FAMU-FSU College of Engineering

System Level Design Review

ECE Team #1

IEEE SoutheastCon Autonomous Robot

Members:

Michael Pelletier (map13m)

Colin Fortner (crf13)

Hunter Fitch (hmf14)

Nicole Perry (np13b)

Faculty Advisor

Bruce Harvey

Instructor

Jerris Hooker

Table of Contents

1 Abstract

The students of this project have been tasked with designing and constructing a fully mobile autonomous robot capable of meeting the specifications and needs spelled out by the IEEE Southeast Con Hardware Challenge 2017 rules (IEEE Southeast Division). The competition has been separated into four separate stages in which each member of the team was assigned a stage as their focus, while also having additional research that is needed to complete this robot. The main stages for the competition involve determining unknown circuit components, detecting electromagnetic fields, deciphering the code using a rotary dial, and firing projectiles through a target. The additional research extends to finding microcontrollers, drive trains, navigation sensors, and chassis design. The following report will outline each the approach and solution to each stage, as well as the decisions made with the other research assignments.

2 Acknowledgement

The Southeast Con group would like to extend a special thank you to Dr. J. Hooker, Dr. B. Harvey, Dr. R Roberts, Dr. M. Yu, the FAMU-FSU COE Machine Shop, and the Institute of Electrical and Electronic Engineers for their roles in the designing of this robot.

3 Introduction

This group is tasked with the design and construction of a fully autonomous robot capable of meeting the needs and requirements of the 2017 IEEE Southeast Con Hardware Challenge. Each stage of the competition will require various tasks of the robot to be completed as described below:

Stage One will have the robot "uncovering the unknown" (IEEE Southeast Division, 2016), by testing five various circuits in unknown configuration to determine what the hidden component is. Each component, a resistor, a wire, a diode, a capacitor, and an inductor, will be assigned a numeric value between and one and five. The robot will then store this information into memory for later use, as well as display the gathered code on a digital display.

Stage Two will require the robot to compete in a "lightsaber duel" (IEEE Southeast Division, 2016). After detecting the presence of a time variant electromagnetic field, "The Force", the robot will initiate repeated contact with the arena's "Lightsaber," only when the field is being momentarily produced.

Stage Three will call upon the values gathered in stage one to "Bring down the shields" (IEEE Southeast Division, 2016). The robot will turn a dial a full rotation for each value collected from the circuit in stage one. With each value turning the opposite direction of the previous value. With an allowable ±15°.

Stage Four will task the robot to "Fire the proton torpedo" (IEEE Southeast Division, 2016). The robot will be loaded with 3 Nerf N-Strike© Darts and tasked with launching them from a distance determined by the robot's ability to navigate steps. The target will be positioned 7.5" from the base of the arena and will consist of a 6"x6" square.

Given the tasks above, the robot will need to be designed to encounter each of the stages in an efficient manner. Each stage will be broken down into the specific needs and requirements to be met by the design. Each requirement will have several solutions associated with it and will be evaluated for various factors including cost, implementation, and feasibility.

4 Project Definition

4.1 Task Assignment

Michael Pelletier – Team Leader

In charge of researching best option for microcontrollers as well as batteries to operate the robot at an efficient pace for the allotted time. Things to consider with the research incudes pin mapping on the microcontroller as well as power output. The battery must be able to maintain the recommended power to the microcontroller to power everything efficiently and effectively. He is also the lead software engineer who will be coding the robot to run the course autonomously, and in charge of the design and coding of stage 1.

As team leader, he manages the team, develops a plan and timeline for the project, finalizes all documents and provides input on other positions where needed. The team leader is responsible for promoting synergy and increased teamwork. If a problem arises, the team leader will act in the best interest of the project.

He keeps the communication flowing, both between team members and Sponsor. He is responsible for setting up appointments and making sure the team members are aware of said meetings. The team leader takes the lead in organizing, and planning. In addition, he is responsible for keeping a record of all correspondence between the group and 'minutes' for the meetings. He gives or facilitates presentations by individual team members and is responsible for overall project plans and progress.

Colin Fortner – Financial Advisor

In charge of researching navigation for the stage. Things to consider when navigating the stage are proximity to walls and the stages as well as optimal routes and sensors to determine position. He is also in charge of the design and coding of stage 4.

As financial advisor, he manages the budget and maintains a record of all credits and debits to project account. Any product or expenditure requests must be presented to the advisor, whom is then responsible for reviewing and the analysis of equivalent/alternate solutions. They then relay the information to the team and if the request is granted, order the selection. A record of these analyses and budget adjustments must be kept.

Hunter Fitch – Lead Mechanical Designer

In charge of researching and developing the chassis for the robot. Thing to consider are locations for the attachments for each stage, balancing the weight of each object and keeping the robot stable. He is also in charge of the design and coding of stage 2.

As lead mechanical engineer, he takes charge of the mechanical design aspects of the project. They oversee the design of the robot chassis with motors and servos

He is responsible for knowing details of the design, and presenting the options for each aspect to the team for the decision process. Keeps all design documentation for record and is responsible for gathering all reports.

Nicole Perry – Lead Electrical Designer

In charge of researching and developing a solution for our drive train. Things to consider are type of motors used to navigate the stage, as well as the best approach for subsequent motors needed for individual stages. She is also in charge of the design and coding of stage 3.

As lead electrical designer, she is responsible of the EE, IE, or CE design part in support of the project. She maintains line of communication with the lead ME. She keeps all design documentation for record.

All Team Members:

- Work on certain tasks of the project
- Buys into the project goals and success
- Delivers on commitments
- Listen and contribute constructively (feedback)
- Be effective in trying to get message across
- Be open minded to others ideas
- Respect others roles and ideas
- Be ambassador to the outside world in own tasks

4.2 Needs Statement

The needs of this project are to design and construct a robot capable of the following. The robot must be small and low cost, capable autonomous operation to navigate and move around the arena, as well as test a five-point circuit, detect using sensors for an electromagnetic field, rotate a combinational dial, and fire projectiles.

4.3 Objectives and Goals

The overall objectives and goals are to comprise a design that can meet the needs and requirements set by each stage in the Introduction to be successful at the Competition.

4.4 Constraints

The constraints on the robot include its cost and size. The estimated budget for this project is $750. Thus, the complete construction of the robot must be at or under this budge. The robot must fit entirely in a 12” by 12” by 12” cube at the start of the match. However, after the run has started, the robot can expand in size or break into multiple independent robots if the robot does not exceed the playing surface (IEEE Southeast Division, 2016).

4.5 Background research

Microcontroller

Since the microcontroller is an essential piece of the robot, a lot of consideration went into which on would be best suited for our robot. When considering microcontrollers, a few key things had to be met. It needed to have enough source pins, it needed analog and pulse width modulation pins, and it needed to fit within our budget. The breakdown of different Microcontrollers looked at can be seen in Table 1.

Table 1: Microcontroller Options

Microcontrollers	Type	Cost	Advantage	Disadvantage
	Raspberry Pi	$40	Familiar Easy to code	No PWM pins No analog pins
	Arduino Uno	$25	PWM and analog pins Easy to code	Not enough GPIO pins
	MSP Launchpad	$20	PWM and analog pins	Difficult coding Not enough GPIO
	Arduino Mega	$35	Plenty of GPIO Easy coding Well known for reliability	
	Axon	$80	Plenty of GPIO	Cost Limited reviews for reliability

Drivetrain

The robot must navigate autonomously around the arena. Potentially, the robot may climb steps to reach have an easier firing of the darts in stage four. The two main drive trains considered are wheeled and tracked robots. Legs are also a possibility. Wheels are very versatile as they come in different sizes and can have a varying number of wheels. Another option, tracks are particularly useful as they move easier through bumpy surfaces and could climb the steps better that the wheels for stage four. Finally, legs could be implemented as they are highly mobile (Benson, 2010). Table 2 discusses the advantages and disadvantages of the different platforms.

Table 2: Platform options

Type of Motor	Advantages	Disadvantages
Wheeled	Simple design; many options	Slip due to little contact with ground
Tracked	Little skip; distributed weight, able to move on elevated grounds	Difficult to turn; complex mechanically
Legs	Close to natural motion; able to overcome rough terrain or obstacles	Complex coding and design, high power demands, high cost

Navigation

Arena Navigation is highlighted in Table 3 with costs and advantages of each method listed within the table. Ultrasonic seems to be the most promising route, but some more research and time will be needed to determine the components being used.

Table 3: Navigation Options

	Type	Cost	Description
Arena Navigation	Infrared Distance Sensor	$12	The advantages of using infrared sensors are their low-cost, accuracy, and reliability.
	Ultrasonic Distance Sensor	$5	The advantages of using ultrasonic sensors are their low-cost, long range, but paint finishes can affect range accuracy.
	Laser Distance Sensor	$150	The advantages of using laser sensors are their accuracy, much more than the IR and ultrasonic, but the cost is much greater than the IR and ultrasonic sensors.

Stage 1

Stage 1 requires the use of circuit analysis to decipher which component is being used. The components can be seen in the figure below. Things that are needed for this stage is a microprocessor for controlling input voltages to the circuit, as well as a multi-meter to read the output voltage. A digital to analog converter may be useful for determining the components for the capacitor and inductor. The correct code will be displayed using some sort of screen. (Table 4).

Table 4: Component to code values

Code	Component Type	Component Value
1	Wire	N/A
2	Resistor	10K, 10% tolerance
3	Capacitor	0.1uF, non-polarized
4	Inductor	500mH
5	Diode	1N400-cathod/anode can be oriented in either direction

Stage 2

Stage 2 requires the robot to detect an electromagnetic field produced by a coil constructed from 40 turns of #20 stranded copper wire wound around a 0.5” diameter bobbin. A current of 1 A will be fed through the magnet to generate a positive field (as measured from the front side of the wall on the robot arena side) (IEEE Southeast Division, 2016). The lightsaber will be constructed to contain 8 LED indication lights and a vibration sensor to accurately detent contact, made from the robot to the arena mounted components. These components are as listed in the Table 5.

Table 5: Lightsaber Technical Components

Vibration Sensor	Tech Specs • Maximum Operating Temperature: 260°C ± 10°C • Contact Time: 2 - 2.5ms Dimensions: • Diameter: 5mm / 0.2" • Height (w/ pins): 23mm / 0.9" • Height (w/o pins): 11mm / 0.4" • Weight: 0.2g
LED Indication Lights	Dimensions: 51.10mm/2"x10.22mm/0.4"x3.19mm/0.12" Weight: 2.57g

To meet the needs of the electromagnetic fields, the robot will be equipped with an electromagnetic field sensor. Preliminary research resulted in the Table 6, consisting of a couple options for sensors capable of meeting the needs set. While both sensors operate in the same manner and would produce the required results for this stage of the challenge when connected to the circuit built with the microcontroller, each has a different operating voltage range. This range can change the way in which the sensor is able to operate with the robot and its other components. Design requirements will decide which type of electromagnetic sensor will be needed to successfully take on this stage. The rotational movement needed for the robot’s lightsaber to make contact with the arena's lightsaber will be supplied by some sort of rotational motor, see Table 6 for various motor options.

Table 6: EMF Sensors

	Name	Cost	Description
EMF Sensors	Honeywell SS495A	$1.41	• Operates between 4.5V to 10.5V • Ideal for various fields, operation proportional to produced field
	Honeywell 2SS52M	$3.23	• Operates between 3.8V to 30 • Can be implemented to operate within more than 1" of the field • Ideal for low fields

Stage 3

Stage 3 requires using the code from stage 1 to unlock a combination lock. The lock is a quadrate encoder with a RGB LED (Figure 1) and a clear plastic knob attached to it (IEEE Southeast Division, 2016). When the encoder is turned, it outputs a 2-bit gray code that represents the direction and amount of turns.

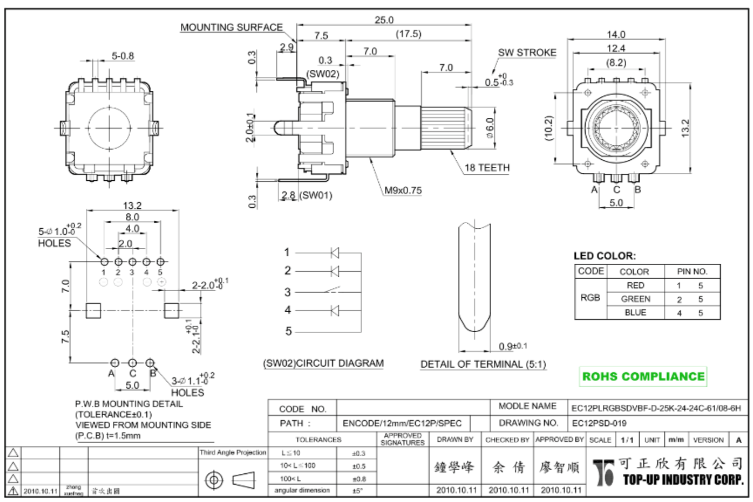

Figure 1: COM-10982 ROHS Data Sheet

Actuators are special types of output transducers. To turn the knob, rotational actuators could be used to transform electrical energy into rotational motion. Two possible types that would efficiently turn the knob are a servo or steeper motor. Servos consist of a direct current motors, a gearing set, potentiometer, and control circuit all contained in one unit. DC motors are rotated by the current. Two terminals determine the direction the motor will spin. Switching the polarity of the terminals reverses the direction of the motor. The speed of the motor is controlled by the current supplied. Servos are precise and have speed control. Three wires control the servo. The first is power, the second is ground, and the third is a digital control line. The digital control line regulates the position of the servo. A coded signal determines the direction and rotation speed. As long as the same signal is applied, the direction and speed of the servo is maintained (Hughes, 2016). Stepper motors are synchronous electric motors that use digital pulses to rotate. The rotation and its direction is divided into steps controlled by a pulse (Stepper Motors). Motor options are discussed in Table 7.

Table 7: Motor Options

Type of Motor	Cost	Description
Continuous Rotation Servo	\$5-\$30	Rotates 360°; Fast rotation; Smooth motion
Stepper Motor	\$15-\$30	Easy to control; Simple implementation; Little power; Limited movement
Rotational Actuator	\$5-\$15	Ideal for “flipper” actions; low power draw; Very limited movement

Stage 4

Stage 4 requires the robot to fire Proton Torpedoes (Nerf© darts) through a 6” x 6” cutout framed in 1” x 2” wood with the frame located 3.5” (Figure 2) above the top step of the arena. Depending on where the torpedo is fired from in the arena the firing angle may need to be in a positive or negative direction to allow the torpedoes to go through the framed opening.

Table 8: Projectile Options

	Type	Cost	Description
Projectile Firing	Nerf Gun	\$30	Precision built for the projectiles being used in competition, however the size of the guns can hinder the robots complete design.
	Hand Built	\$30	Would be more suited to the robot’s specifications for the size constraints of the competition.

From research the methods to fire a nerf dart are limited to using a stock nerf gun or building a custom nerf firing device that fits the robot. Each method will cost about the same to implement on the robot, and will need further discussion to determine the method that will be used for competition.

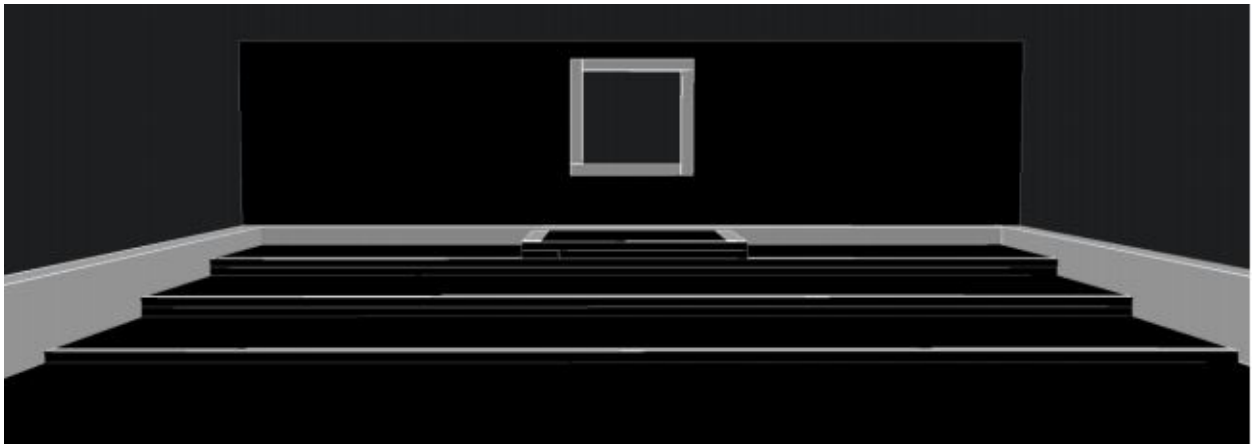

Figure 2: Stage 4 Layout

5 Environment

The robot will be tested in a 45” wide by 93” long playing field (Figure 3). There are four levels. Each stage is located on one of the walls. Stages 1, 2, and 3 will on the lowest and largest level. On this level is the 15” by 15” starting square. Stage 4 is on the top level. A run starts when the robot moves. Stage 1 must be completed before Stage 3, while Stage 4 stops the timer an thus must be completed last.

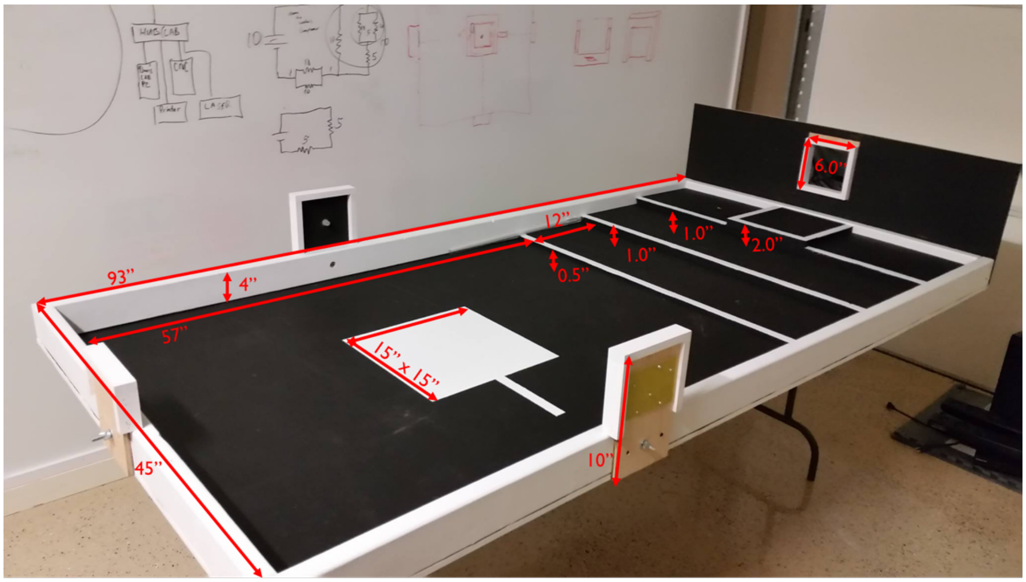

Figure 3: Arena Layout

6 Deliverables

6.1 WBS

- Navigation
  - The robot needs the ability to sense where in the arena it is to engage and complete the stages.
  - Final decision on sensors to be approved by the group and purchased on November 7th.
  - Completed by November 7th
  - Colin
  - Resources
  - Drivetrain, chassis design, microcontroller
- Chassis Design
  - Robot Body designed to house all components and fit within a 10"x10"x10" volume
  - Official designs approved by group and sent to proper machine shop for construction resulting in a complete robot chassis ready for motors, sensors and other various components to be added
  - Completed by Dec 2nd
  - Hunter
  - Resources
  - Drive Train, and Stage 1-4 components must be completed prior to official design implementation
- Microcontroller
  - Microcontroller must be chosen that can house enough pins in order for all parts, servos, and sensors.
  - Official choice approved by group. Part ordered and implemented.
  - Completed by Nov 7
  - Michael
  - Ordered Parts
  - No predecessors
- Power Supply
  - Battery must be chosen that can supply enough power to our robot.
  - Official choice approved by group. Part ordered and implemented.
  - Completed by Jan 9
  - Michael
  - Ordered Part
  - Calculations of power consumption must be completed prior to power supply selection.
- Drive Train
  - The movement system for the robot. Includes the platform and motor controller.
  - Official design approved by group. Parts ordered, constructed, code written, and tested.
  - Completed by Jan 30

    - Nicole
    - Ordered parts.
    - Stage 4 design must be completed prior to official design implementation.
- Stage 1 - "Uncover the Unknown"
    - Circuit component identification process
    - Official Designed approved by group, Parts ordered and ready for implementation, Code Written and ready to be implemented
    - Completed by Jan 30th
    - Ordered Parts
    - Michael
    - Microcontroller must be chosen.
- Stage 2 - "Lightsaber Battle"
    - Electromagnetic Field Sensing and Lightsaber movement
    - Official Designed approved by group, Parts ordered and ready for implementation, Code Written and ready to be loaded
    - Completed by Nov 10th
    - Ordered Parts
    - Hunter
    - EMF Sensor must be implemented before lightsaber motion can be implemented
- Stage 3 - "Bring down the Shields"
    - Implements code into an encoder.
    - Official design approved by group. Parts ordered, constructed, code implemented and tested.
    - Completed by January 30th.
    - Ordered parts
    - Nicole
    - Stage 1 design must be completed prior to writing code.
- Stage 4 - "Fire the Proton Torpedo’s"
    - Fires three NERF darts through a 6”x6” target area.
    - Official design approved by group. Parts ordered, constructed, and ready for implementation, code written and implemented.
    - Completed by January 30th
    - Colin
    - Drivetrain, chassis, microcontroller

6.2 Critical Tasks

Tasks that need to be finished first include receiving the microcontroller, chassis design, and navigation. The microcontroller needs to be chosen in order to start testing code. The chassis design needs to be finished so we can start looking at the actual robot in the field. The navigation needs to be determined on order to decide how we are going to move autonomously from stage to stage. Without these three components, the robot will not even be able to make it to the stages to receive points.

6.3 Gantt chart

Work Completed during Fall 2016:

Task	Lead	Start	End	9/12	9/19	9/26	10/3	10/10	10/17	10/24	10/31	11/7	11/14	11/21	11/28	12/5
Rules and F	All	9/12	9/26													
Testing anc	All	1/30	3/27													
2017 IEEE S	All	3/27	4/3													
Microcontroller																
Research	Michael	9/19	10/24													
Device Sele	All	10/24	11/7													
Coding	Michael	12/5	1/9													
Drive Train																
Drive Train	Nicole	9/19	10/24													
Motor Con	Nicole	9/19	10/24													
Platform Sc	All	10/24	10/30													
Platform D	Hunter	10/24	11/7													
Drive Train	Nicole	1/9	1/30													
Power supply																
Power Resc	Michael	9/19	10/31													
Power Sup	Michael	10/31	11/7													
Parts Orde	Colin	1/9	1/9													
Robot Chassis																
Chassis De	Hunter	11/7	1/9													
Chasssis Bu	Hunter	1/9	1/30													
Navigation																
Navigation	Colin	9/19	10/31													
Sensor Sele	All	10/31	11/7													
Parts Orde	Colin	11/7	11/7													
Sensor Cod	Colin	11/14	1/9													
Implement	Colin	1/9	1/30													
Stage 1																
Circuit Desi	Michael	10/24	10/31													
Parts Orde	Colin	11/7	11/7													
Code writir	Michael	11/14	1/9													
Display Imp	Michael	11/14	1/9													
Stage Build	Michael	1/9	1/30													
Stage Test	Michael	1/16	2/6													
Stage 2																
EMF Senso	Hunter	9/19	10/31													
Lightsaber	Hunter	9/19	10/31													
Motor Desi	Hunter	10/17	10/31													
Sensor Des	Hunter	10/17	10/31													
Parts Selec	All	10/31	11/7													
Parts Orde	Colin	11/7	11/7													
Motor Cod	Hunter	11/14	1/9													
Sensor Cod	Hunter	11/14	1/9													
Stage Build	Hunter	1/9	1/30													
Stage Test	Hunter	1/16	2/6													
Stage 3																
Motor Resc	Nicole	9/19	10/31													
Motor Con	Nicole	9/19	10/31													
Gripper/ A	Nicole	10/10	10/31													
Design Sele	All	10/31	11/7													
Parts Orde	Colin	11/7	11/7													
Motor Cod	Nicole	11/14	1/9													
Stage Build	Nicole	1/9	1/30													
Stage Test	Nicole	1/16	2/6													
Stage 4																
Launch Me	Colin	9/19	10/31													
Firing Mecl	Colin	10/24	11/7													
Barrel Desi	Colin	10/24	11/7													
Propulsion	Colin	10/24	11/7													
Part Select	All	10/31	11/7													
Parts Orde	Colin	11/7	11/7													
Fire Coding	Colin	11/14	1/9													
Stage Build	Colin	1/9	1/30													
Stage Test	Colin	1/16	2/6													

Work to be completed in Spring 2017

Task	Lead	Start	End	1/9	1/16	1/23	1/30	2/6	2/13	2/20	2/27	3/6	3/13	3/20	3/27	4/3
Rules and F	All	9/12	9/26													
Testing anc	All	1/30	3/27													
2017 IEEE S	All	3/27	4/3													
Microcontroller																
Research	Michael	9/19	10/24													
Device Sele	All	10/24	11/7													
Coding	Michael	12/5	1/9													
Drive Train																
Drive Train	Nicole	9/19	10/24													
Motor Con	Nicole	9/19	10/24													
Platform Se	All	10/24	10/30													
Platform D	Hunter	10/24	11/7													
Drive Train	Nicole	1/9	1/30													
Power supply																
Power Rese	Michael	9/19	10/31													
Power Sup	Michael	10/31	11/7													
Parts Order	Colin	1/9	1/9													
Robot Chassis																
Chassis De	Hunter	11/7	1/9													
Chasssis Bu	Hunter	1/9	1/30													
Navigation																
Navigation	Colin	9/19	10/31													
Sensor Sele	All	10/31	11/7													
Parts Order	Colin	11/7	11/7													
Sensor Cod	Colin	11/14	1/9													
Implement	Colin	1/9	1/30													
Stage 1																
Circuit Desi	Michael	10/24	10/31													
Parts Order	Colin	11/7	11/7													
Code writir	Michael	11/14	1/9													
Display Imp	Michael	11/14	1/9													
Stage Build	Michael	1/9	1/30													
Stage Test	Michael	1/16	2/6													
Stage 2																
EMF Senso	Hunter	9/19	10/31													
Lightsaber	Hunter	9/19	10/31													
Motor Desi	Hunter	10/17	10/31													
Sensor Des	Hunter	10/17	10/31													
Parts Selec	All	10/31	11/7													
Parts Order	Colin	11/7	11/7													
Motor Cod	Hunter	11/14	1/9													
Sensor Cod	Hunter	11/14	1/9													
Stage Build	Hunter	1/9	1/30													
Stage Test	Hunter	1/16	2/6													
Stage 3																
Motor Rese	Nicole	9/19	10/31													
Motor Con	Nicole	9/19	10/31													
Gripper/ Ar	Nicole	10/10	10/31													
Design Sele	All	10/31	11/7													
Parts Order	Colin	11/7	11/7													
Motor Cod	Nicole	11/14	1/9													
Stage Build	Nicole	1/9	1/30													
Stage Test	Nicole	1/16	2/6													
Stage 4																
Launch Me	Colin	9/19	10/31													
Firing Mecl	Colin	10/24	11/7													
Barrel Desi	Colin	10/24	11/7													
Propulsion	Colin	10/24	11/7													
Part Selecti	All	10/31	11/7													
Parts Order	Colin	11/7	11/7													
Fire Coding	Colin	11/14	1/9													
Stage Build	Colin	1/9	1/30													
Stage Test	Colin	1/16	2/6													

7 Budget

The total budget for the project is $750.00. $301.11 was spend in Fall 2016 leaving a remainder of $448.89 (Table 9). The remaining funds to be send is shown in Table 10.

Table 9: Budget Spend

Product	Qty	Total
Rotary Encoder	1	$3.95
Clear Plastic Knob	1	$0.95
Continuous Servo	1	$11.95
Drivetrain	1	$78.93
Arduino Mega	2	$73.98
Magnetic Sensor	1	$2.00
IR Sensors	8	$108.20
Shipping	1	$21.15
Total Spent		$301.11
Budget Left		$448.89

Table 10: Estimated Spending

Product	Estimate
Batteries	$100
Materials for Stage 1	$50
Materials for Stage 2	$50
Materials for Stage 3	$30
Materials for Stage 4	$50
Materials for chassis	$50
Estimated to be spent	$330
Emergency Fund Left Over	$118.89

8 Product Specifications

8.1 Design Specifications

This product is limited to one cubic foot of area. There is a limit of 30 PSI for firing of the nerf projectile, which if implemented, will be pressurized manually before each run. Tentative chassis design is a three tiered structure with the microcontroller and motor controllers on the first level. The circuit board and rotational servo for stages one and three respectively, as well as any distance sensors on the second level. The third level with consist of the EMF sensor and nerf firing mechanism for stages two and four respectively. The LED display will be mounted on the side of the robot for readout in stage one.

8.2 Performance Specifications

The distance sensors used will need a maximum range of at least 36 inches. The battery on the design must be able to supply an input voltage to the microcontroller in a range of 7.2V to 12V constantly for a four minute period. The robot must run autonomously so error detection must be implemented in coding to correct any errors. Due to the fact that it is autonomous, accuracy of the sensors and positioning of the components is crucial to success. The smallest error in accuracy can ruin a run if not properly handled. Most power consumption will probably come from the EMF sensor in order to detect the field, however calculation needed to be made.

9 Conceptual Design

The design for our project is set to have the front and back of the robot to have two extensions each. Each extension will correspond to an individual stage of the competition. For stage one and three, the heights are at a fixed position that cannot be altered, due to this fact, it makes sense that these sensors be on opposite sides of each other. The light saber for stage two and the projectile launcher in stage four do not have designated locations so they can be mounted above the extensions for the previous two stages. The sides of the robot would be difficult to use with extensions due to the fact that we are using tracks and it would be unnecessary to approach an obstacle sideways as opposed to head on. For that reason, the sides of the robot will be used to monitor the display screens, distance sensors as well as the drive train of the robot.

Other designs that were considered for the build of the robot include a rotating platform that could change 90 degrees in order to have one extension on each side. However due to the fact that we have plenty of room vertically, this added complication was not necessary. Wheels were another option for our motion. It would have been just as easy to implement and design, with faster movement. However, the decision to use tracks was made for the purpose of stage four. The use of track makes climbing the stairs to get closer to the target.

The system is shown in Figure 4. Subsystems are described below in *Solutions and Designs*. The input will just be an "On and Off" switch only due to the autonomous nature of the robot. The output will be mechanical movement.

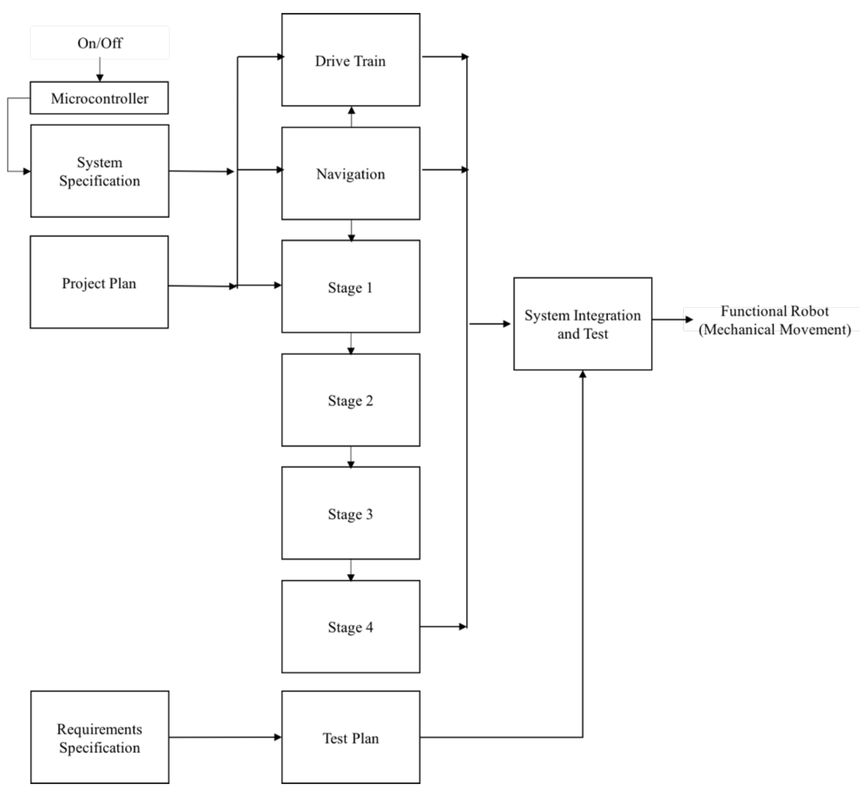

Figure 4: System Design

10 Solutions and Designs

10.1 Microcontroller

Raspberry Pi and MSP 430 were familiar with the team since members had some previous experience coding with it. However, they lacked the specific types of pins needed for our robot. The Arduino Uno was good with functionality but running out of analog and PWM pins was a fear. Between the Axon and the Arduino Mega, both of which had plenty of GPIO pin, the Arduino Mega was ultimately chosen due to pricing and credibility from multiple users.

10.2 Drivetrain

The platforms we are considering are wheels, tracks, and legs. The robot needs to move mainly in linear paths due to the arena layout. Pending approval from the competition designer, the stages will be completed in the following order, 1, 3, 2, and 4. This allows for the least amount of turns. It does not need to achieve high speeds but should be able to move to the stages in a timely manner as time will be tie-breaker if all stages are completed. Wheels are a good solution as they are low cost and simple to use. However, finding wheels to climb stairs can be difficult. In that regard, tracks would be more efficient as they allow for greater ground clearance without the need for a larger drive wheel. They are more expensive and complex to implement than wheels. Finally, the last platform is legs. Although they would allow for the climbing of stairs. For this project, they are too expensive and complex to implement without offering a significant increase in performance.

For the final stage, we decided to climb stairs to make completing this stage easier. Thus, a Vex Robotics tank tread kit was chosen. This kit includes all components to create the platform except for the chassis base, motors, and axles. Each track is 32.75 inches if laid out in a straight line. For reference, if the tracks were placed in a circle, the diameter is about 10.43 inches. The robot will have a platform of 10 inches or less, so the kit has plenty of links to accomplish this. Further, spare links are available if there are damages. Tracks tend to stretch over time. A tensioner is included in the kit to extend the use of the tracks. Also, with the extra links and because the tracks are affordable, the tracks are easily replaced. Table 11 shows all components of the kit.

Table 11: Vex Robotics Tank Tread Kit Components

Description	Quantity
Tread Links	170
Tank tread drive/idler wheels	4
Double Bogie wheel assemblies	4
Single Bogie wheel assemblies	2
8-32 x 1" Bogie wheel support screws	12
Keps nuts	12

The tracks are controlled by a motor. Vex Robotics recommends using the corresponding motor (Table 12) and motor controller. The Vex Robotics tanks tread kit have unique square axel connection. The Corresponding DC motors have this axel shape, so using the motors will not require convertors. The Vex Robotics 2-wire DC motor can freely rotate at 100 RPM when powered at 7.2 V. A high-speed option can also be configured to allow the motor to rotate at 160 RPM. The Vex Robotics motor controller used can control 1 motor at a time. The microprocessor connects to the motor controller that controls the motor (Figure 5). The direction and movement of the robot are determined by sensor readings.

Table 12: Vex Robotics Motor 393 Specifications

Description	**Quantity**
Output Stage Driving Gear	10t
Output Stage Driven Gear	28t
Output Speed (RPM)	100
Output Stall Torque (N*m)	1.67
Weight (lbs)	0.192

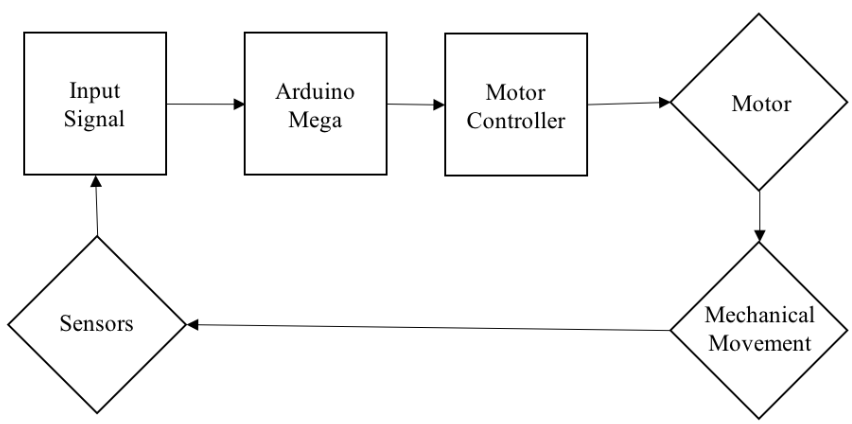

Figure 5: System-level design of drivetrain

Before purchasing the motor and motor controller, more calculations are to be conducted to determine if the motor has enough torque to move the robot. At this current moment in the process, the weight of the robot is undetermined. After the chassis is build, the final motor will be selected and purchased.

10.3 Navigation

The solution for navigation is shown in Figure 6. There are six infrared sensors placed strategically around the robot, and two bump sensors located at the front and rear of the robot. There are two infrared sensors placed on the front and the rear of the robot. One sensor is a long-range sensor that has a range of 20cm – 150cm, and the second sensor is a short-range sensor that has a range of 4cm – 30cm range. These sensors will control the speed as the robot approaches stages, and the bump sensors will tell the robot when it has reached a stage. The long-range sensors on the side of the robot also have a range of 20cm – 150cm, that will be placed at the extremes of the robot on those sides to allow the robot to see if it is travelling straight and true to whatever stage is to be engaged. The front bump switch will be mounted in a way that will allow it to not engage the first two steps that the robot must climb, but will engage the two-inch step and allow the robot to stop and fire the three nerf darts through their target area.

The two infrared sensors mounted on the side of the robot will measure both distance and whether the robot is driving straight and true. It is possible, that when the robot turns, the sensors will read an equal amount off of two walls during the turn. The robot will start going in a diagonal and not towards the stage. This is something that will be worked out in the testing phase to determine how the sensors will read and if the sensors will even read during the turn, and once the robot completes the turn allow the robot to find the single wall this design is meant for. Once that wall is found the robot will align itself to the wall to start driving straight to compete stages two and four.

The decision for infrared sensors was made because of the reliability and accuracy of the sensors. Infrared was chosen over two other types of sensors, ultrasonic and laser. The drawbacks to these sensors is that while the ultrasonic is cheap, outside noises can interfere with the distances being measured. The laser sensors on the other hand are very accurate, but only at long distances, and are very expensive to implement.

Figures 6, 7, and 8 show the way the sensors on the front and rear of the robot will read the data taken in. Figure 7 is for the long range infrared sensor on the front of the robot, and checks to see if the robot is within 25 cm, if it is not, the robot continues at the original speed, if not it hands the control over to the short range infrared sensor. Figure 7 shows the block diagram for the short range infrared sensor and adjusts the speed so that the robot does not hit the wall at full speed, to do this the robot will check to see if it is within the 7-cm threshold, if it is the robot will set a slow constant speed and wait for the bump switch to be engaged. Figure 8 shows the bump switch circuit which shows that when the bump switch is activated, stop the robot and engage the stage. The final block diagram is shown in figure 10, it is for the two-broad side long range infrared sensors. It basically says that when the sensors are not equal the robot will align itself to the wall and the proper distance from the wall the robot needs to be to engage the next stage.

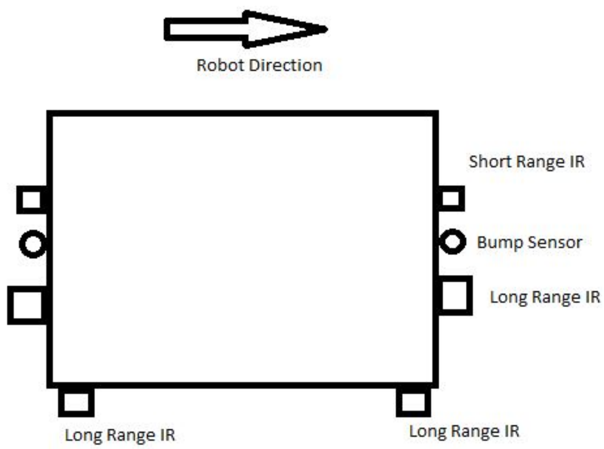

Figure 6: Sensor placement

Figure 7: Long Range Sensor Design

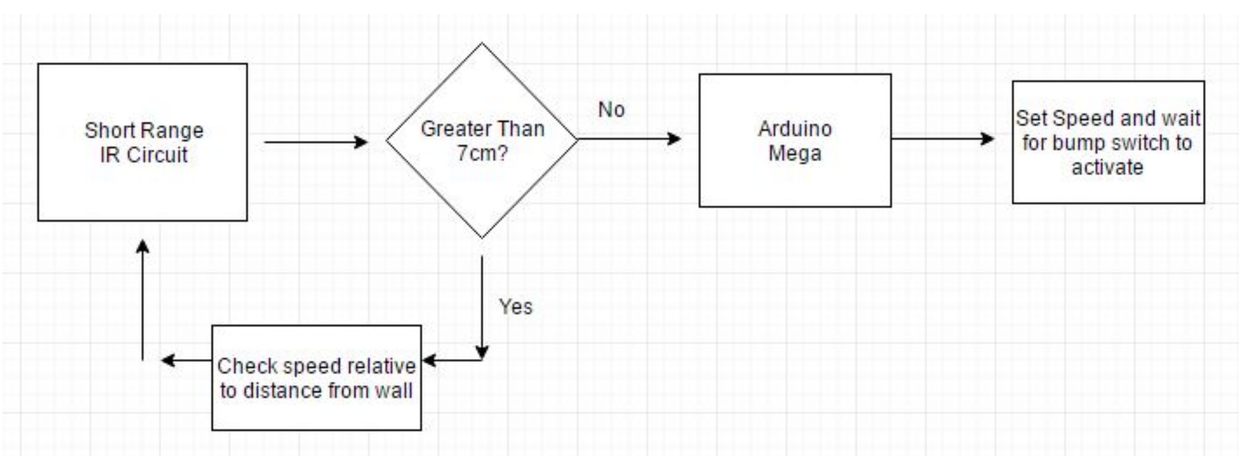

Figure 8: Short Range Sensor Design

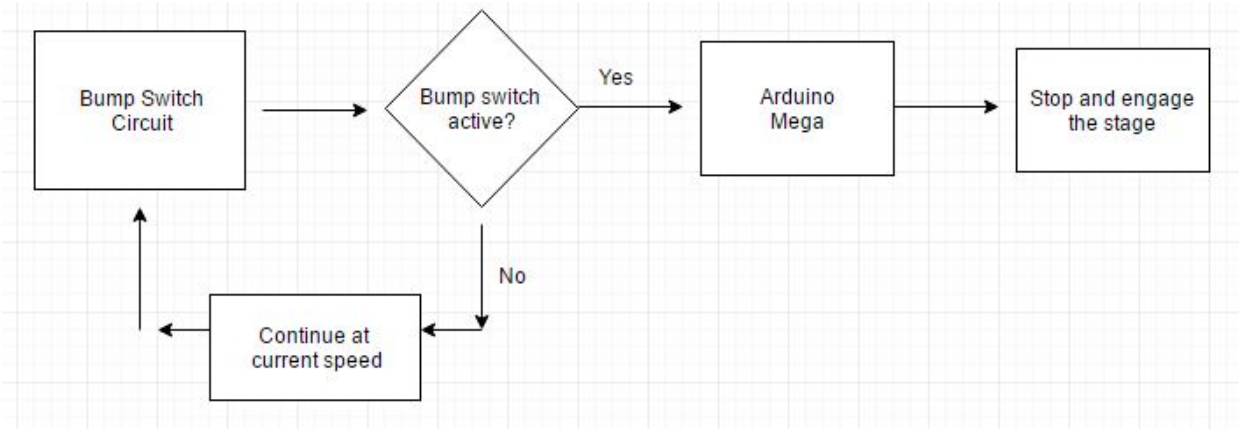

Figure 9: Bump Switch Design

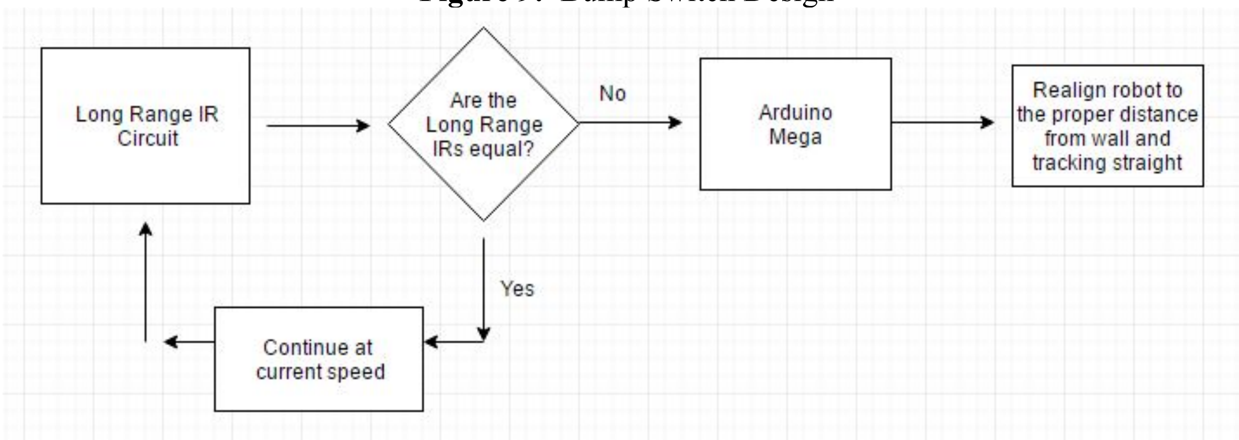

Figure 10: Complete System Design

10.4 Stage 1

The design choice for the attachment was whether to use a single prong to connect the robot to the stage component and rotate through the other terminals, or to have all five prongs attach to each of the terminals and read them individually. The idea of using one prong was not used due to it adding unnecessary difficulty with rotating to find the next prong. Because the approach on stage one is largely dependent on decoding the capacitor and inductor, these components were the focus for designing the stage. Initially, the plan was to use a pulse width modulation pin to simulate a sine wave. From there, we would be able to use an oscilloscope reading to determine if the output voltage was leading or lagging. This could determine if it was a capacitor or inductor respectively. This approach was scrapped when it was determined that using sensors determining the power factor would be difficult to do autonomously. The next approach that was ultimately chosen as the solution our team went with was a simple circuit that took voltage readings at certain time intervals to determine the component (Figure 11).

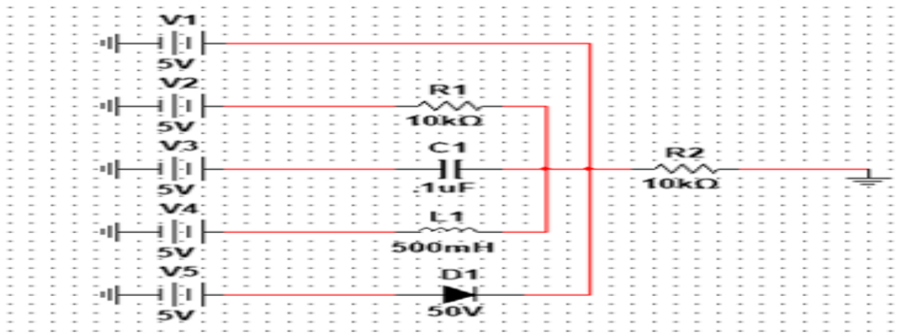

Figure 11: Circuit layout

Each of the five components in parallel are the ones hidden behind the stage. The voltage reading is taken over the highlighted resistor initially when the pin was turned on, and then again one second later. For the wire, resistor, and diode, voltage will remain constant. For the capacitor, as the capacitor is charging, the voltage across the resistor will drop, and vice versa for the inductor. These differences are recorded and can be used to determine the components.

Voltage calculations are taken across each path seen in *Figure 11* and are as followed:

Wire: Total voltage from pin to ground = 5V

Resistor: $V_R = V_{in} * \frac{R_2}{R_1+R_2} = 5 * \frac{10K}{10K+10K}$ = 2.5V

Diode (forward bias): $V = V_{in} - V_F = 5 - 0.6$ = 4.6V

Diode (reverse bias): Will act as an open circuit = 0V

Capacitor: $V_R = V_{in} - V_{in}(1 - e^{\frac{-t}{RC}})$

When t=0: $V_R = V_{in}$ = 5V

When t= 1: $5 - 5(1 - e^{\frac{-1}{10K*.1\mu}}) \approx$ 0V

Inductor: $V_R = V_{in}(1 - e^{\frac{-Rt}{L}})$

When t=0: $V_R = 0V$

When t= 1: $5\left(1 - e^{\frac{-1*10K}{-500m}}\right) \approx$ 5V

The values for the resistor voltage are going to be the basis for determining the hidden component. The approach for coding this section would be to first determine if the voltage in the beginning matches the voltage after one second. If the initial voltage is significantly higher than the voltage at one second, the component must be the capacitor. If the voltage after one second is significantly greater than the voltage at the beginning, the component must be an inductor. If the two voltages are the same, then the voltage will be checked to determine the component. If the voltage reading is 5 volts, the component must be the wire. If the voltage is 2.5 volts, the component must be the resistor. Finally, if none of those are true, then the component must be the diode. Checking the diode at the end allows us not to worry if it is in forward or reverse bias.

10.5 Stage 2

"The Lightsaber Duel" has been approached from several different angles until ultimately deciding on the solution below. The original idea was to determine the magnitude of the magnetic field induced into the arena, then using a Hall Effect sensor in conjunction with the microcontroller with a set range for when the electromagnetic field is active, determine if the robot was sitting in an active electromagnetic field. Once confirmed, the robot would activate its motor attached to the Lightsaber, and complete the stage. After further research and testing, the student group decided upon the use of a Reed Switch. A reed switch is a mechanical switch typically comprised of two metal contacts inside a glass or plastic housing, in the presence of an electromagnetic field, the contacts touch thus closing the switch. The reed switch will be implemented into a parallel circuit with the microcontroller. This circuit will determine if the field is on or off with the active low circuit. The diagram below shows the basic flow for the Reed Switch use.

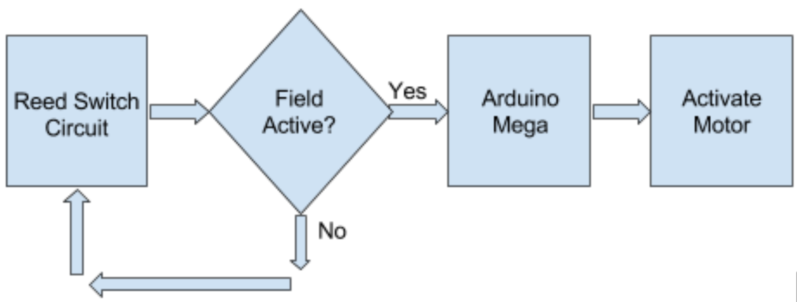

Figure 12: Block Diagram of Reed Switch Operation

The reed switch will utilize a simple parallel circuit connected to the Arduino Mega microcontroller to determine if the field is active. The circuit below depicts the configuration of the reed switch

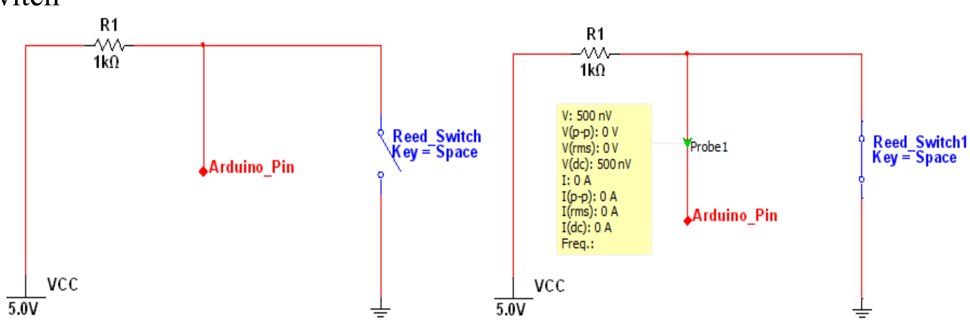

Figure 13: Reed Switch Circuit to be implemented on the robot

The 5V VCC pin comes from the output of the Arduino, and connects to an input pin, as well as ground on the Arduino. An inactive field will leave the reed switch open and all the pin to read 5V. Once the field is active, the switch will close connecting the circuit to ground and reading very low voltage over the pin. As seen in figures 12 and 13. Once the active field closes the switch, the Arduino will power the motor attached to bot-mounted lightsaber which will then contact the Lightsaber on the arena.

The reed switch used will be the Electronic Brick Reed switch. This device fully incorporates the pin ports, the resistor, and the reed switch into a single easy to implement chip. This device was chosen over a standard reed switch to be built into a circuit for a few reasons. The first reason for selection was the price, both the Electronic Brick and a standard reed switch cost the same amount. By choosing to use the Electronic Brick, the group can reduce costs by not needing to order additional parts, or assemble the circuit. This also allows for a more precise connection by not having the expected human error associated with producing the circuit. The final reason for selection of the Electronic Brick is the reduced sensitivity to vibrations. A standard reed switch is very sensitive to vibration, as the metal components inside tend to touch when the robot moves, whereas the Electronic Brick has proven, through testing, to not be sensitive to movement and will accurately determine if the robot is sitting inside an active electromagnetic field.

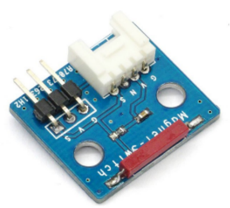

Figure 13: Reed Switch

The motor selection and design of the robot's lightsaber are still being worked on and will be finalized after group consideration before full implementation of the Robot. The design in Figure 14 shows the conceptualized idea for the completion of the stage. The motor will be mounted below the top plate of the robot, and the lightsaber will be mounted perpendicular to the arena mounted lightsaber.

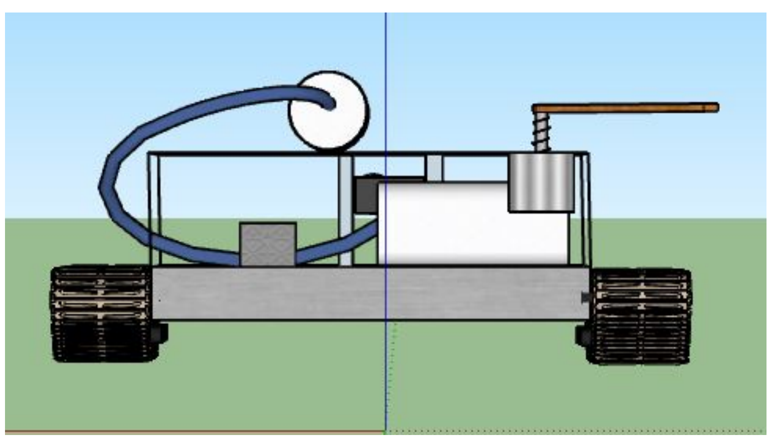

Figure 14: Robot Chassis Concept with Stage 2 lightsaber mounted on Robot Backside

10.6 Stage 3

Stage 3 implements the code found in stage 1 on a quadrature encoder (Table 13). The encoder is able to rotate freely and records the direction and number of turns. The robot needs to turn this knob a full 360 degrees to represent a value of one. The knob is continually turned in the same direction until the turns equal the value of the digit. To change digits, the knob is turned in the opposite direction. There is +/- 15 degrees for each turn. A total of five figures needs to be implemented. The approach is to use a motor that has some type of gripper attached to it. The motor needs to rotate 360 degrees and should be fast and precise.

Two motors initially considered are a continuous rotation servo and a stepper motor. Servos are fast and can rotate smoothly. Stepper motors are easy to control and allow for precise turns. Currently, a micro-continuous rotational servo is in effect. Some precision is lost through the use of the servo, but due to the +/ 15 degrees for each turn, we have some room for error. A position sensor may be added to the motor to achieve more precise rotations. Figure 15 shows the overall design of the system.

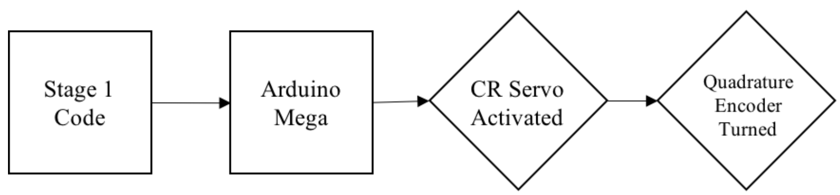

Figure 15: System-level design of Stage 3

The continuous rotation servo (Table 14) chosen offers enough torque to turn the rotary encoder. When powered at 4.8 volts, the servo can turn 360°, clockwise or counterclockwise, in 0.96 seconds.

Table 13: Rotary Encoder Specifications

Description	**Quantity**
Shaft rotational direction	4
Shaft rotational speed	360°/second
Detent torque	30 -200 gf.cm
Shaft Diameter	6.0 mm
Shaft Diameter with knob attachment	15.0 mm

Table 14: Micro Continuous Rotation Servo Specifications

Description	**Quantity**
Voltage	4.8 Volts
Torque	2002 gf.cm
Speed	360°/0.96sec

In Figure 16, a block diagram is shown for Stage 3. The Arduino "Servo.h" library is used with servos. A servo object is created and connected to a PWM pin on the Arduino. The digital code from Stage 1 is read into forward and reverse function as integer values. Continuous rotation servos are controlled by values from 0 to 180. A value of "90" will stop the servo. The farther the value from 90, the faster the servo will rotate. 0 to 91 represents a counterclockwise direction, while 91 to 180 will rotate the servo clockwise. A forward function is used for digits 1, 3, and 5. This function will rotate the servo and thus the encoder clockwise. The reverse function is implemented for digits 2 and 4. The number of turns in controlled through delay values.

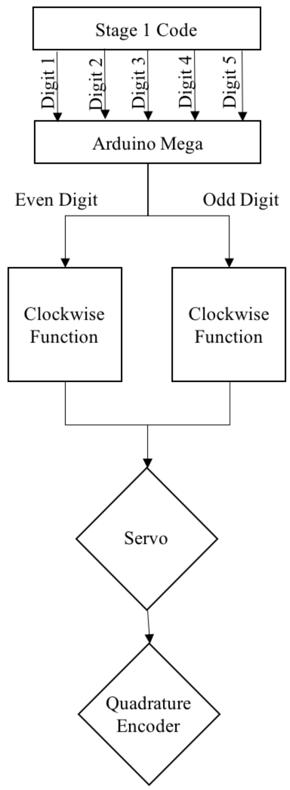

Figure 16: Stage 3 System Design

10.7 Stage 4

The solution for stage four is a very simple solution with only one moving part in the design. Mounted forward facing and towards the top of the robot will be three ½" PVC barrels that are roughly 6 inches in length. These barrels will each contain a nerf dart that will be fired when the robot reaches the predetermined area where it is decided that the robot will fire from efficiently and accurately to hit the 6-inch by 6-inch target. The other parts of the firing system are the pressure vessel and the solenoid valve that will be activated when the nerf dart is to be fired. The reason that we chose to not go with a spring powered device is because of the lack of moving parts required for an air system versus the process of compressing the spring and finding a way to release the spring and fire the dart. To pressurize the air system a bicycle pump will be used to easily and quickly fill the pressure vessel with air. The reason for using ½" PVC pipe for the barrels is because the PVC is the same diameter as a nerf gun barrel. It is also hard to find a cost effective nerf gun to take the barrel out of because most nerf guns are molded with the barrels into the body of the gun, with no way of getting the barrel out to use. This led to the decision to build the firing system, so it would be easily designed and integrated into the robot and could achieve the performance needed to complete the stage. The basic design concept is shown in Figure 17, which is not drawn to scale. In this figure the barrel is mounted to the top of the robot, the pressure vessel is located within the chassis, and the solenoid is represented by the cube that has the tubes connected to it. It would also be very difficult to mount three regular nerf guns to the robot, finding the space to put them would not be easy, and the firing mechanism would have to be heavily modified to allow a device to fire the gun. The block diagram for the firing system can be seen in Figure 18, it shows that you wait until the bump switch is off to keep moving forward, and when it is on to fire the nerf darts to complete the stage.

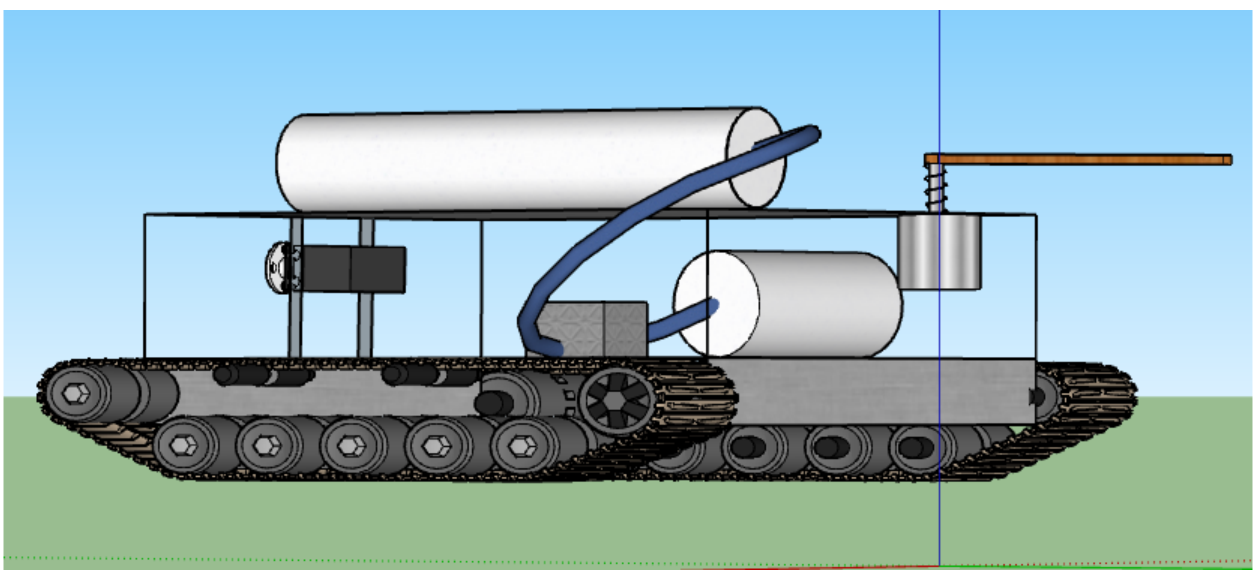

Figure 17: Stage 4 components (One barrel only)

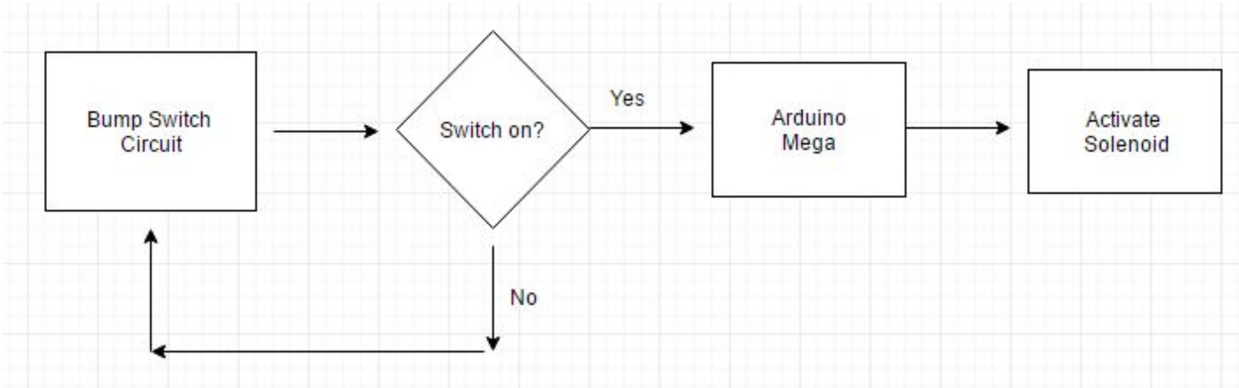

Figure 18: Stage 4 System Design

11 Risk Assessment

11.1 Technical Assessment

The robot requires metal work and circuitry. The team will only be doing circuitry. The chassis and arena will be sent to the COE Machine Shop to prevent any injuries for the team. When handling the circuits, the power supply will be monitored carefully to ensure the circuit is always grounded. Further, the team will inspect all circuits to ensure they are connected correctly. This will prevent any components from blowing out and any fire hazards from starting.

11.2 Schedule Assessment

SoutheastCon will start on March 30. Thus, the robot must be completed by this deadline. The robot is expected to be fully built and ready for testing on January 30th. This gives two months for testing and rebuilding if there are any errors in the systems. For Fall 2016, the robot is on track for completion.

11.3 Budget Assessment

$301.11 was spend in Fall 2016. The remaining balance is $448.89. After buying the remaining components, it is expected that there will be $118.89 for emergency funds. The most expensive component in the project is $100. With the current budget, there is not much room for error. Thus, all components need to be fully researched before purchasing to ensure the budget is kept.

12 Conclusion

This report describes the needs of the robot based on the April 2016 edition of the 2017 SoutheastCon Hardware Challenge rules. The robot is tasked with completing four stages in an arena. The robot must navigate autonomously and will have sensors to determine its position in the arena. The three proposed movement trains are wheels, tracks, or legs. The first stage requires decoding a code by determining the components within a circuit. The code will be displayed on an LCD or LED screen. The second stage is a "lightsaber duel." Using an electromagnetic sensor, the robot will be able to process when an electromagnetic field is deployed. During this time, the robot will hit a lightsaber that contains a vibration sensor. The third stage has the robot turn a quadrature encoder using the code found in stage one. Either a continuous rotation servo or stepper motor will be used to turn the knob. Finally, stage four consists of launching nerf darts into a portal at the end of the arena. The match will take less than four minutes to complete. Points will be awarded for successful completion of each stage.

13 References

Asmat, Carlos. "Lesson 7: Using Sensors." RobotShop. RobotShop Inc., 4 Apr. 2011. Web. 30 Sept. 2016. <http://www.robotshop.com/blog/en/how-to-make-a-robot-lesson-7-using-sensors-2-3683>.

Bensen, Colemen. "Lesson 2: Choosing a Robotic Platform." RoboShop. RoboShop Inc., 12 Aug. 2010. Web. 30 Sept. 2016. <http://www.robotshop.com/blog/en/how-to-make-a-robot-lesson-2-choosing-a-robotic-platform-2-3706>.

Benson, Coleman. "Lesson 3: Making Sense of Actuators." RoboShop. RoboShop Inc., 2 Sept. 2010. Web. 30 Sept. 2016. <http://www.robotshop.com/blog/en/how-to-make-a-robot-lesson-3-actuators-2-3703>.

Hughes, Cameron, and Tracey Hughes. Robot Programming: A Guide to Controlling Autonomous Robots. Indianapolis: Que, 2016

IEEE Southeast Division. "Southeast Con 2017 Hardware Competition Rules."Episode MMXVII: The Engineering Force Awakens (20117): 1-18.Southeast Con 2017 Hardware Competition Rules. IEEE, 3 Apr. 2017. Web. 30 Sept. 2016. <http://sites.ieee.org/southeastcon2017/files/2016/04/MMXVII.pdf>.

"Rotary Encoder - Illuminated (RGB)." Spark Fun. N.p., n.d. Web. 30 Sept. 2016.