Slug Wars

THE LAST SLUG-I

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Abstract—The report below is a technical summary of the Fall CMPE118 Mechatronics Final project; ”Slug Wars The Last Slug-I”. The final project is designed to incorporate each subject that was taught through out the quarter including topics such as Analog Filters, Hierarchical State Machines(HSM), Finite State Machines(FSM), Mechanical Design and Rapid Prototyping. The final project forces strong understanding of each of these areas and further teaches rapid prototyping by combining each piece together.

NOTE: This report is also being turned into CMPE118 for the lab write up for the final project and also for CMPE185 Final paper.

Index Terms—Robotic, Attitude Estimation, Controls, IEEEtran, Journal, Literature, paper, Review, Sensors, Analog Filter, Solid Works, Mechincal Design, Rapid Prototyping, Finite State Machines, Hierarchical State Machines,

1 INTRODUCTION

Course Setup

Mechatronics is taught in two phases, phase one is lab based where through out each lab, partners are constructing pieces that can be combined together to the final project. The course then moves into phase 2 where students are grouped into teams of 3, that consist of a strong Electrical Engineer, Software Engineer and Mechanical Design. These teams are then tasked with designing and building an autonomous robot that conforms to the Final Project Rules.

Slug Wars The Last Slug-I rules

As this report is going to be a technical lab report, presented will be enough detail for an Engineering student to be able to replicate the final robot that was made by my team. To gain background behind the project, the rules for the final project are outlined below.

1) A white field is outline with black tape that outline parts of the filed that are in play and out of play, if at any time your robot exceeded more then half way out of the play area, the robot is disqualified.

2) The robot is to ”shoot” a ping pong ball through 3 randomly place ATM6 target, that will always be around the exterior of the field and have vertical ”Track-Wires” oscillating at 25KHz. An ATM6 is a rectangular box with a 6in diameter hole cut out where the ball must pass through.

3) Once successfully shooting down 3 ATM6 targets, it is now time to target the ”Ren Ship”, the Ren Ship is a larger stationary box with a lot smaller hole cut out at the top. The hole is only slightly larger then the ping pong ball that needs to pass through.

4) In attempts to make the final project slightly more interesting, two additional pieces are added to the field, the first is short ”Alignment” 6in pieces of tape and the second is a static obstacle that is randomly placed at the start of the round.

There are many more rules and in fact an entire 15 page document that outlines the nitty gritty for each dimension and placement of the field and final project rules, however these facts go outside the scope of this report. That report can be found on the CMPE118/Fall2017 website if needed.

2 Approach

After reading the large project specifications, our team was left with more questions then answers. When attempting to tackle this large scale project, our team decided to tackle each piece sequentially. The structural design was a modified from the earlier prototyping lab that conformed to the 11x11x11in requirements specified in the project specification document. Once a general base was decided, a delivery method was then decided so that we can reliably kill the ATM6 and Ren ship. When designed the shooter and catapult, we looked to constructed the simplest and most repeatable methods we could design.

2.1 Chassis Design

As stated earlier the chassis was an earlier design that was re purposed to conform to the final project specifications. The chassis was designed to have as much clear real-estate as possible to allow for easy electronic placement. The top and bottom plate are then mounted to each other with a $\approx$ 2in gap to also provide placement for electronics. These gaps are separated by vertical spacers that allow for stronger structural integrity and rigidity in the bot design. Along the 2in gap are motor mounts that are mount vertically as well providing further rigidity. The entire structural design was built with the "Tap and Slot" method allowing for easy assembly and access to electronic storage compartment.

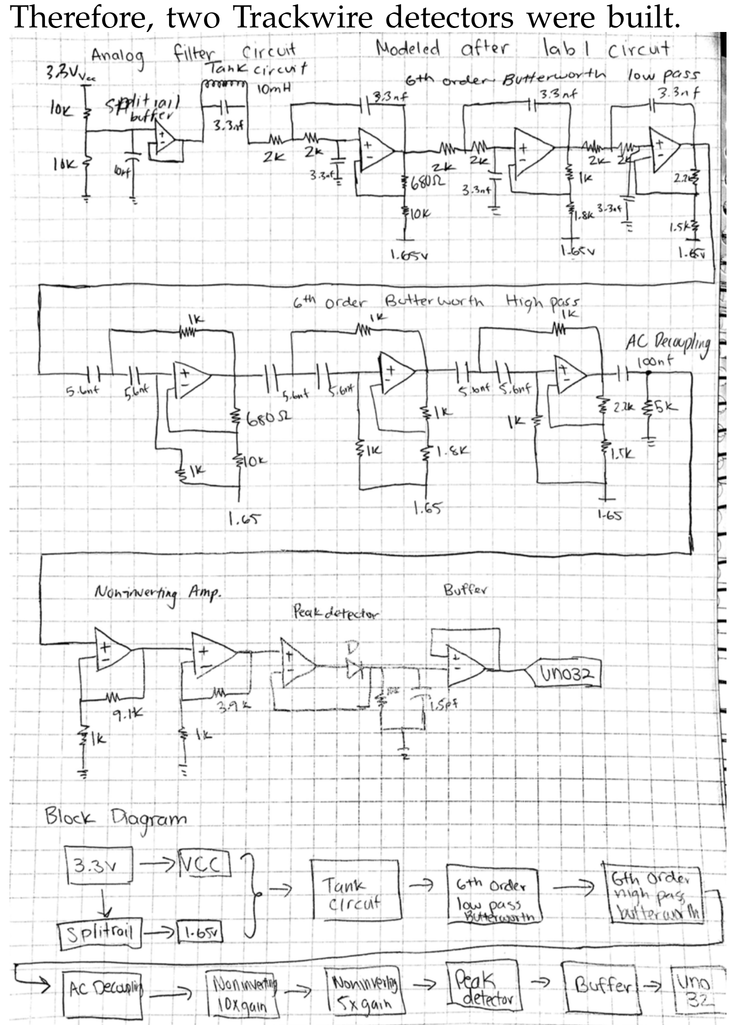
2.2 Ping Pong Ball Delivery Systems

To reliably shoot ATM6 target with a ping pong ball, our team decided to separate our delivery systems for ATM6 and Ren ship targets. Being able to have two different delivery systems allowed for simplicity across our delivery methods. The two systems that we decided to use were, a shooting pipe, where ping pong balls would get loaded into then shoot out and the second was a rotating servo arm that rose to the proper hight of the Ren ship and would deliver two balls through the hole.

2.3 Self Built Sensors

2.3.1 Trackwire

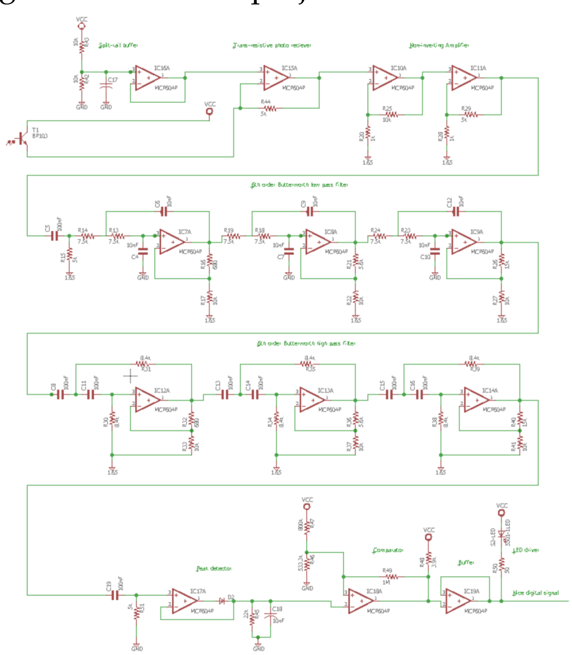
An assortment of sensors were built during the final project. During initial design reviews, two Trackwire detectors were going to be used on opposite sides to gain double the chances of being able to find an ATM6 if we passed it on the left or on the right. Therefore, two Trackwire detectors were built.



The trackwire consists of multiple subcomponents of the final circuit. We used a tank circuit with a solenoid which purpose is to detect signals. Then we used multiple gain stages to have a large and precise signal for us to work with later on. Then the gained signal would be passing through a 4th-order butterworth bandpass filter that is good enough to filter any noise besides our wanted range of 20-30kHz. The order of the filter is required to have a large enough attenuation for us to filter out the unwanted noise. The signal is then being gained again to modify the working range for our analog-to-digital converter on our UNO. Then we are using a peak detector to have a DC signal which is required for our analog-to-digital converter.

2.3.2 BEACON

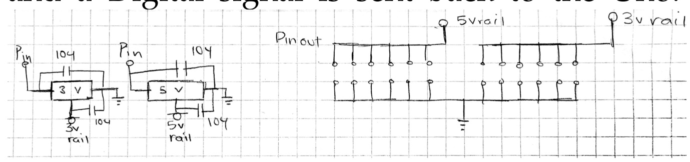
The 2Khz oscillating beacon sits above the Ren Ship and illuminates at the beginning of the round for 15 seconds and is off until all ATM-6 are shot and the Ren ship is ready to be targeted. It was found that for us, the use of a Beacon detector is not needed though it was initially built in case we cared to competitively compete in competition. For further understanding how a beacon detector would help in competition, I point you to the technical documentation regard the final project rules once more.



The circuit for the beacon detector is very similar to the trackwire detector. The only differences are the gain of the gain stages and that we are using a 6th-order butterworth bandpass filter for a range of 1.8-2.2kHz.

2.4 Additional Circuits

Additional power rails and power distribution board (PDBs) were created to provide regulated voltage to the respective components such as servos and shooting motors. Tape sensors were built initially based on the provided parts from B.E.L.S., however to get snappier, more accurate reads the tape sensors were swapped out and rearranged to off the shelf IR distance sensors that worked for distinguishing the difference between the white filed and black boundary tape. The 3.3v and 5v PDB was also used to power the tape sensors and a Digital signal is sent back to the Uno.



3 Block Diagram

The block diagram shows each component that is connected to the robot in it's final state. Including each of the sensors that were already addressed above. The brain behind the robot is the Uno32.

3.1 Uno32

The Uno32 is the provided Microcontroller that acts as the central hub and computing power behind our autonomous shooting robot. At this time it is important to note that this "Autnomus Shooting Robot" is by no mean harmful but rather a harmless rather simplistic thinker. The Robot's ability spans being able to shoot at ATM6s and deploy a ball to the Ren Ship and occasionally follow tape. We claim the pseudo random turns are a feature rather then a Bug. The Uno32 was provided for the class a long with the Power Distribution Board and H-Bridge that commands the DC Drive Motors.

3.2 Additional Hardware

Aside from the Uno and its stack, and H-Bridge all other components were either built by our

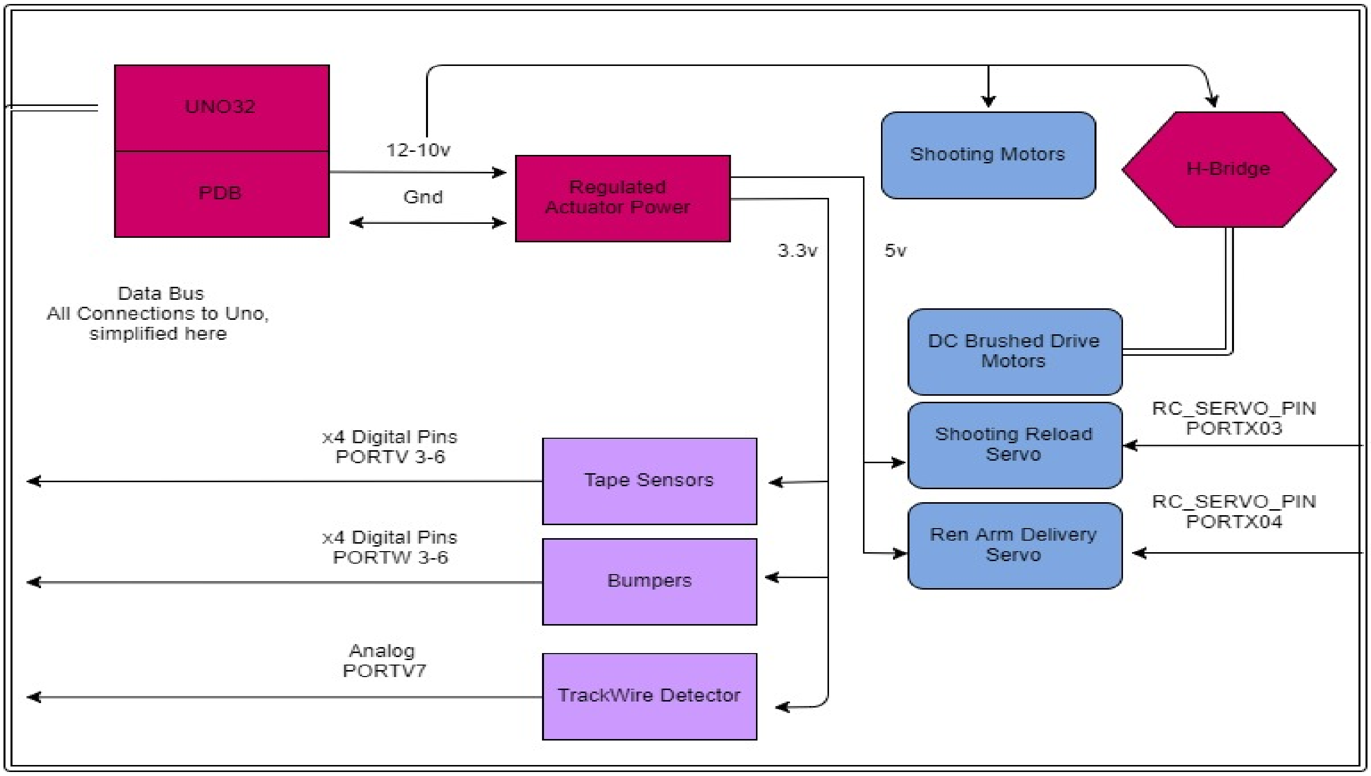


Fig. 1. Block Diagram: Electronic and design layout

team or store. Once again these components include Tape Sensors(used for Tape following and obstacle detection), Bumpers (obstacle detection), Trackwire Detector(used to detect ATM6 targets).

3.3 Delivery Hardware

The ATM6 shooter is constructed of PVC pipe has cut out for the thrust wheels that compress the ping pong balls and accelerate them enough to clear the 6in gap between the play area and outer boundary. The Ren shooter is a servo that rotates and Arm that holds two balls at the top of the arm. The top of the arm has a small pipe that holds two ping pong balls and releases them by gravity when the arm is rotated.

4 State Machine (SM)

The core of the software, aside from the Event Checkers and Services and basic Pin set up is the State Machine. In the final design a HSM and one movement FSM was written. For those who are unfamiliar the SM is our robots ”code of Conduct” metaphorically. The SM governs how the Robot will react or ignore each of its interactions with the outside world. Example of this would be, decide how to maneuver away when the bumpers are hit.

4.1 Hierarchical State Machine

For readability and easy debugging, the SM is designed to have one governing HSM and one FSM. The HSM consisted of 3 main states, ”ATM6”, for when the robot is looking for phase 1 targets that outline the edge of the field. The next state is, ”Ren” which asserts that the robot is looking to attack the Ren ship which is in a stationary place. The state was ”GameOver”, that put the robot into a silly dance by twisting and turning.

4.1.1 ATM6

The ATM6 state was tasked to control the ATM6 shooter motors and ping pong ball reloading servo that fed balls from the ball hopper to the acceleration wheels.

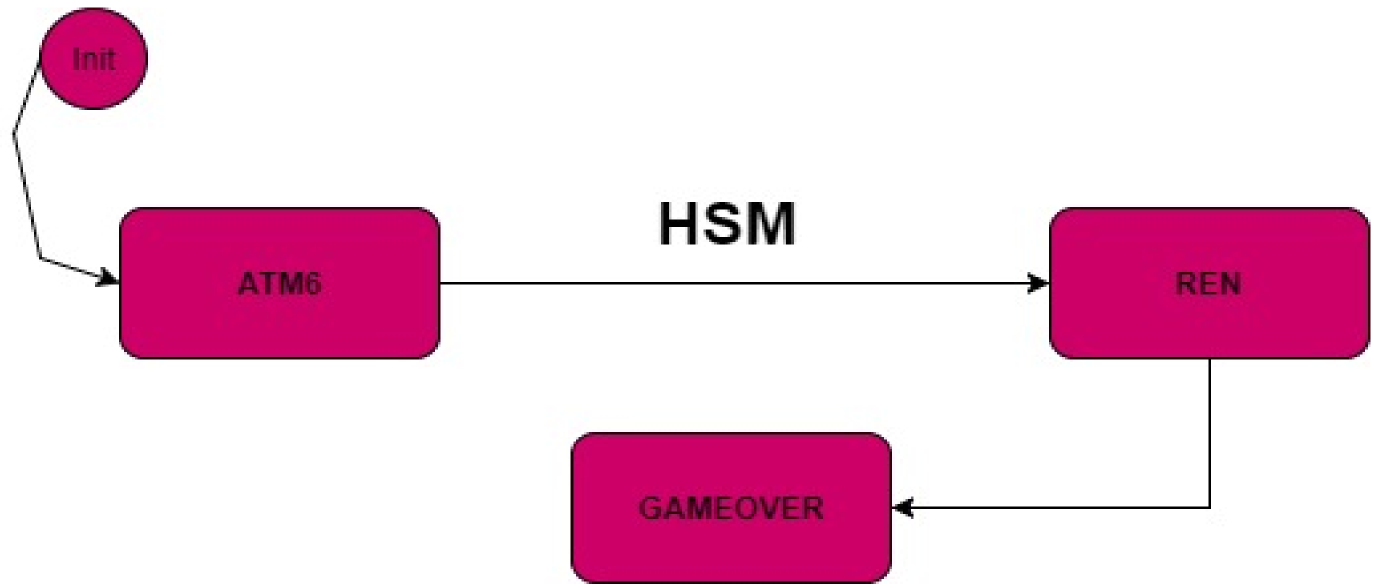


Fig. 2. Hierarchical State Machine : General Game SM that transitions between both phase

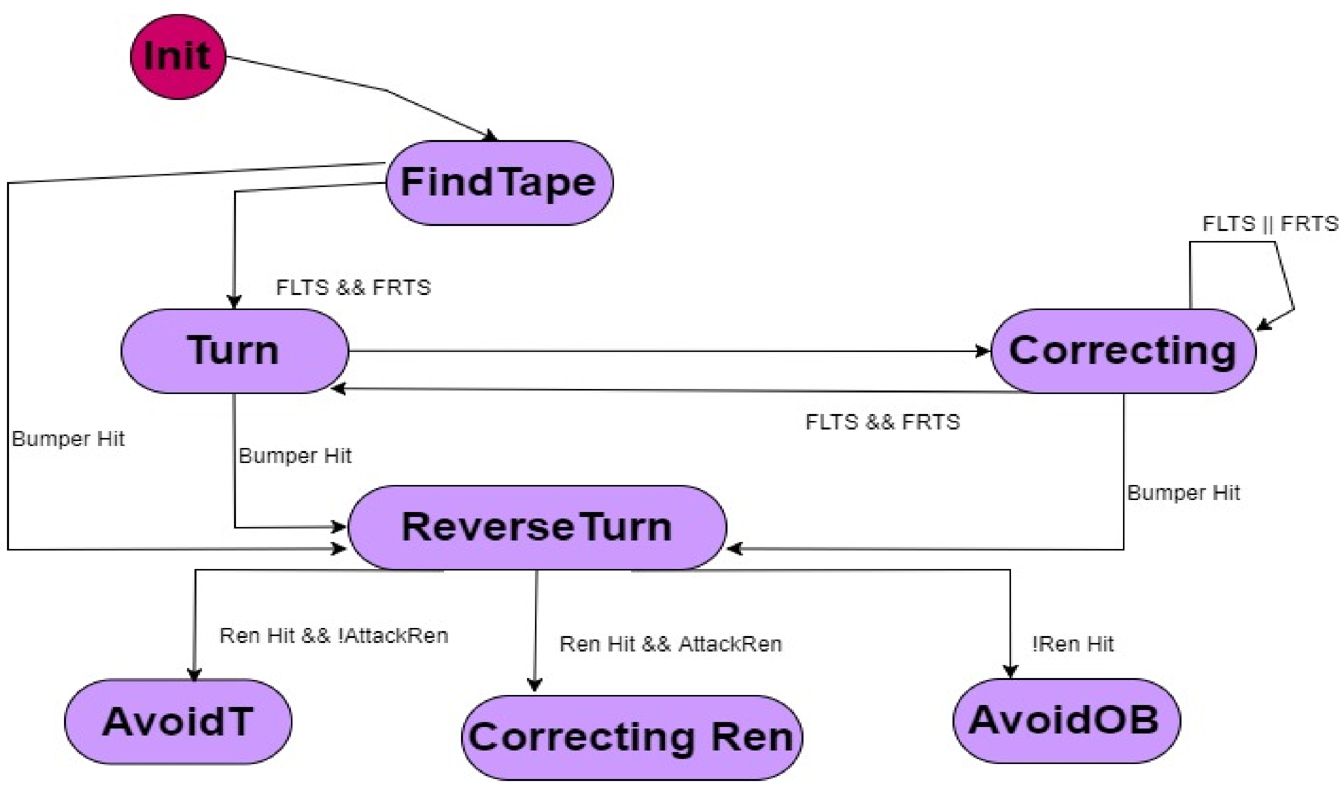


Fig. 3. SubHierarchical State Machine: Movement and Maneuvering SM

4.1.2 Ren

The Ren state was tasked with rotating the Ren delivery arm when the Ren ship is hit and 3 ATM6 targets have been killed. Again for purposes of minimum specification, the Beacon is ignored entirely and no beacon detector is used to dictate motion/movement or state changes.

4.1.3 GameOver

Once again this state is tasked with the complex job of humoring the developers upon completion of the Game nothing to meet minimum specification.

4.2 Sub Hierarchical State Machine (SHSM)

The bulk of the SM lies in the one MovementSUBHSM, this sub HSM is also called our FSM as this is how this portion of the machine was initially designed during the incremental development process. The movement Sub HSM is in charge of tape following, avoiding obstacles and crossing the field. The HSM would override the PWM signals set to the motors from MovementSUBHSM when special manuvers were needed. For example sopping to shoot the ATM6 targets or wiggling around the Ren Ship to get the balls in the hole.

4.3 Tape Following

Tape following was were most of the development time was spent as it needed to be the most robust. Tape following is crucial for the design of the robot as it needs to be able to reliably find and kill 3 ATM6 targets that are always located on the perimeter of the field area. There was many iterations of this algorithm and should have become its own state machine. The physical placement of tape sensors were also placement and rearranged a number of times to account for literal corner cases and not allow the robot to drive out of the play area or worst the field.

4.4 Obstacles Maneuvering

Unwisely the Obstacle maneuvering was built into the same SM that governed tape following and resulting ended with slightly cluttered code which allows for several edge cases. The fields that we can successfully pass are unique and often obstacles do throw the robot off without it being able to realign on the tape.
An additional tape sensor was added on the bumpers so that the type of obstacles can be determined and the robot can move around it accordingly. Again a good idea, but even more reason why this needed to be a separate SM.

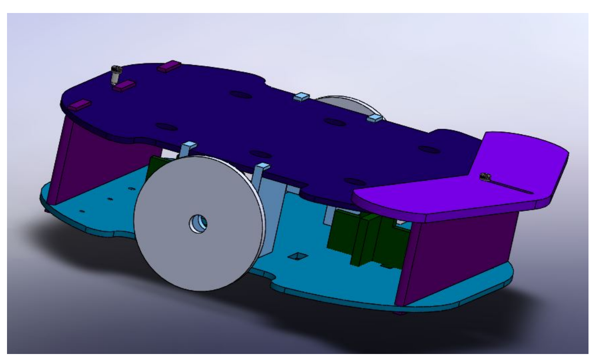
5 Bill of Material

Most individual components for the circuits i.e. resistors and capacitors are not listed as these materials came in the lab kits provided during the start of the quarter. What is listed are the additional materials that were purchased after.

Item Desc.	Qty.	Cost Per Unit
DC Drive Motors	2	$30
Shooting Motors	2	$30
PVC Piping(4 ft)	1	$10
Drive Wheels	2	$5
MDF	4	$2
Hot Glue	10	$2
Bumper Switches	1	$10
Ren Servo	1	$20
Loading Servo	1	$10
Misc Electronic Comp.	1	$30

6 Results

From the inital CAD in week 1 to the final Hot Glue Mess seen here. The ”Supreme Robot” as it was nick-named due to the flashy sticker located on the rear of the robot can be seen in the figure above. The Robot is shown overlooking the beautiful Santa Cruz views moments prior to competition.



Chassis CAD Design: Note Shooters not shown here.

Final Robot: The Final robot, is show above, on the day of Public Demo

7 Last Comments

This class does not try and mislead about amount of work that you will be putting in. It is very true that students are pushed to their limits and grow more in this one quarter then then have in their entire time are university. It is often found that the technical skills learned here, not only help students in other courses at UCSC but also have merit when they venture off into the workforce. For our team it was not the course material where we truly grew this quarter, but rather learning to work under pressure and with those whom you do not get along with. Having different types of partners with various schedules and ability to work under pressure proved to be the toughest challenge during this project. In addition, simple problems such as covering tape sensors with tape, breaking soldered wires, switching driving left and driving right instructions, and not updating the .hex file to be uploaded for many were just some of the problems which used up valuable time. All in all, this was a solid character building project.

References

[1] The Art of Electronics Horwitz and Hill
[2] Filter Wizard, Analog Filter Design Tool, http://www.analog.com/designtools/en/filterwizard/