# Amphibious Spherical Explorer

## Design Review

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# Contents

# 1 INTRODUCTION

## 1.1 Title and Objectives

This project intends to build a amphibious spherical explorer (ASE), which is a spherical robot that can perform data collection tasks on load or in water. Our concentration in ECE is control system. Therefore, we want our senior design to be an application of control. Inspired by spherical robots in movies such as Star Wars and Jurassic World, we decided to create one of our own. After we conduct a series of researches on spherical robots that are currently in the market, we come to realize those robots are run on a fairly unstable mechanism which causes wobbly movements. Therefore, we would like to challenge our knowledge on control by using a different implementation which may eliminate the instability issue that we observe from those other spherical robots.

### 1.1.1 Goals

- Eliminating wobbly movements.
- Optimizing the size of PCB board.
- Improving the robustness against collision.

### 1.1.2 Functions

- Traveling in extreme conditions such as water, desert, swamp, etc.
- Collecting data using interchangeable task module
- Sending control signal from PC to the explorer.

### 1.1.3 Features

- Pendulum drive mechanism.
- Superior mobility and versatility.
- Expandability to various interchangeable task modules

### 1.1.4 Benefits

- Spherical shape enables the robot to pass low-accessible areas.
- Improvement balance control makes the robot perform stability-demanded tasks like videoing.

# 2 DESIGN

## 2.1 Block Diagrams

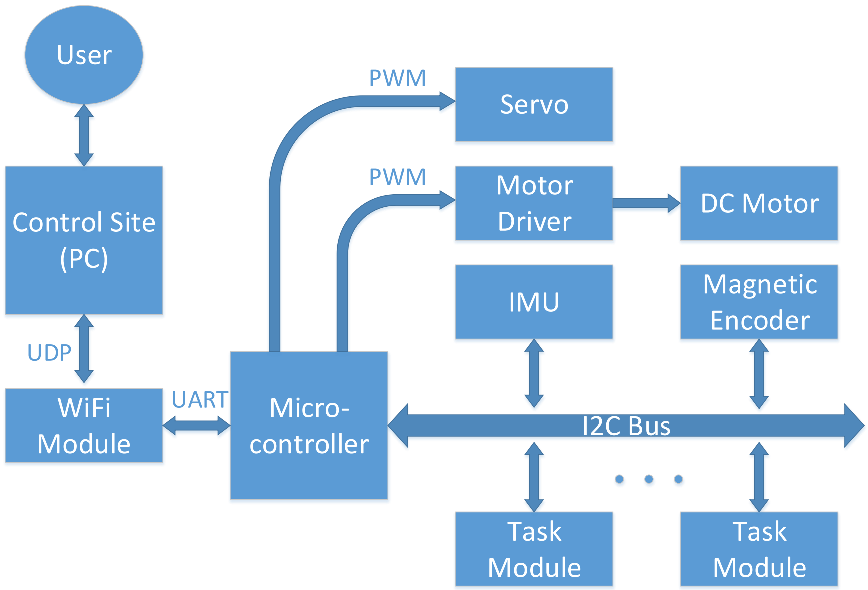


Figure 1. Block diagram of the system.

## 2.2 Block Descriptions

### 2.2.1 Control Site

The control site is the personal computer that runs a program (tentatively MATLAB) for communication. This program mainly perform two tasks: sending commands to the robot to control the actions, as well as receiving and decoding the information sent back from the robot. Communications in both directions are completed via IEEE 802.11 (WiFi) and User Datagram Protocol (UDP). The WiFi access point is created by the control site.

### 2.2.2 WiFi Module

WiFi Module is the communication module of the robot. The WiFi module works in passive mode, which only connects to the access point created by the control site, and works as client, which periodically sends and pulls data from the server, the control site.

### 2.2.3 Servo

The servo control the relative position between the spherical shell and the internal weight of the robot. By shifting the center of mass with a deviation from the vertical, the servo can adjust the balance and control the turn when moving forward or backward.

### 2.2.4 Motor Driver

The motor driver is a switch or amplifier. There is a MOSFET H-bridge circuit inside the motor driver. Its on/off state is controlled by the square waves generated by the microcontroller. The duty cycle of the square wave will determine the effective voltage applied on the motor and therefore control the power of the motor. This is known as Pulse Width Modulation (PWM).

### 2.2.5 DC Motor

The DC motor drives the robot forward and backward. Unlike ordinary wheeled vehicle motors, it does not drive the robot directly. This motor, along with the mass, hangs on a fixed axle inside the sphere. When moving forward, the motor gives the mass that hangs on the motor a disturbance to the front, away from the vertical. At the same time, the gravitational torque will drag the whole robot rolling forward. Repeating this process will keep the robot moving forward.

### 2.2.6 Inertial Measurement Unit (IMU)

The IMU consists of a three-channel gyroscope and a three-channel accelerometer. Data from the both sensors can be transformed into attitude angles with the help of a patented algorithm. However, since we do not pay for such algorithm, a simplified version will be developed and used as substitute.

### 2.2.7 Magnetic Encoder

The magnetic encoder is a sensor measuring the angular displacement of the rotor of DC motor. The sensor consists of a Hall effect sensor and a magnet. When the magnet rotates along with the rotor, the Hall effect sensor can measure the change of magnetic field and return the angle rotated. Angular speed of the rotation can also be obtained by differentiating the angle measured.

### 2.2.8 Microcontroller

The microcontroller is the core of the system, which takes charge of control and signal processing. It implements the following functions:

- Reading/transmitting data from/to sensors and the communication module via $I^2C$, SPI and UART.
- IMU Algorithm implementation.
- Controller implementation.
- Control on actuators using PWM.

### 2.2.9 Task Module

As a feature of "modular design", the task modules are modules for extended use. The modules communicate with the microcontroller via $I^2C$ (some of them UART) to perform different tests. Some tentative choices, including temperature sensors, audio recorder or even digital camera, are commercially available. As long as the corresponding library are built as interface to the firmware, the users can customize their robot according to their purposes.

## 2.3 Technical Overview

Due to the inevitable yet unforeseeable adjustments that will be made, this project will require a fair amount of time investment. Unlike a typical embedded systems project, it is much more complicated to modify a control systems project. Changes will more than likely involve changing multiple mechanical parts as well as adding and replacing the existing electrical components. In addition, we also need to make individual parts compact enough to integrate perfectly. This implies that a lot of effort will be spent in minimizing the area of the PCB while being able to integrate all the electrical and mechanical components into one package.

In order for the robot to sustain in harsh collisions, we decided to use soft plastic shell as the outer surface. Interchangeable task module will be implemented to achieve the goal of data collecting. As for communication between PC and robot, our team will be transmitting signal and data through WIFI.

The robot uses the continuous track mechanism to drive the spherical explorer from the inner surface. Comparing to other spherical robots, like Sphero, in the market, this project uses gravitational torque to generate the forward movement.In addition to the gravity torque, a servo will be used to control the position of the mass in a perpendicular axis. This allows us to control roll motion which helps eliminate oscillation during turning. Another unique thing about our robot is the communication via WIFI while most of the others use Bluetooth connections.

### 2.4 Schematic

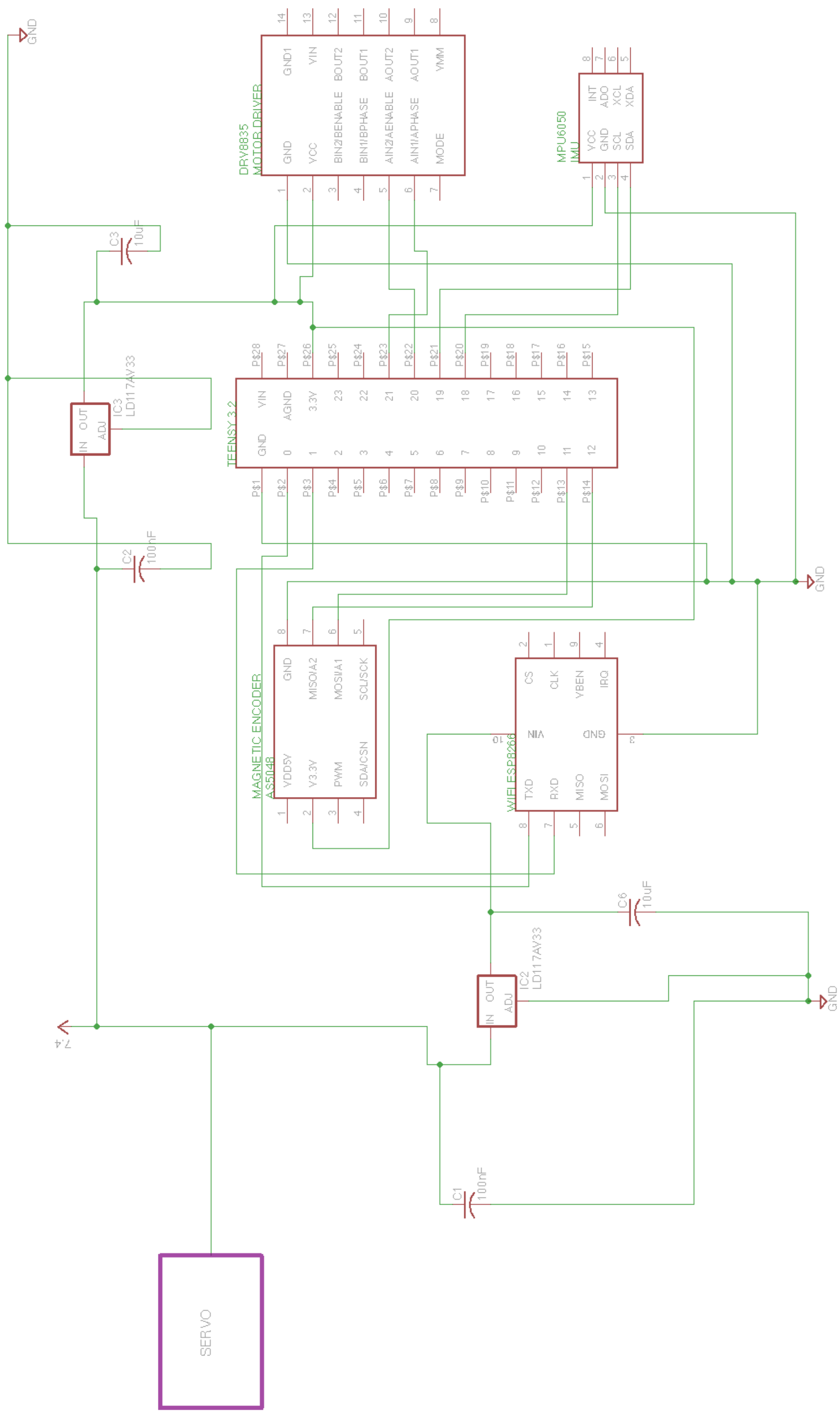


Figure 2. System schematic.

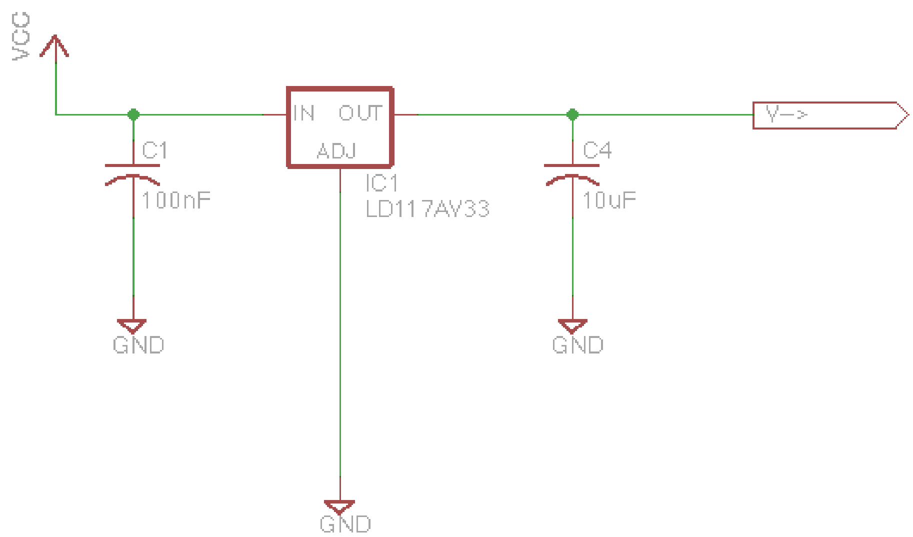


Figure 3. Voltage regulator circuit.

## 2.5 Mechanical Design

The most common mechanism to drive a rolling robot is based on an internal car-like actuator. The shell rolling forward as the car inside the shell runs forward. This design is the easiest to design but suffered from a coupling effect between the control on pitch angle and roll angle, since the output of the car-like actuator does not exert on the angles seperately. Another method is to use a flying-wheel-based mechanism [1]. This design actuate the robot when the robot exchanges angular momentum with the flying wheels. But when the flying wheels rotate too fast, the motors that rotate the flying wheels will saturate and no longer give correct torques to control the robot.

The design of ASE uses a pendulum mechanism. The main motor raise the weight hanging below it from the equilibrium position and makes the robot moving forward or backward. Another servo motor actuates the weight latitudinally, controlling balance and making turning actions. The diameter of the robot is 140 mm and the weight with battery is around 500 g. The visualized design is shown in Figure 4 and Figure 5.

Figure 4. Assembly diagram of ASE.

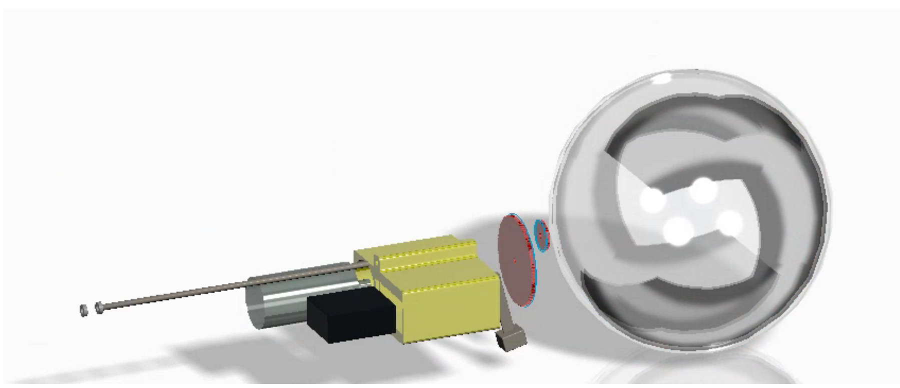

Figure 5. Parts explosion diagram of ASE.

## 2.6 Derivation and Simulation

Since a rolling system like ASE is nonholonomic, a complete dynamic analysis of such system is related to Lagrange equations of the first kind [2]. On the current stage, we are not going to give the complete derivation of dynamic model, and mainly use a experiment-based model as well as a set of controller parameters based on trial-and-error.

However, understanding the mechanics behind the turning motion is necessary for controller design. When the robot is making a turns, how much actuation angle $\alpha$ the servo should shift the mass is related to the turning radius $r$ demanded, and the velocity $v$ at which the robot is running at. The non-liearity of such relation makes generic linear controller to be less effective. To clarify this relation, here we give an short analysis based on Newton method and D'Alembert principle.

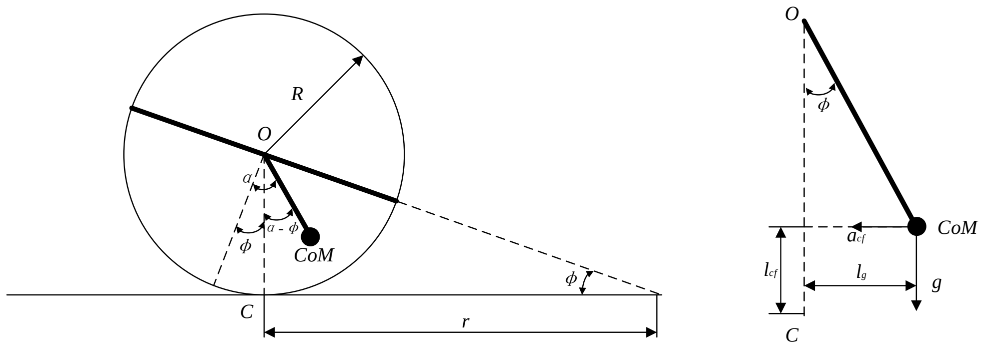


Figure 6. Sketch for mechanical analysis on turning motion.

Define the roll angle of the robot as $\phi$, the actuation angle of the servo as $\alpha$, the radius of the spherical shell as $R$, the distance between the center of mass (CoM) and the geometric center as $l$, and the turning radius as $r$. Figure 6 shows the geometry relations between these quantities.

In a smooth turn, D'Alembert principle indicates the net torque with respect to the contact point with ground (including the torque caused by inertial forces) should be

$$\sum_i M_i = mglsin(\alpha - \phi) - \frac{mv^2}{r}(R - lcos(\alpha - \phi)) = 0$$

Simplifying, we have

$$\begin{aligned} glrsin(\alpha - \phi) &= v^2(R - lcos(\alpha - \phi)) \\ v^2 lcos(\alpha - \phi) + glrsin(\alpha - \phi) &= v^2 R \\ l\sqrt{v^4 + g^2r^2} sin\big((\alpha - \phi) + atan(\frac{v^2}{gr})\big) &= v^2 R \end{aligned}$$

Note that $r = Rcot\phi \Rightarrow \phi = atan(\frac{R}{r})$, we obtain

$$\alpha = asin(\frac{v^2 R}{l\sqrt{v^4 + g^2r^2}}) + atan(\frac{R}{r}) - atan(\frac{v^2}{gr})$$

On-chip computation for actuation angle $\alpha$ is almost impossible for microcontroller, however, we can prepare the value needed and use look-up-table method on microcontroller. A simulation of controller reaction at different turing radii is shown in Figure 7.

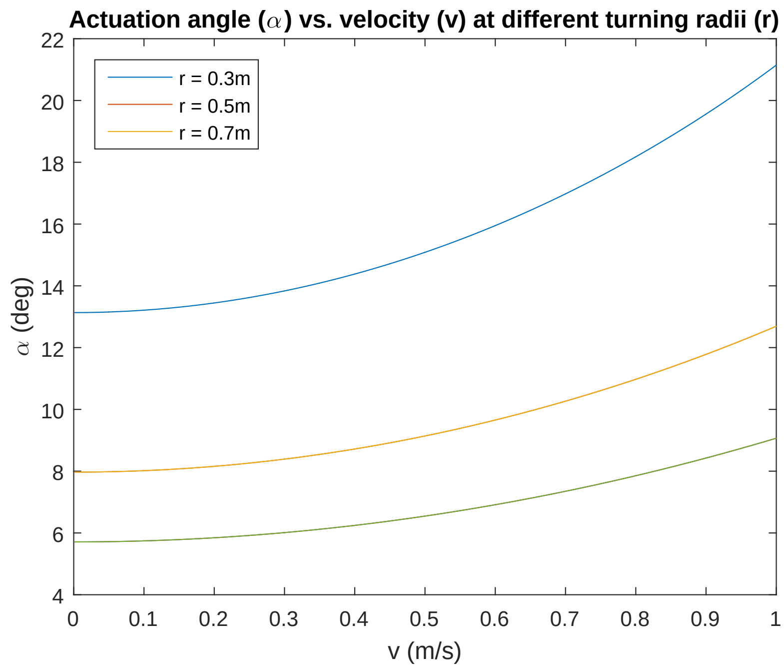


Figure 7. Servo actuation angle *vs.* velocity.

# 3 REQUIREMENTS AND VERIFICATION

## 3.1 Requirements and Verification

**Table 1. Table of Requirements and Verification**

| Module or overall performance | Requirement and Verification | Points |
|---|---|---|
| Control panel on PC | • R: Send command to the robot and show all the data received without crashes (5 pts). The delay of command transmission should be $< 2$ s (5 pts).<br>• V: To verify this functionality, first check if all data, including speed and attitude angles are sent back. Then, send command to drive the robot. Measure the delay between the instant a command sent to robot and the instant the robot starts to move. | 10 |
| WiFi | • R: Packet loss rate $< 10\%$<br>• V: Separate the robot and the computer which generate the WiFi network by $20 \pm 2$ m. Send 100 packets from the control panel, count the echo packets received.<br>$$\text{Packet loss rate} = 1 - \frac{\#\ \text{received}}{\#\ \text{transmitted}}$$ | 5 |
| Microcontroller | • R: Interrupt cycles should be executed at frequency $> 20$ Hz, that is, each task schedule cycle (a list of tasks that run in peroidic cycles) has to cost $< 0.05$ s.<br>• V: Modify the test program, let the microcontroller pull-up an idle GPIO at the beginning of each task schedule cycle, and pull-down the same GPIO at the end of that task schedule cycle. Using oscilloscope to measure the pulse width generated on that GPIO port, we can measure the time cost for each task schedule cycle. | 5 |

| **Module or overall performance** | **Requirement and Verification** | **Points** |
|---|---|---|
| Servo | • R: Give the servo proper PWM signal so that it can rotate within the range about $-60°$ to $+60°$ (use correct pulse length, 2 pts). The servo should also converge to the desired position smoothly without random, intensive oscillation (use proper pulse frequency, 3 pts).<br>• V: Use a test program, which maps an analog input from 0 to 3.3 V, to a PWM output with pulse width from 800 $\mu$s to 2200 $\mu$s, to generate PWM wave with proper pulse width to control the servo. Use an oscilloscope to view the PWM and record pulse length as well as frequency. Rotate the potentiometer, check if the servo can rotate over the full range required, and observe if the transition is smooth. | 5 |
| Motor driver and motor | • R: The motor should be able to change speed (5 pts) and direction(5 pts).<br>• V: No quantitative requirement involved in this verification. Use test program, which maps an analog input from 0 to 3.3 V, to a PWM output with duty cycle from 0/255 to 255/255, to generate PWM wave given to the motor driver. Check if the speed increases monotonically as the input voltage increases, and whether the direction of rotation reversed when the voltage level on the phase pin of motor driver is flipped. | 10 |

| Module or overall performance | Requirement and Verification | Points |
|---|---|---|
| Magnetic encoder | • R: Communicate with the microcontroller (3 pts). The angle for speed calculation should be compensated for the modulus effect, which means $360° + \alpha$ should be recorded when the angle goes to $\alpha$ in the next revolution (3 pts), to avoid discontinuity in angle measurement. Speed measurement in m/s (4 pts).<br>• V: Check the angle data and speed data of magnetic encoder by letting microcontroller print them via WiFi. For speed measurement test, we only need the relation between speed and the rate of angle change to be consistent. | 10 |
| IMU | • R: Communicate with the microcontroller (5 pts). The attitude angle measurement error should be below 15% between 0° to 45° (5 pts).<br>• V: Check the accelerometer data and gyroscope data by letting microcontroller print them via WiFi. Place the robot on a hollow cylinder to prevent it from rolling away. Use protractor to place the robot at a certain angle between 0° to 45°, compare the data measured by IMU and calculate the relative error. | 10 |
| Power circuit | • R: Circuit take input voltage from 7.4V battery, output in 3.3V (3 pts). Power circuit should be decoupled for power devices (motor and servo) (2 pts).<br>• V: Use oscilloscope to measure if the average output voltage is correct (within ±10%). Run the motor and add different drag force to it, and check if there is visible pulses of amplitude more than 50% of the output voltage. | 5 |

| Module or overall performance | Requirement and Verification | Points |
|---|---|---|
| Moving Speed | • R: The average constant maximum speed when moving forward straightly should be $\geq 1$ m/s.<br>• V: This speed is measured by the magnetic encoder. The data will be processed in the microcontroller and sent back to control panel in m/s. If there are too much noise in the speed measurement, take the average speed of the steady state as the average constant maximum speed. | 10 |
| Acceleration/brake | • R: The rising time of the maximum speed (1 m/s) step response of the robot should be $\leq 15$ s (4 pts). The time taken to stop the robot from the maximum speed should also be $\leq 15$ s (4 pts). The overshoot of both process should be $\leq 50\%$ (2 pt).<br>• V: Send command to let the robot run to the maximum speed. Log the speed data received by control panel and measure the rising time and overshoot of the both step response using MATLAB. If there is too much noise in the speed measurement, use spline fit it and then measure the response specification. | 10 |
| Wobbliness | • R: Being applied a constant perturbation of $30^\circ$ to roll angle, the robot should be able to re-balance itself to $\pm 10^\circ$ from equilibrium roll angle $\leq 20$ oscillations.<br>• V: Use the protractor to place the robot with a roll angle of $30^\circ$. Then, release the robot and let IMU measure roll angle. The data will be sent back to control panel. Log the data to MATLAB and plot the data versus time to count the total oscillations before it goes into steady state (region within $\pm 10^\circ$). | 10 |

| Module or overall performance | Requirement and Verification | Points |
|---|---|---|
| Turning radius | • R: The minimum turning radius should be $\leq 0.5$ m.<br>• V: Set the robot to rest and let it start to turn in one direction. After the turning motion reaches its steady state, put a ruler inside the turning circle and use a camera to take three pictures from the same position right above the estimated center of the circle. Merge the three pictures into one and use the three positions of the robot to reconstruct the turning circle. Use the relative size of the reconstructed circle and the length of the ruler in the picture, we can calculate the real size of the turning circle. | 10 |

## 3.2 Tolerance Analysis

Different parts of the block diagram has different requirements. Some of these requirements are threshold based and are judged based on pass or fail while some requirements have to achieve a specific value with a range of tolerance. For example, speed and acceleration are threshold based. Because these output results can be varied depending on the control input signal, it would be more intuitive to judge these characteristics by using a minimum threshold value eg. the speed of the robot must be at least 1m/s or faster.

Below are the tolerance analysis of the modules where applicable:

### 3.2.1 Packet Loss Rate

The robot is designed to work around 20 meters such that the packet loss is within the threshold of 10%. However, this radius allows some tolerance due to the different amount of obstacles in between the host and the device. When there are more obstacles in between, the distance from the device will need to be shortened while a clear path will allow for the distance to be further. The tolerance is chosen to be $\pm 2$ m because the distance will be measured with a flexible string.

### 3.2.2 Power Circuit

Another issue is the performances of battery (Venom LiPO 2S 7.4V 210mAh 30C) and the voltage regulators (LD1117V33) because they could greatly impact how each module is powered. In our design, there are total of two voltage regulators, and one of them is only connected to the WIFI module whereas the other one is connected to the rest of the modules. From the voltage regulator datasheet, we find that the load regulation coefficient to be 0.00125. We also find that the maximum current input for WIFI module in running state is 215 mA. Therefore using the load regulation coefficient and the current, we are able to calculate the range of voltage fluctuation, which is 3.3V $\pm$ 0.000269V. Applying the same method, we are able to calculate the range of voltage fluctuation for the rest of the modules, which is 3.3V $\pm$ 0.000337V. According to the voltage regulator datasheet, the maximum quiescent current is 10 mA, thus the current drawn from the battery should be fairly close to the voltage regulator output current. To sum up all the currents that need to be drawn from the battery, 484 mA from all the modules and 1.6 A from the motor, the result is 2.08 A. According to the battery datasheet, the continuous discharge is 30C(6.3A) and max burst rate is 50C(10.5A), which both are greater than the total current needed and therefore both the battery and the voltage regulators should be sufficient to accomplish the task.

### 3.2.3 Wobbliness

The tolerance of 10° is chosen because from observation of the Sphero, there is a wobbliness degree of approximately 60°. This device will try to achieve 0° with a tolerance of 10° which is still considered to be successful by cutting down the wobbliness by 80%.

To further ensure the correct functionality of the device, a constraint of sudden physical disturbance is added.

The robot uses sensors as feedback to control the movement around the roll and pitch axes. However, there are limits to how much deviation from the upright position that the robot can fix and correct itself. For example, sudden bumps on the path may cause the robots incline angle to spike or wind blow may introduce an offset to the angle. The tolerance to physical disturbance is calculated to be about 30°. Do not confuse this with the maximum turning radius that the robot can perform. Under ideal circumstances, the robot can make turns beyond 30°. This tolerance addresses the disturbances from the surrounding and not the system itself.

Angle around the pitch axis is measured using an accelerometer module. When the accelerometer module is set upright, x = y = 0 m/s$^2$ while z = 9.81 m/s$^2$ component. To measure the angle, we can use the different components and basic trigonometry to figure out the angle from the upright position. Figure 8 shows how angle is measured using acceleration. Due to the inefficiency of trigonometric calculations on a microcontroller which is too costly in terms of time and memory, the angle is calculated by linearizing it from 30° sudden physical disturbance up to ±30°. When it is angled, x, y, and z will all have a different to +30°. This ultimately leads to a tolerance of sudden physical disturbance up to ±30° from which the robot can safely use feedback to correct itself.

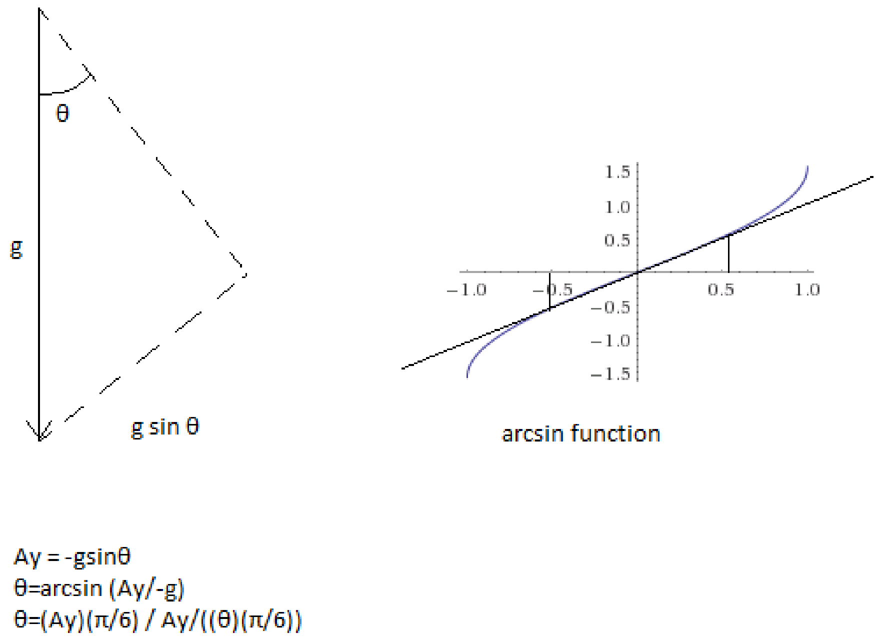


Figure 8. Illustration for attitude measurement linearization.

# 4 COST AND SCHEDULE

## 4.1 Cost Analysis

### 4.1.1 Labor

$$\begin{aligned} \text{Labor Cost} &= \text{Hourly Rate} \times \text{Total Hours} \times \text{Number of People} \\ &= \$25.00 \times 400 \times 3 \times 2.5 \\ &= \$75000 \end{aligned}$$

### 4.1.2 Parts

**Table 2. Parts Costs**

| Part | Quantity | Cost($) |
|---|---|---|
| WiFi Module (ESP8266) | 1 pc | 6.65 |
| Servo (Power HD 3688HB) | 2 pcs | 39.90 |
| Motor Driver (DRV8835) | 2 pcs | 8.98 |
| DC motor (Maxon A-max 22 diameter) | 1 pc | 20.00 |
| IMU (MPU-6050) | 1 pcs | 6.84 |
| Magnetic Encoder (AS5048B) | 2 pcs | 69.90 |
| Microcontroller (Freescale MK20DX256 MCU) | 1 pc | 25.93 |
| Camera (OV7670) | 1 pcs | 13.59 |
| Plastic Ball | 4 pcs | 9.96 |
| 3D Print Filament | 1 roll | 18.00 |
| Gears | 2 bags | 3.92 |
| Li-Po Battery (Venom Fly 30C 2S 210mAh) | 2 pcs | 15.63 |
| **Total** | | 239.30 |

### 4.1.3 Grand Total

$$\text{Grand Total} = \text{Labor Cost} + \text{Part Cost} = \$\ 75202.59$$

## 4.2 Schedule

**Table 3. Project Schedule and Weekly Deadlines**

| Week | Tasks | Students | Major Tasks Due |
|---|---|---|---|
| 8-Feb | Work on proposal together. | All | Project Proposal due (Wed). Mock Design Review Sign up (Thu). |
| 15-Feb | Write firmware for controlling motor using motor driver. | Kaiwen Chen | Mock Design Reviews (Tue-Thu). Eagle Assignment due (Fri). |
| | Attached axle to ball and 3d printed motor/servo chamber. | Zhong Tan | |
| | Rough estimation of component placement on PCB. | Junhao Su | |
| 22-Feb | Write firmware for servo. | Kaiwen Chen | Design Review Sign up (Mon). Eagle Assignment due (Fri). Soldering Assignment Due (Fri) |
| | Attach gears to axle and align gears properly. | Zhong Tan | |
| | Sketch PCB layout according to rough draft. | Junhao Su | |
| 29-Feb | Write $I^2C$ code for gyroscope. | Kaiwen Chen | Design Reviews (Mon-Wed). |
| | Attach mass to servo. | Zhong Tan | |
| | Continue with PCB layout. | Junhao Su | |
| 7-Mar | Ability read signal from magnetic encoder. | Kaiwen Chen | |
| | Ensure the stability of the mechanical infrastructure. | Zhong Tan | |
| | Submit first PCB to manufacturer + prototype board . | Junhao Su | |
| 14-Mar | Ability to control speed of motors and servo orientation. | Kaiwen Chen | |
| | Placement of the magnetic encoder into mechanical design. | Zhong Tan | |
| | Test protoboard. | Junhao Su | |
| 21-Mar | Attempt to integrate separate components into one package and testas a team. | All | |

| Week | Tasks | Students | Major Tasks Due |
|---|---|---|---|
| 28-Mar | Ability to connect WiFi module to WiFi network. | Kaiwen Chen | R&V Table (2nd Attempt) due (Mon).<br>Individual Progress Report due (Mon). |
| | Revisit any mechanical failures. | Zhong Tan | |
| | Receive PCB board from manufacturer. Solder and test. Solder and test. Submit second edition of PCB layout to manufacturer if first try doesnt work. | Junhao Su | |
| 4-Apr | Ability to send data over WiFi. | Kaiwen Chen | R&V Table (Final Attempt) due (Fri). |
| | Prepare final form of robot. | Zhong Tan | |
| | Prepare an alternative for PCB while waiting for second edition. | Junhao Su | |
| 11-Apr | Ability to receive signal over WiFi. | Kaiwen Chen | Mock Demos during TA meeting |
| | Create spare parts for robot in case things go wrong for demo. | Zhong Tan | |
| | Finalize components into PCB. | Junhao Su | |
| 18-Apr | Finalize robot for demonstration. | All | Demonstration Sign up (Mon).<br>Mock Presentation Sign up (Mon).<br>Presentation Sign up (Mon). |
| 25-Apr | | All | Demonstrations (Mon-Wed).<br>Mock Presentation (Thu,Fri). |
| 2-May | | All | Presentations (Mon-Wed).<br>Final Papers due (Wed).<br>Lab Notebook Due (Thu). |

# 5 SAFETY AND ETHICAL ISSUES

## 5.1 Safety Statement

This project consists of both mechanical and electrical components leading to both mechanical and electrical safety concerns. The following are the sources of potential hazard.

### 5.1.1 Saws and Drills

In order to protect ourselves and others from injuries, we will taking extra precaution in handling sawing work. Gloves and goggles will be worn at all times. A clamp will also be used to hold on to the object being sawn and drilled.

### 5.1.2 Glue gun

During the project we will also be working with glue gun. Therefore extra attention is needed while working with one. The following rules should be strictly followed:

- Do not touch the hot nozzle or hot glue when working with glue gun.
- Do not leave glue gun plugged in and unattended
- Make sure to set it down upright on its holder when not using it.
- Do not pull glue sticks out from the glue gun once the gun is plugged in and glue has begun to melt.

### 5.1.3 Soldering

Although soldering is common knowledge, we will take great precaution due to the danger that it can impose. Fume extractor will be used at all times during the soldering process to ensure clean air. Clamps will be used to hold the boards and components to prevent burns on the hands. All wires will be trimmed down and insulated with electrical tape.

### 5.1.4 LiPo Batteries

We will be using Lithium Polymer batteries (LiPo) batteries for their superiority in energy capacity, fast charging speed, and high output current. However, the disadvantage of these batteries is their safety and must be handled with care. After reading the safety guidelines of the LiPo battery manufacturer [3], we will be taking precautions specific to our project as follows:

- Charging will always be monitored due to the potential fire hazard that may occur when left charging for too long.
- Because our project will be tested in water, the LiPo battery will be wrapped such that it becomes water resistant for the possibility that there is a water leak into the robot.
- The robot will be tested in an open area away from flammable energy sources. This prevents danger from potential battery explosion which may emit harmful fumes and fire.
- The battery will be stored separately in a non metal box. This prevents any stray jumper wires from shorting the terminals, causing a potential fire.

## 5.2 Ethical Issues

The project obeys IEEE Code of Ethics as followed [4]:

- to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;
- to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;
- to be honest and realistic in stating claims or estimates based on available data;
- to reject bribery in all its forms;
- to improve the understanding of technology; its appropriate application, and potential consequences;
- to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;
- to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;
- to treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;
- to avoid injuring others, their property, reputation, or employment by false or malicious action;
- to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

This project is inspired by movies such as Star Wars and Jurassic World. Although both of these movies have some elements of violence, our spherical explorer is not created for such reasons. The spherical explorer is made purely for recreational use such as an RC car or a quadcopter. The IEEE Code of Ethics that are applicable to our robot is addressed as follows.

- to improve the understanding of technology; its appropriate application, and potential consequences.

The intentions of the creation of the device is a proof of concept and a way to apply controls theory.

- to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others.

Although there is already a spherical robot sold in the market today, we intend for this to be an improvement and to apply our knowledge in Electrical Engineering. Therefore, we take no credit for the originality of the idea of a spherical robot. As mentioned before, this idea was inspired by movies and the already existing Sphero.

- to avoid injuring others, their property, reputation, or employment by false or malicious action.

The spherical explorer is for recreational purposes. It does not contain any components intended to harm the public nor the environment.

Although we do not intend for violence, it is important to realize that it has the potential to be used for unethical practices. Therefore, we address this issue by leaving very little room for addition of components to the inside of the device, making it as compact as possible. We will also address this issue by making the device more permanent such that modifications cant be easily made. This is an attempt to prevent intentions of unethical use. That being said, we do not intend for this to be used in the military but rather for educational and recreational purposes.

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