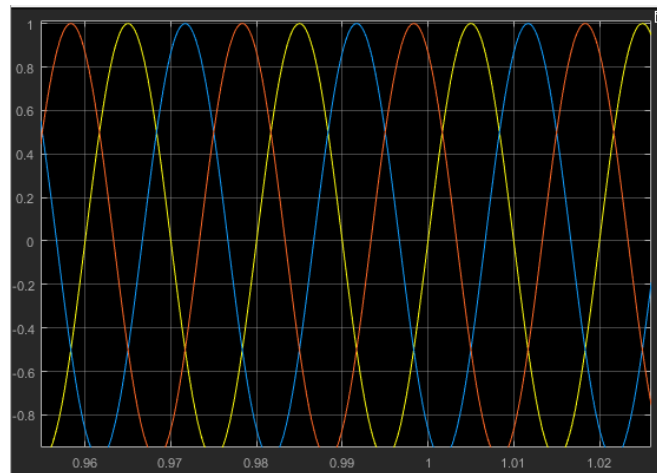
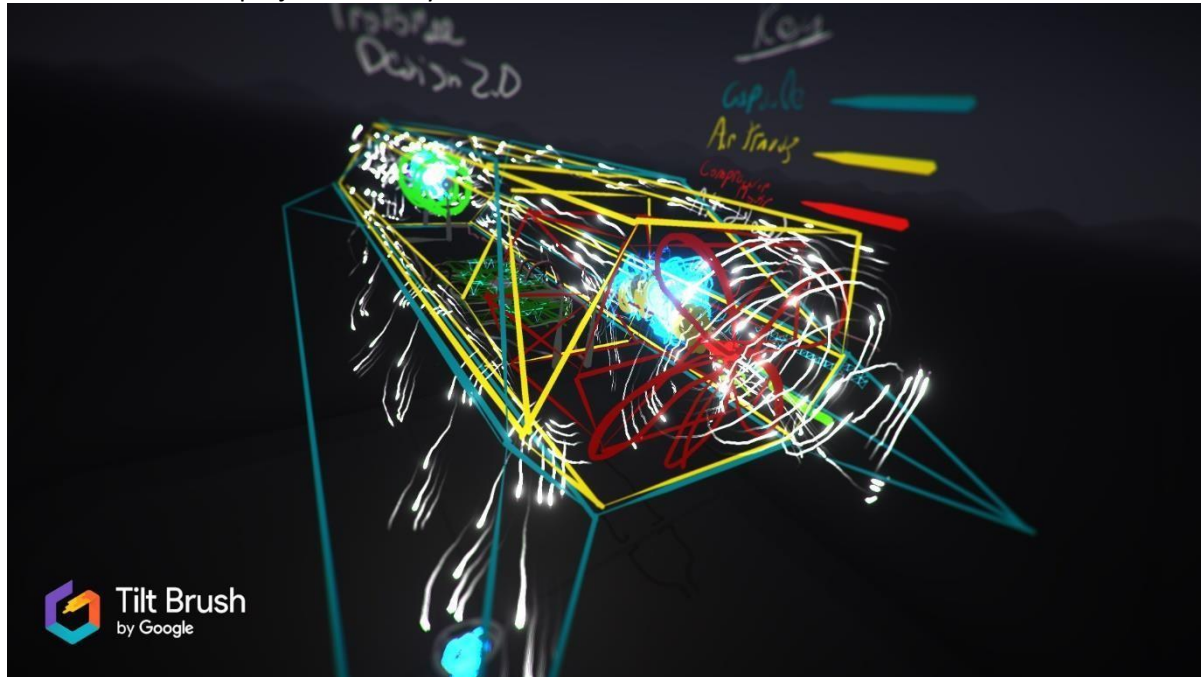


Figure 23: Pwm signal fed into the invertor/motor drive

3D AIRFLOW DIAGRAM

For the air bearing version of hyperloop to function the air track needs to be fully thought out if sufficient airflow is supplied to the rear air thruster and the levitation bearings. The air flow diagram shows the airpath in which the air will flow through to achieve what is needed for this system to function. Below are the 3D air flow diagrams created in Google tiltbrush software. An animated version can be found in the project directory online.



GUI – CONTROL SURFACE INTERFACE

The Hyperloop Control Panel design uses Tesla's on dash as a designing inspiration not because of the man behind both ideas but the fact the both are Electric Vehicles and a modern form or representation of what an adaptive solution to transportation should be. The Modern Tesla control panel function as a setting panel allowing the user to adjust the different configuration from adjusting the power and battery settings to auto pilot settings. The Hyperloop is not a car but the system is similar. As stated in the sketch design note about the Hyperloop or at least this version performs on batteries and motors which channel air throughout the capsule, the air level and output needs to be adjusts able an optimizes through the user of built in solenoid valve in the AirTrack. This aids the control system in optimising the moto drive to allow appropriate levitation and propulsion of air to the respective location. The Control system of the hyperloop will be house on a tablet pc which will perform very similar function to the tesla version in controlling and allowing access and flexible control to the Hyperloop both serially and wirelessly through the networking Interface.

SECTION 5: FABRICATION AND IMPLEMENTATION

HARDWARE FABRICATION

Hyperloop Shell

CAD Process & 3D Printer used to Produced Prototypes Variation

The Hyperloop was first designed in adobe Illustrator in a form of blueprints which is then exported as a .dwg file a CAD drawing format that is then imported into creo where the drawing is extruded and modelled into the predesigned shell with housing prep for components like the microcontroller and motor. Once the CAD file have been export to. STL Binary File the model is inspected in meshmixer for any imperfections before printing and will be auto fixed by the software based on the parameter and threshold given to the meshing software. The model is now ready the Printing process begins. The printing time for each prototype varies and the cost calculated through the amount of filament used depended upon the design of each prototype. The less filament used the cheaper and the faster the print would be. However, since rafting and complex area which required printing support does exist in out design. The estimated amount of previously printed or expect for each prototype are as below. The cost also varies from the Shipways cost analysis outlined in the cost estimation section above. The Model then must be sanded to remove access printing material around it and have the raft and support remove for a clean build ready for assembly with the other subsystems.

Porotype Versions	Filament Type	Filament used	Print Time	Cost (Estimated)
Version 1	PLA	180g	4 hours	£5 GBP
Version 2	PLA	120g	3.5 hours	£4.5 GBP
Version 3	PLA	176g	4 hours	£5 GBP
Version 4	PLA	220g	6 hours	£8 GBP
Version 5	PLA	340g	3 days (Separate parts)	£13 GBP

Printing Cost and Material Table

The amount of filament used is from a spool of 900g PLA plastic. One Spool of the 900g PLA plastic costs at least £32 GBP excluding the shipping cost. One of the Prototype can take up to 100-200g of Filament which will make the printing cost ranging around £3 GBP to £5 GBP if support and rafting is used in the printing of the prototype. As we can see the prototyping process became drastically cheaper once access to prototyping tools is granting lower the cost of the overall project. Although it does not reflect the real size production of the system.

MICROCONTROLLER IMPLEMENTATION

With substantial amount of microcontroller programming have be done in past projects working with the particle photon is not too difficult. The Particle IO grants access to programming the microcontroller remotely form the browser. The Controller has a program to control/interact with the motor drive, solenoid valve written can be uploaded/flash straight from the browser over Wi-Fi or flash manually offline using command line tools provided with the Particle Photon documentation. In this case, the offline method was use as it was much faster to recode and flash the device manually. This code would also include the Network TCP client code which will be elaborate further in the next software implementation section.

PWM is an essential component in driving the motor drives in this case the Arduino can provide and generate a PWM signal form 6 of the IO pins on the board. The PWM control for the motor drive is set by the Arduino IO pins which will be outputting one PWM signal at a 100% duty cycle for the DC motor H-bridge driver and outputting 3 PWM signal also at 100 % duty cycle into the individual circuit and IC versions of the motor drive design.

(Prior to this condense report a t PWM generator circuit was built and tested for early versions of the motor drives).

MOTOR IMPLEMENTATION



Figure 24 Hyperloop Proof of Concept Prototype Assembly

The motor is used for this proof of concept prototype is a 3 phase BLDC EDF motor. The BLDC EDF Motor is brushless motor using a 3 phase AC signal from a controller regulated by a PWM signal. The controller is then used in conjunction with a transistor MOSFET to Help channel the current straight from the battery to the Motor Controller in controlling the motor. Later, in the project the Motor Controller will be replace with a design and build motor drive specifically for this project which will be soldered on to a type of flexible PCB board which should curl up snugly within the interior of the Hyperloop shell. Currently a 7.4V battery is used to power both the board and the Motor but is proven to be insufficient. The connect is set up as an umbilical set up since the battery does not fit within the Hyperloop shell. As a proof of concept using the esc the motor was able to spin at the minimum rpm requirement.

BDC DUAL HALF BRIDGE MOTOR DRIVE IMPLEMENTATION

MOTOR DRIVE SYSTEM BASED ON INDIVIDUAL COMPONENTS

This first design is the design of the H-Bridge motor drive using individual components. Below is the prototype circuit implemented on a bread board. This design is based on the design planned prior and simulated.

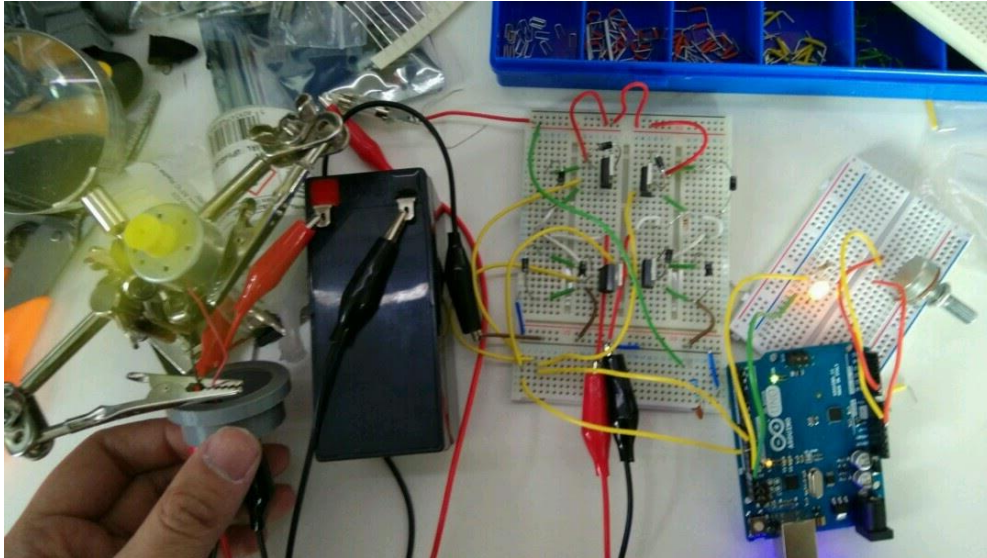


Figure 25.1: breadboard motor drive implementation

BLDC THREE-PHASE HALFBRIDGE IMPLEMENTATION

MOTOR DRIVE SYSTEM BASED ON INDIVIDUAL COMPONENTS

This first design is the design of the 3-phase motor drive using individual components. Below is the prototype circuit implemented on a bread board. This design is based on the design planned prior and simulated.

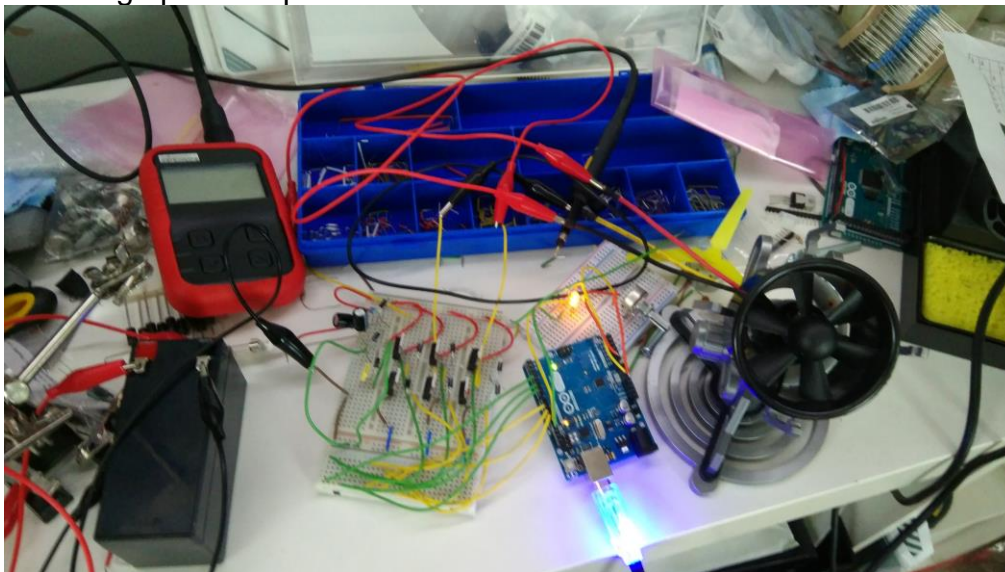


Figure 26.1: breadboard motor drive implementation

MOTOR DRIVE SYSTEM BASED ON IC (REDUCED SPACE MOUNTED ON PROTOTYPE)

The Circuit below is based on same design as the one above but the motor drive has been replaced with a IC version of the drive to reduce space to be mounted on the hyperloop prototype. This circuit is implemented and soldered on to an etched circuit board which is now a lot more robust and well organized than the breadboard version.

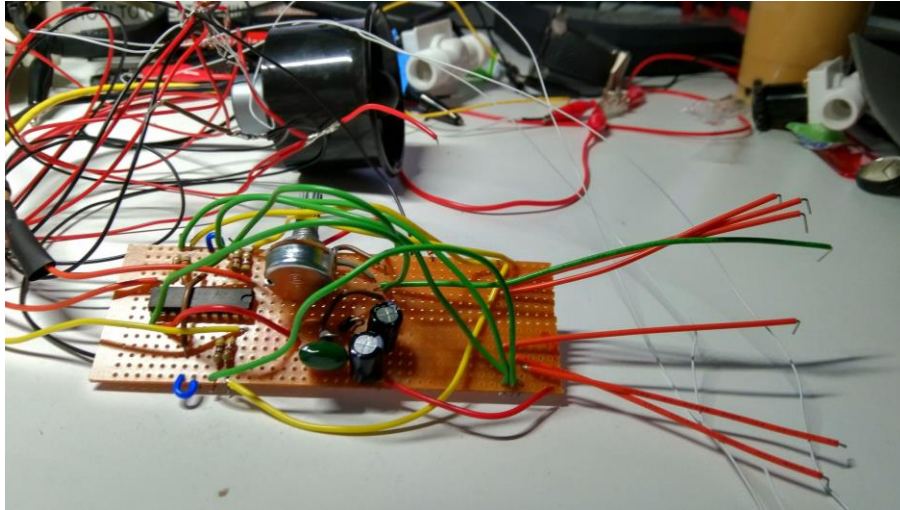


Figure 26.2: breadboard motor drive implementation

HALL SENSOR IMPLEMENTATION:

Three Hall sensors are mounted/ glued on to the base of the motor. Since hall sensors are there to provide commutation to allow the Arduino to feed



Figure 26.3: Hall sensors on BLDC Motor

DESIGNS EVALUATION

Hyperloop Capsule Design

DESIGN #1: BASIC RAFT DESIGN:

Design Notes :

This design is the initial Hyperloop prototype design. The Shape and size of this design is meant to resemble a stereotype hyperloop prototype based on the air pressure tube mailing system. This is the most basic Design with the main functionality in mid. The front of the capsule has a hole for the Motor to be mounted and room to fit the microcontroller, Motor drive circuit and battery system. Below is the air bearing raft which is designed to distribute air evenly throughout the length of the hyperloop capsule. All around should be an image of a typical hyperloop system.

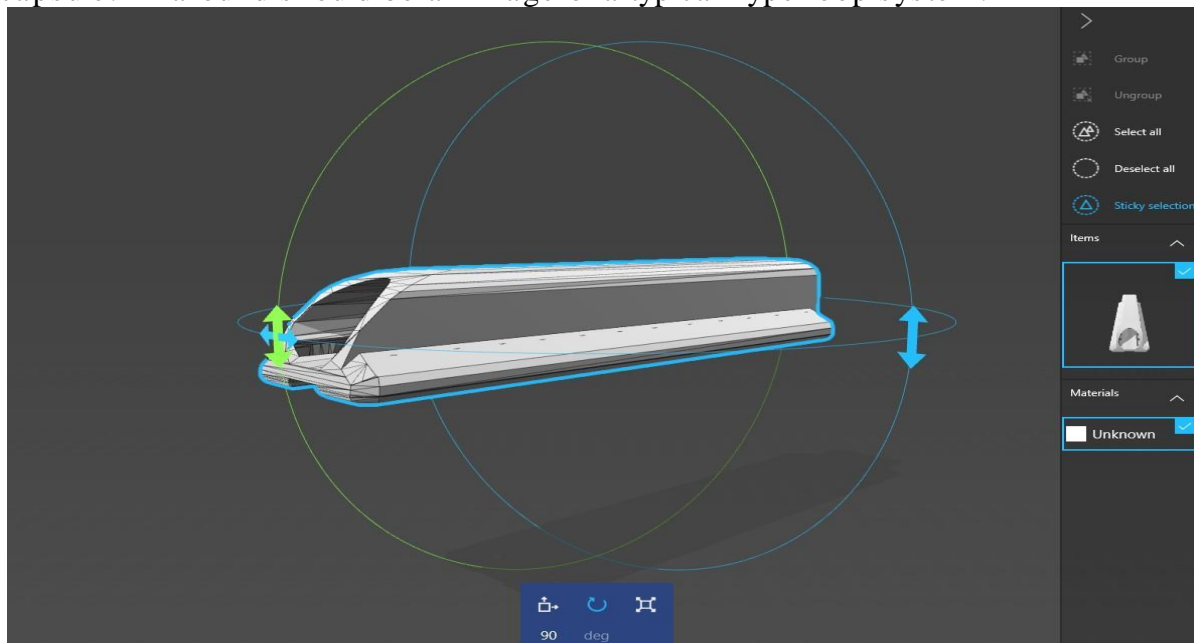


Figure27: Hyperloop Design #1 Cad File

Design Evaluation:

To evaluate this design, the hyperloop above is a basic design but in terms of size might be too bulky in terms of capsule to tube diameter ratio. As this project, does not simulate low pressure conditions or at least not too low. This design will catch a bit of air resistance accumulating inside the tube. Also in terms of system efficiency. Since the air bearing is distributed for the entire length of the hyperloop capsule, air will be escaping very quickly. Even with the solenoid valve in place the motor must operate much faster to channel more air through the capsule for both propulsion and levitation. The design also isn't a material saving design and contains a lot of material which can be removed to reduce weight.

DESIGN: 2 AERO DYNAMICS + AIR DRAG DESIGN:**Design Notes:**

This second hyperloop design takes the design evaluation to heart a little too practically. The size of the Hyperloop capsule has been reducing drastically closer to the design sketches. The Shell of the hyperloop has reduce the amount of material used both in size and design dimension which has better aero dynamic system in mind and increase the air drag over the top of the curve surface in order for air to channel through the compressor motor in front of the hyperloop system and with excess air which is not channel to be channel upwards around the curvature of the capsule pushing the capsule down on both top side of the capsule keeping the capsule more stable countering the levitation below while traveling at greater speed. The amount of air bearings has been reducing to just the 3-major section of the hyperloop capsule which is the front rear and mid to maintain levitation where weight is mostly distributed making the system more efficient due to less air channelling needed from the motor system.

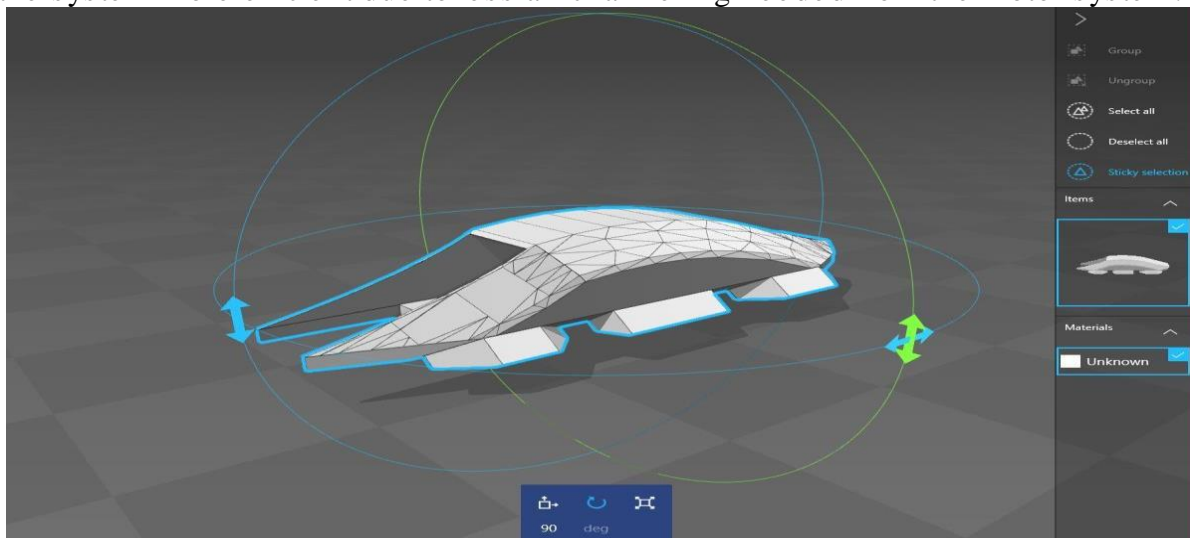


Figure28: Hyperloop Design #2 Cad File

Design Evaluation:

Evaluating this drastically improve design, there are a lot of points which this second design has taken too far. For example, the excessive reduction in length material as cost the capsule the room to house components and motor. The selection choices for motor has reduce due to the opening of the front capsule even when it is rounded the ratio of the shell the model invades is deemed very high in this context creating imbalanced within the system as the curve back eliminating the ability to store any kind of battery storage, not even compatible with the button watch battery cell which technically not suitable to power this kind of system anyway. Although seem like a good design initially the cost or constraint put in the system is not appropriate for this project.

DESIGN: 3: AIR CHANNELLING/TUBULAR DESIGN

Design Notes:

This third design has been more or less the combination of two previous designs. The length of the hyperloop has been stored to its original length in order to house the components which includes a variety of batteries, microcontroller and EDF motors. However, the design is more angular than the first but less curved than the second which ends up with a spear tube design which would be sufficient in terms of material used to channel and reduce air resistance while offering some aerodynamics and air channelling path around the outside of the hyperloop capsule shell up top and towards the flank of the tube above the air bearing tracks. The Air bearing tracks and rear propulsion resembles the second design more allowing efficient flow of air with minimized space after release through the solenoid valve to maintain minimal space for the air to travel creating a more efficient system while maintain the length of the capsule. The main air bearing still channels to 3-major area distributing the levitation weight evenly resulted in less air needed to be channel through the compressor motor.

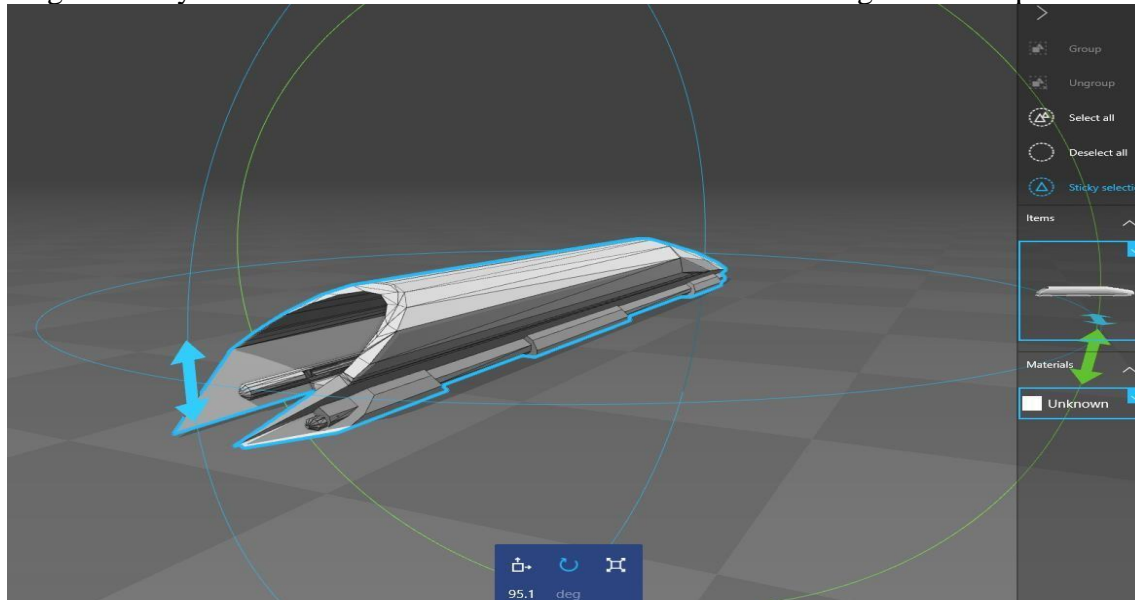


Figure 29: Hyperloop Design #3 Cad File

Design Evaluation:

Not much is needed to criticize this design since it is the best of both previous designs and appropriately distributed and meets the criteria in terms of design and efficiency. However, it is obvious that this complex design creates a lot of obstacles and challenges in fabricating as Shapeways estimation predicted up to £250 GBP which means for that for a self-print model (still under £10 GBP) will show a lot of complexity printing the shape of the shells and internally due to support materials filling up the air track and inner compartment which needs to be cleaned out. The process is not impossible but needs to be simplified. To sum up this design the cost of fabricating is quite high either way.

DESIGN 4: MODULAR SUB SYSTEM DESIGN

Design Notes:

At this point in time this Design is still under work and refinement but this fourth design resembles very much like the third design but split up into a modular design which splits

up the 3-major section allowing the fabrication process to be simplified since each of the sections can be printed individually and cleaned out easily. Even though it was cost slightly more the extra £2GBP cost for print is very much worth the simplicity and this modular design.

This design while contain almost all the advantages points from the third design is has its own addition features. Especially modularity, since the design is now split into modules the internal system design can be switch around. For example, the Motor system will be in the front most module, the motor drive system will be in the second, the microcontroller system will be included in the third, a Passenger or cargo capsule in the fourth if intending to simulate a life scale one and the power source module in the last. This make the experimentation process very easy when testing out different built motor drives or batteries when one runs out. Each module has their own Air Bearing system allowing weight to be distributed evenly for any number of modules connected with minimal air track and solenoid valve between each of them allowing the AirTrack to adjust per the proportion of the air needed to channel through the capsule making design four a very smart design in comparison to previous prototype.

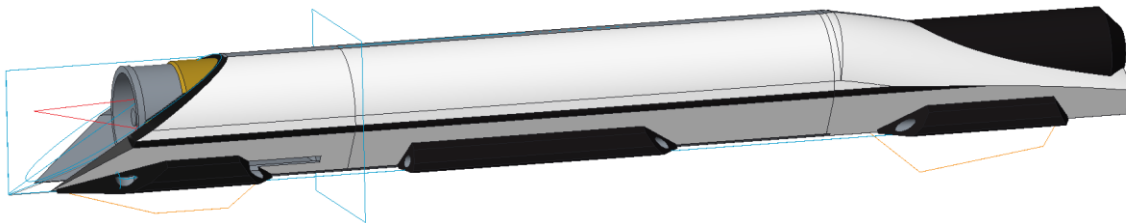


Figure30: Sketch for Design 4

Design Evaluation:

This fourth prototype is now to be fabricated and evaluate upon experimentation and the implementation of the motor into this fourth design is successful and the modularity of the design has proven to be quite useful. However, when placing the circuit board into the mid-section of the capsule a pair of tweezers is require placing and mount the board due to the restrictive cylinder whole. This also makes it difficult to connect components from the front and rear end of the capsule as well. Overall, this design would represent the 1:1 scale as there will be sufficient space to amount the components and provide rooms for cargo and passengers in the midsection of the capsule.

DESIGN 5: MODULAR SUB SYSTEM DESIGN FOR DEMONSTRATION SIMPLIFICATION (CONCLUDING DESIGN)

Design Notes :

This fifth and final design within the duration of the final year project is based on the fourth design with refinements in multiple area taking the ease of implementation, maintenance and demonstration of the miniaturize scale into account to provide a better access to different subsystem of capsule which included access to the circuit board, exchangeable rear module for wired and wireless configurations. In terms of printing cost the cost went up to £12 as the mid-section and the rear module are too complex to be printed separately which would include more rafts and more support which costs more filament to print. However, materials from the midsection has been remove to help reduce the costs in filling up the entire casing.

This design while contain almost all the advantages points from the fourth design which includes the modularity which still allow each part main section to be exchangeable. Not much has been change for the front of the capsule as it must remain airtight but with an addition of slot to lock the motor in place and a pair of led indicators for operations. The mid-section has experienced the most changes as the top half of the capsule is now removable allowing easy access to the circuit board. The sides of the mid-section have also been remove to accommodate the solenoid valve selected for this project to be mount to the side with air tube attached to the front-end rear of the capsule. The material on the top lid was also remove to reduce weight gained from the solenoid valve and reduce printing costs. The rear-module has minor changes, the rear cylinder is now removable to accommodate different type of communication and power modules. This means that additional battery, communication methods or power electronics modules can be placed on the rear for further experimentation

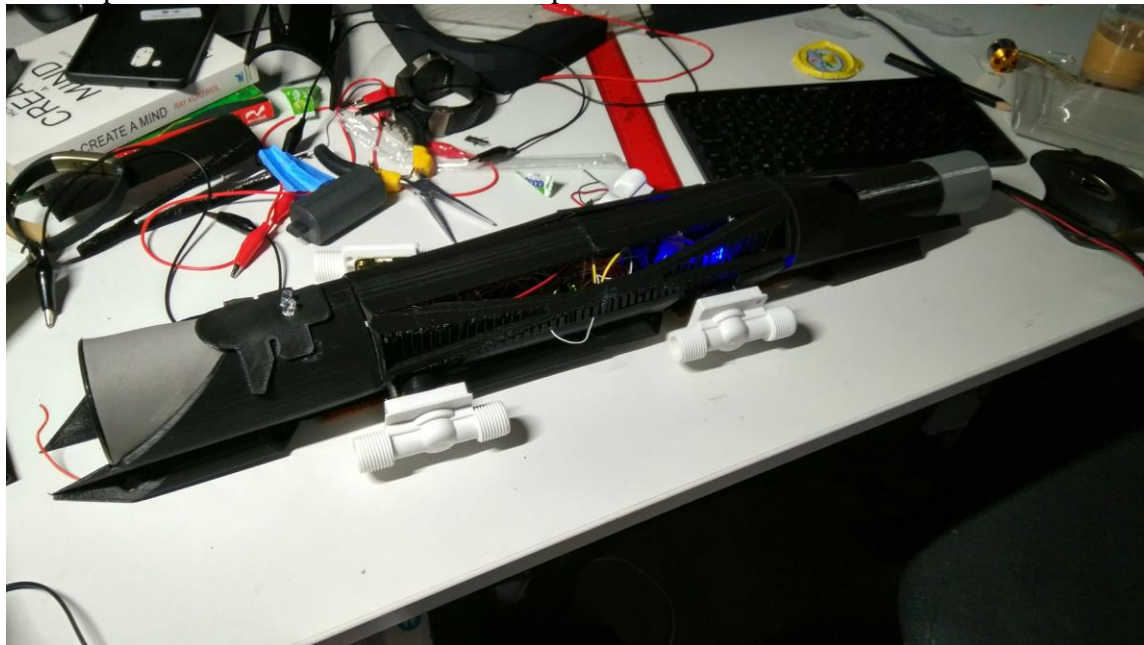


Figure 31.1: Photos of final prototype

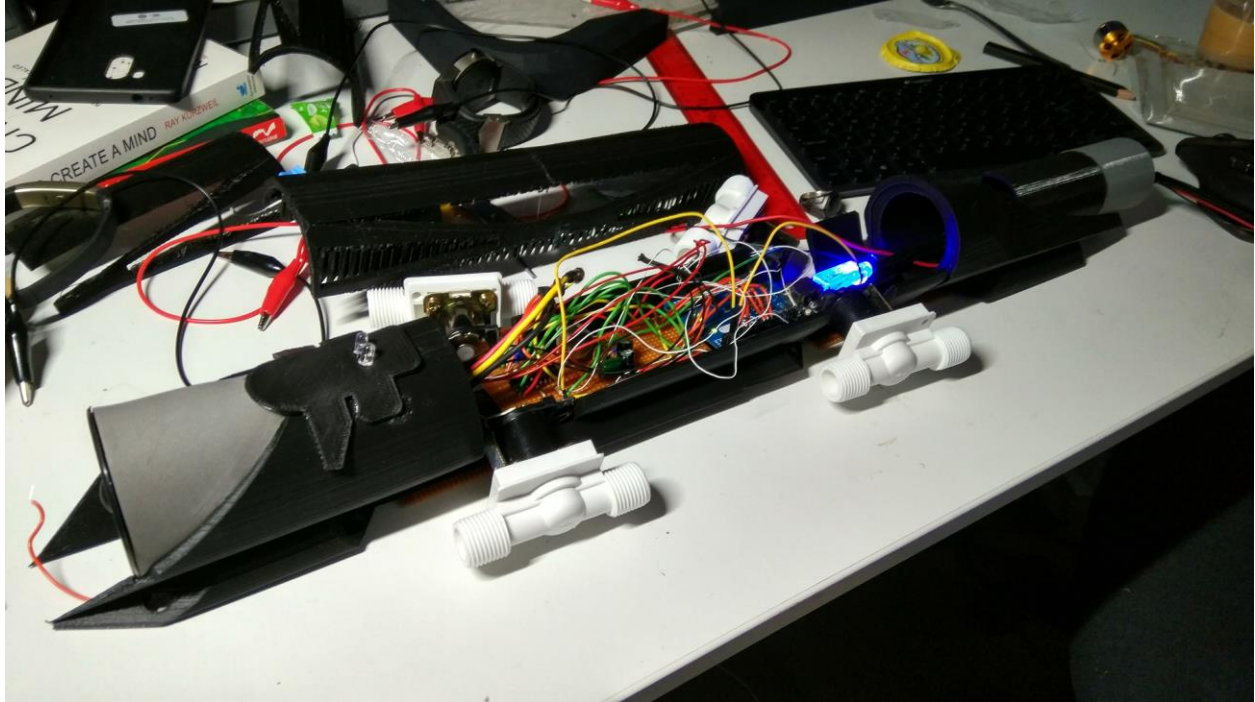


Figure 31.2: Photos of final prototype

Design Evaluation:

This last prototype should fit into the scope of this project but does display some design flaw and complexity in fabricating. Overall it is a suitable miniature prototype but would not translate well to a functional transportation version due to the minimal design suitable for prototyping to explore the different development aspect of this capsule and treat it as an experimental version of the hyperloop.

SECTION 6: ADDITIONAL ASPECT SOFTWARE

In terms of the software use to control the entire system, a Graphical user interface was created in Visual Studio for quick prototyping in the language Basic. The process of designing the GUI is quite simple with a WISIWIG and a drag and drop interface without the need to set any constraint. The Code implementation of the software is also very simple as a simple click with link the function code the respective area i.e the function of can be coded into the button straight away or can be called to quite easily. The software program follows the initiate sketch very closely and is separated into three main section which is the status bar, control panel and the communication panel which will perform their respective roles of providing the execution of functions and communicating them to the microcontroller either serially or wirelessly using TCP over Wi-Fi.



Figure32: The Designing and coding of the Control Panel in VS2015 (V1.0)

HYPERLOOP CONTROL SOFTWARE INTERFACE

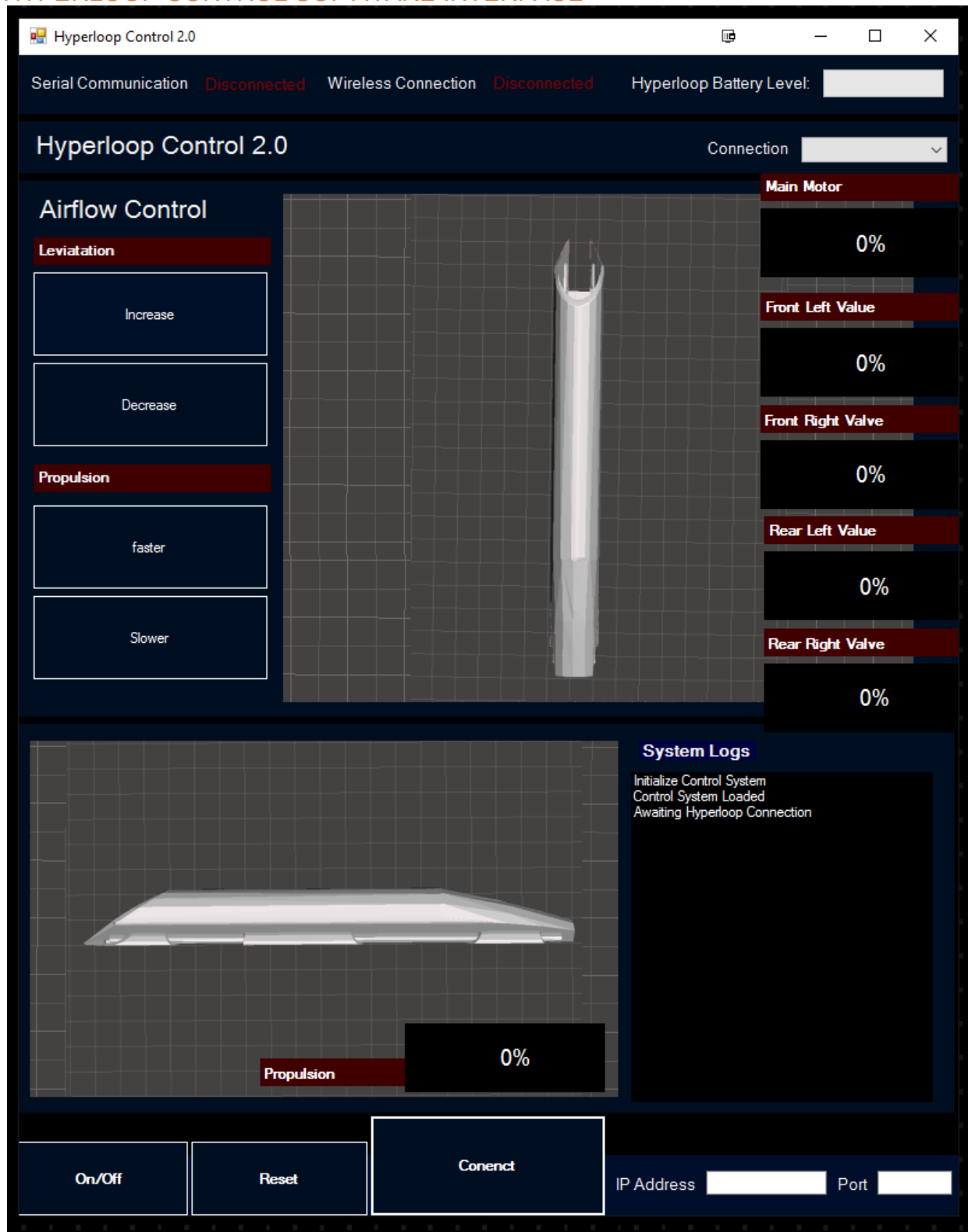


Figure 33: Final Control Software Program (v2.0)

SOFTWARE FUNCTIONS:

CONNECTION

The connections methods can be selected through the drop-down box from the 3 options of serial communication, Wireless Communication and Bluetooth (Added as a future option). Once the connection type has been selected and configurations have been set, the user can initiate the connection to the hyperloop through the connect button at the bottom of the window. This button will detect which mode the software is currently in if the capsule is not connected it will show and prompt a connection level but if the user wishes to disconnect the button will display "Disconnect" during connection mode. This indicator will also be updating the connections label above respective to the connection type in use.

LEVITATION CONTROL

In levitation control, a simple button will allow the user to either increase or decrease the amount of air running through the valve in increments to adjust the position within the valve allowing the airflow for levitation to be more independent from the main motor and propulsion control and remain consistent. On a later design a control for individual valve can be implemented to allow even weight distribution through the hyperloop system regardless of the weight in each section.

PROPULSION CONTROL

The propulsion control is a basic button that also allow the user to adjust the speed of the BLDC in increments. However, the calibrated speed currently have to be set using the potentiometer on connected to the microcontroller. Every time the user attempts to adjust the speed the incremental value will either increase or decrease from the original value read through the analogy pin of the microcontroller which would usually be set to around 550.

SYSTEM LOGS

The system log is a list box that displays all the activities that occur within the software and feedback from either controller. This is mainly to aid with the debugging process and help the use keep track of everything that occurs to ensure that their command on click have been registered and initiated. For example, the logs will display guide text throughout the connection process with prompting instructions or when the user attempting to increase or decrease the motor speed the logs will display and confirm the process.

SYSTEM FEED BACK

The feedback displaying on the software are feedback received either serially from the Arduino or wireless receiving encoded data through a TCP frame from the particle photon depending on the value of the speed in which the motor is set is currently set to or how far the solenoid valve is open or closed. The data feedback is also including warnings, battery level and logs from either microcontroller which will be updated on the interface.

SECTION 7: TESTING AND ANALYSIS

As can be seen from the project progression report, several tests have been conducted in this project but to keep this information relevant this testing and analysis will be comparing the two-main motor drive system and analysing the observable performance of the levitation and propulsion properties of the hyperloop capsule system.

ANALYSIS OF THE THREE PHASE H-BRIDGE SYSTEM AND THE DC MOTOR SYSTEM

To begin with, the DC motor when tested physically did not live up to the simulated result, chances are the reason the DC motor did not spin up to the rpm requirement could be due to multiple reasons. Reason such as the design of the duct and turbine which the motor is placed in was not able to be supported by the DC motor, by this I mean that the turbine might have been an additional weight or the placement of the duct was not specifically designed for DC motors. These DC motors are brushed motors which means that they are more friction with these motors and taking the fact that there are no ideal conditions in the real world. Either way, DC motors are not designed to function as the Brushless motors. DC motors are designed to run on small gadgets with low work load unlike the brushless motors which are designed for industrial uses. The Brushless motors in this case had no issues with the duct system as it was installed in. It also performs to level that is required and expected to allow enough airflow throughout the capsule. However due to a flaw in mechanical design more air was required for levitation due to the size of the solenoid valve available, amount of air space needed to be occupied and air propulsion holes.

CAPSULE TEST RESULT

Based on the test of the capsule with the brushless motor design. The system as stated before has performed as intended granting levitation to the prototype. However, the propulsion test was not so successful due to mechanical design. Due to the modularity of the design the air track that regulates the air flow throughout the capsule has minor leakage where the air leaks out and does not build up enough to generate sufficient propulsion force to push the capsule forward. Adjustments can be made with the software but as a result not much change has affected the capsule propulsion speed at all.

SECTION 8: FUTURE DEVELOPMENT

Now evaluating and reflecting this project there are many aspects that should be explored in this area. As this was a project I wanted to pursue and proceed I want to continue this project but move toward other aspects of the project as the span of this project have been heavily focused on motor drives but maybe more to develop these areas below:

OPTIMIZE AND REGULATED AIRFLOW SYSTEM:

Now that the valve system is in place in the fifth prototype, a system through software to regulate airflow throughout the length of the capsule system. The Valve itself does add a lot of weight to capsule but the wireless variation of the capsule with holds the battery on the rear end could potentially be extremely heavy compared to the other sections of capsule on the modular design.

BRAKING CIRCUIT:

As part of the characteristic of a motor once the motor has reached synchronous speed the motor will start to generate more back emf which in turn could generate enough voltage and current to feed back into the inverter or in this case the three-phase motor drive causing the device to overload and be destroyed during operation, a simple braking circuit can be implemented using a resistor, capacitor and a relay to regulate the speed of the motor keeping protecting the circuit from the generation by back emf.

SOFTWARE CONTROL – INDIVIDUAL VALVE CONTROL

Following on from the valve system, if the previous system would to be implemented the software should be able to accommodate adjustment for individual valve allowing the user to manually calibrate the levitation strength of the capsule based on the different modular components use on future versions of the prototype.

PRINTED PCB:

Throughout this project two versions of the circuit board have been used and explored which are the flexible prototype board and etch solder board. The flexible prototype cause a few issues short circuiting components when fold forcing the project to adapt to the etch board. Now that the project has a concluded functional design a printed PCB that can be mounted on to the midsection of the capsule would make the project a lot more robust.

SCALED UP PROTOTYPE:

As this project was inspired by the SpaceX student competition it would be great to scale the latest prototype up and redesign the prototype according to the SpaceX specifications for teams competing. Perhaps to even form a team to pursue this competition if the opportunity ever arises.

GYRO& ACCELEROMETER TRACKING

The MPU 65 is great Gyroscope and accelerometer board to embed into the prototype, this has a potential application to track the orientation of the hyperloop capsule during levitation and actual traveling speed of the capsule inside a length test tube track instead of calculating the speed based on the input fed into the motor or a delimiter/laser rpm reader.

SECTION 9: CONCLUSION

CONCLUDING THIS PROJECT

In conclusion, in the duration of this final year project time span, this project has been extremely eye opening allowing me to fulfill and challenge an idea I strongly wanted to pursue. Having reflect on the past 7 months this project has been extremely demanding in every area attempting to explore especially in the experimentation with different motor drives. Despite the challenges most of the objective have been met have developed further than initially planned.

First, throughout the project 5 hyperloop prototype was designed, printed and implemented with the motor different version of the motor drive prototype control by a pc software that allows the user to communicate with the hyperloop capsule. As of the concluding Prototype it has been proven that a DC motor with a H-bridge Motor drive is not suitable for this application as it does not offer enough power to provide the proper amount of levitation and propulsion to the model. The top speed of the DC motor only "950" rpm which was not enough to lift 900g capsule as oppose to the "1000" and up by the BLDC Motor which was more capable to lift the capsule. Thought the system is not a 100% efficient due to faults in the fabrication process that could have caused air leak or inefficiently regulated air bearing/exhausts. Moreover, the due to budgetary restrictions within the scope of this project mechanical parts such as the valves and air tubes are reused which could cause inefficiency in regulating the air flow as well. As far as the Control software is concerned 2 version of the software have been programmed and met all it's need of controlling the capsule system. The serial communication aspect of the system works perfectly each time as it is a reliable wired connection. However, the wireless connection is slightly buggy due to use the Wi-Fi network used during each test that varied in each location and in addition to the fact that the particle photon wireless protocol restrictions have played a role in a few unsuccessful connection attempts. For example, the particle photon does not support some WEP-2 security protocol and only support network without multiple authentication method such as edurom. However, an alternative approach by using mobile wireless hub device or mobile device can be used as a hosting network but does come with tradeoffs which causes lag in communication between the pc system and the hyperloop capsule system.

On a personal level this project is not over as plenty can be develop to meet the same standard the participate in SpaceX Competition. I am looking to work on a develop this project in all this aspect explored in report and expand the scope and scale with factors that would resemble a model closer to the actual scale hyperloop. Despite the success in multiple prototype there was a lot of failure and mistake that lead to inefficiency within the system I designed a build which shed light on plenty or areas that could have been improve the project. It has been an amazing experience learning not just about the field of power electronics and electrical machinery principals but also a chance to practice my design, CAD/CAM and creative skills but also an opportunity to see and learn about myself and how I've approached this project going through anxiety, stress and overcoming problems to pursue an idea I strongly support. I am extremely grateful for this project and support and anyone reading this report find it insightful and enjoyable as much as me developing the hyperloop.

SECTION 10: APPENDICIES:

EXPERT CITATIONS

Dr. Kamyar Mehran – Power Electronics – Queen Mary, University of London

Dr Chinapat Panasawas- Material Sciences -University of Birmingham

COMPONENTS DATA SHEET

L6234 Motor drive -

http://www.farnell.com/datasheets/1689789.pdf?_ga=1.228561625.537627882.1492442663

<http://www.st.com/content/ccc/resource/technical/document/datasheet/6d/24/36/da/ab/59/43/ba/CD00000046.pdf/files/CD00000046.pdf/jcr:content/translations/en.CD00000046.pdf>

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RISK ASSESMENT:

The table below shows the risk consider to be involved with this project with solutions, stakes and occurrences to better prepared for the work that needs to be done for the second semester. The consideration of these risk should help maintain a safe working environment and efficient work pattern.

Description	Risk level	Type of Risk	Solution	Effected subject	Past Occurrence
Poor Time Management – (Lost control of workload)	High	Time management	Distribute work load ahead of time. Look forward two weeks ahead	Me	Frequent
Conflicting deadlines and lab assignments	High	Time Management		Me	Frequent
Accidents from working with printing parts	Medium	Physical	Follow safety Instructions and wear safety gear such as protective goggles, rebreathers and gloves	Me	Low
Accidents from working with Workshop tools	Medium	Physical		Me	Low
Accidents from Motor System	Medium	Physical		Me	Low
Possible hazard form working with Lithium Ion batteries	High	Physical	Work within recommended parameters	Me	Low
Illness from Environmental and nutritional factors	Medium	Physical	Look after yourself – Eat right	Me	Medium
Restless - Overslept	Medium	Physical	Exercise, adjust sleeping pattern, regulate workload	Me	Medium
Miscommunication with Supervisor	Medium	IT	Sort email out so it does not filter relevant emails	Me & Supervisor	Medium
Miscommunication with relevant parties	Medium	IT		Me and Other parties	Low

IT system Failure – unable to upload	Low	IT	Check System and find back up	Me	Medium
IT system Failure – unable to fulfil potential	Low	IT		Me	Medium
Transportation Delays	Low	Transportation	Check travel Plans and travel earlier	Me	Low