Project Portfolio — Avi Guha

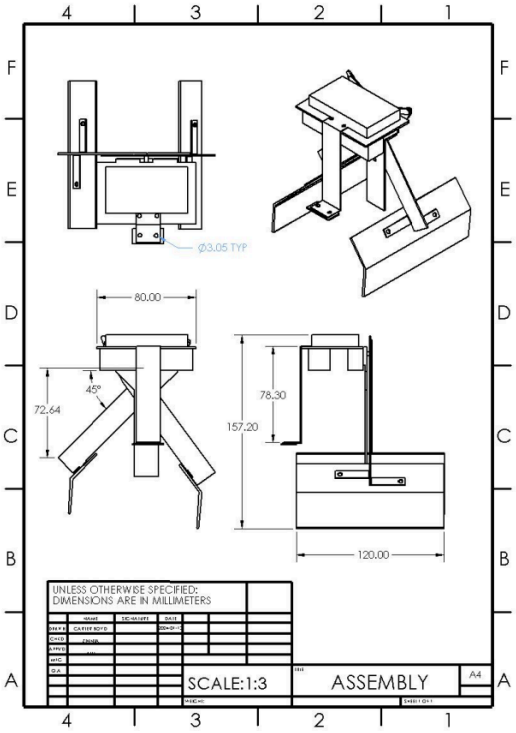
I am Avi, a third year Engineering Physics student at The University of British Columbia. Throughout my degree I have indulged myself in theory through class-work, giving me a first-principles outlook on problems.

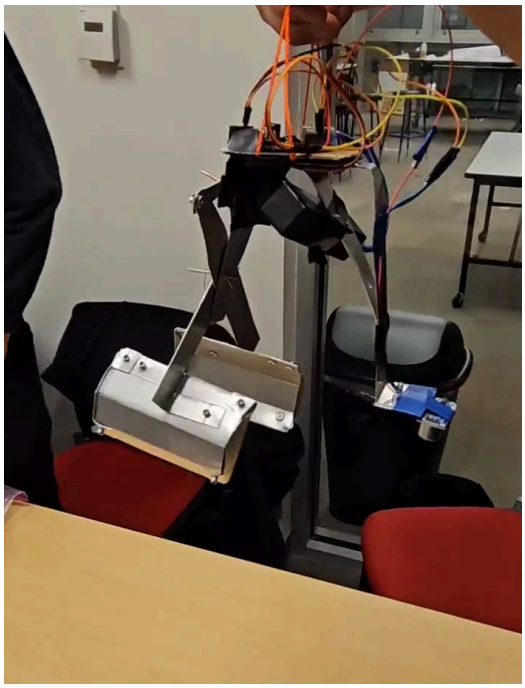
Whenever I tackle a project, I tend to break it down into smaller, more manageable problems and set goals toward them that are achievable in a reasonable timeframe. I consider myself to be a detail-oriented worker, and strive for perfection in my designs.

In my recent years I have specialized in electrical design – whether that is firmware engineering or hardware engineering, these projects have all given me immense learning experiences throughout my time at university.

Below is a collection of my projects since my first year of Engineering.

APSC 101 Autonomous Claw



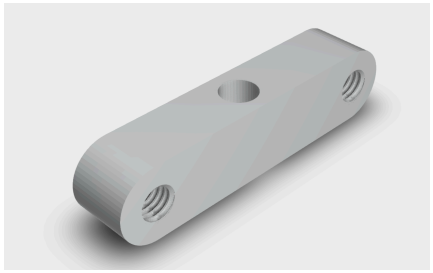


- For this project, I decided to shift my focus over to the electrical and software components of the claw.
- This was my first time working with a microcontroller (ARDUINO). This learning experience offered me invaluable knowledge which I later implemented into another project.
- I also worked with hand tools to cut metal when constructing the physical claw.
- This claw had to be capable of picking up a variety of objects, with varying sizes, shapes and mass. Therefore, we had to be considerate when designing the shape of the claw to ensure it was versatile and robust.

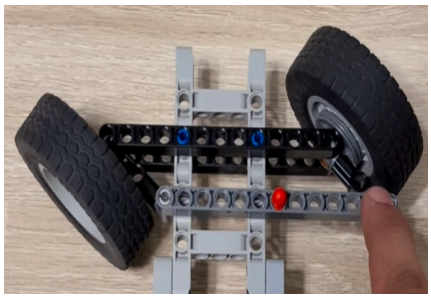
PS4 Controller RC CAR

- For this project, a friend and I decided to model a RC car in Solidworks that could be controlled with a PS4 Controller.
- This car will be 3D printed and assembled once we have access to a 3D printer
- This project was rather ambitious with our current knowledge, however the work put into it was rather rewarding.
- I specifically developed the electrical and software components of the car, as well as the steering components.
    - The code I developed worked specifically with a bidirectional electronic speed controller and a brushless DC motor
    - Connected a PS4 Controller to an ESP-32
    - The steering was controlled with a Servo motor.
- The car was controlled with a ESP-32 microcontroller and powered with a LIPO 2S battery.
- Utilized github repositories to collaborate and make frequent updates to files.

-Steering arms for RC car



-Central arm for RC Car – connects to servo

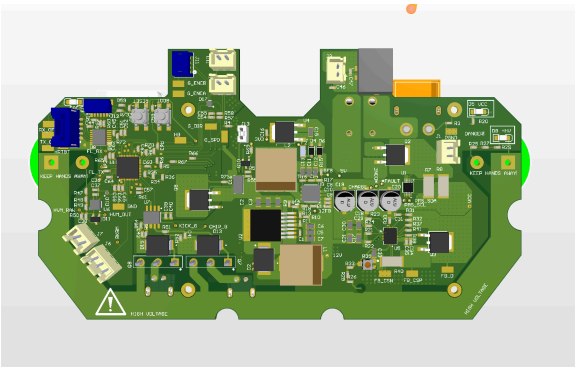


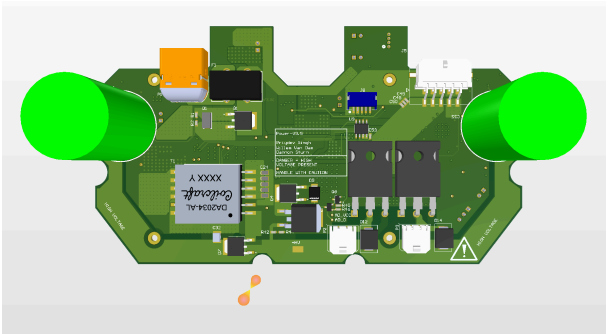
Idea via @brick.masters.builders on instagram to keep the two wheels parallel

Servo and BLDC w PS4.MOV
(https://drive.google.com/file/d/1sjtF62lspIT15LaHqMiN3g_MSkoG-VS6/view?usp=sharing)
Video of PS4 Controller moving a Servo and BLDC motor.

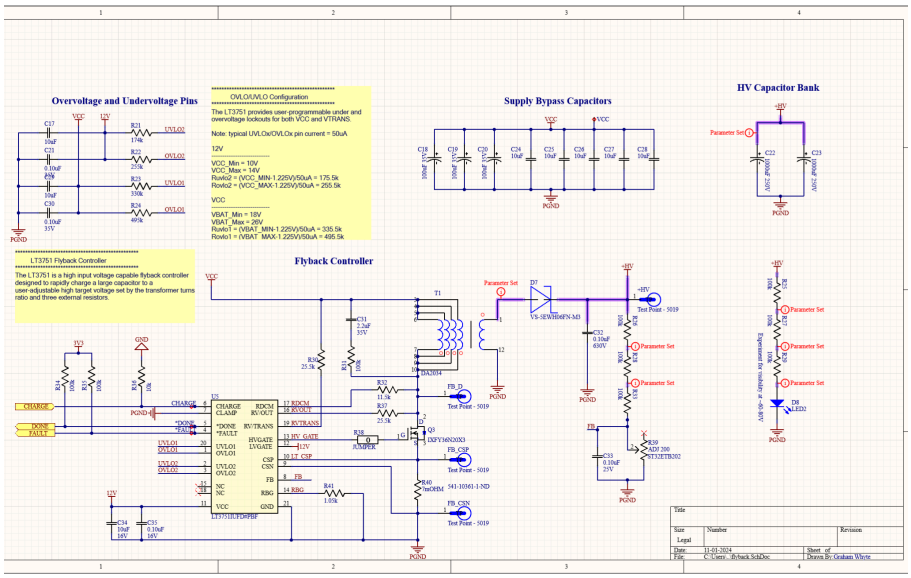
UBC Thunderbots - Electrical Design

- I am part of an interdisciplinary design team that develops autonomous robots to play soccer at the international *Robocup* competition.
- As an electrical designer on this team, I have worked with Altium and LT-Spice to develop circuit boards and simulate them for implementation on the robots.
- Below is an image of the power-board I designed and debugged with a group of three students.
    - The power board supplies power to essential components of the robot, such as the kicking mechanisms, motors, UI boards, etc.



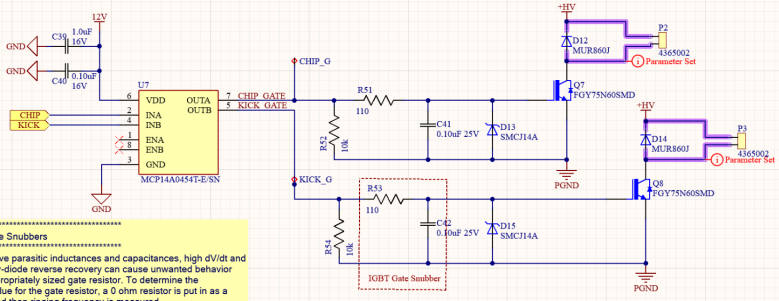


- The main component of the power board I worked on was the flyback converter, which converts 12V to 280V, using a combination of a boost circuit and a flyback circuit. Below is a schematic drawing. This circuit had issues with overvoltage on the capacitors used for the kicker/chipper, so I primarily debugged the circuit to find a reasonable redesign.



- The kicker/chipper board works by rapidly discharging two 1mF capacitors in parallel to provide sufficient power to the system and deliver high-speed kicks.

Kick/Chip Solenoid Switch Control



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Gate Snubbers
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Transistors have parasitic inductances and capacitances, high dV/dt and di/dt, and body-diode reverse recovery can cause unwanted behavior without an appropriately sized gate resistor. To determine the appropriate value for the gate resistor, a 0 ohm resistor is put in as a placeholder and then ringing frequency is measured.

(1) Rg = R(hi or lo) + Rgate + Rg,i
(2) Ls = 1/Ciss(2*pi*f_r)^2
(3) Q = pi*Ls/Rg

Choose quality factor, Q, between 0.5 (critical damping) and 1.0 (underdamped)

See TI's document on "External Gate Resistor Design Guide for Gate Driver"

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TVS Diodes
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The IGBT gates are rated for Vge +/- 20V. To ensure transients > 20V do not damage the transistors, TVS diodes with a Reverse Working Voltage (VRWM) <= 20V is used.

Reverse Working Voltage (VRWM) is the specified voltage at which the device will draw only a very small leakage current.

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10k Pulldown Resistors
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In the case where the chip is not enabled but the HV capacitors are fully charged to 238V, then the gate of the IGBTs would be floating, and there could be the case where the gate rises above 12V, turning the IGBTs on. This could lead to a safety hazard due to the uncontrolled kicker/chipper action. By pulling down the gates with a 10k resistor, the IGBTs will remain off whenever the gate driver is not enabled.

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IGBTs: FGY75N60
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IGBT Field Stop 600V 150A 750W

Figure 10:
Qg = 200nC @ Vge = 12V, Vcc = 250V

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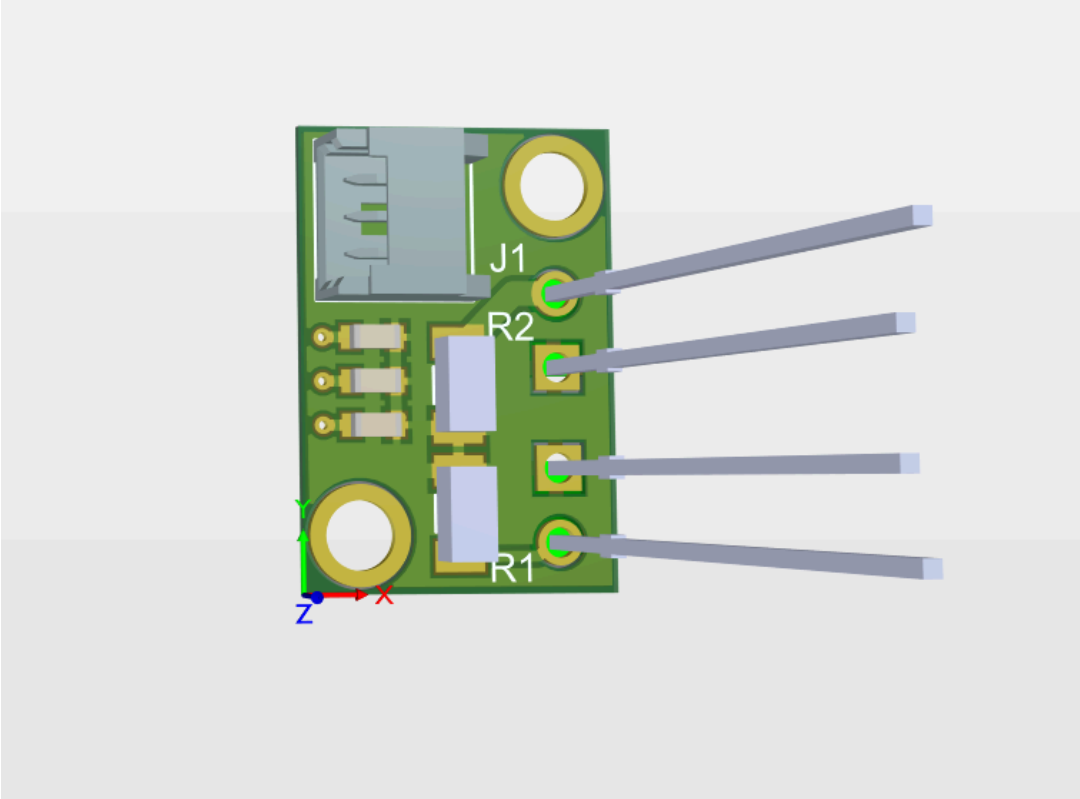
Break Beam Board

- Another project I contributed to on the team was the break beam board, which indicated whether or not the robot was in control of the ball.
- This project was a redesign from the previous, since small debris often tripped the board falsely.
- My contribution to this project was making multiple photodiodes connected in series (like an AND gate) to ensure that only if all were tripped by the ball, would the dribler start.



ENPH 259 - Digital Servo Speed Controller

- A project course as part of my Engineering Physics degree required me to develop a circuit capable of varying the output RPM of a motor, based on the input voltage. For this task, I had to research and implement digital logic analyzers – such as counters, DACs, BJTs, MOSFETs, Op-Amps, Latches, etc.
- This project was very rewarding in terms of learning about how digital logic can provide us with a way to implement negative feedback loops and develop control systems.

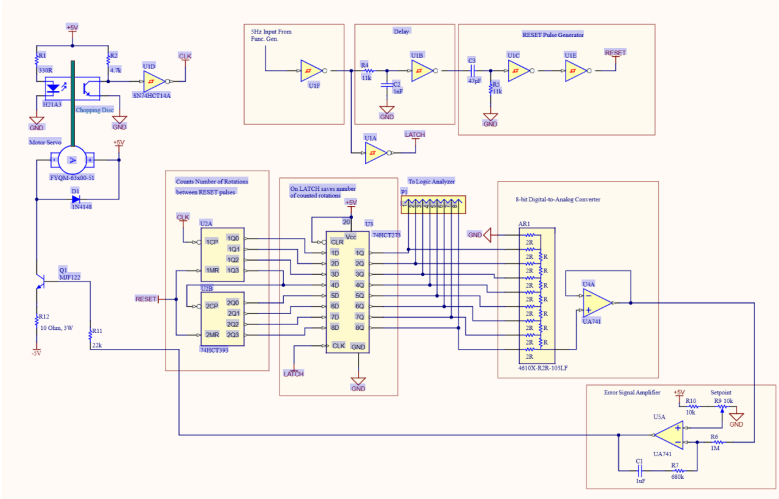
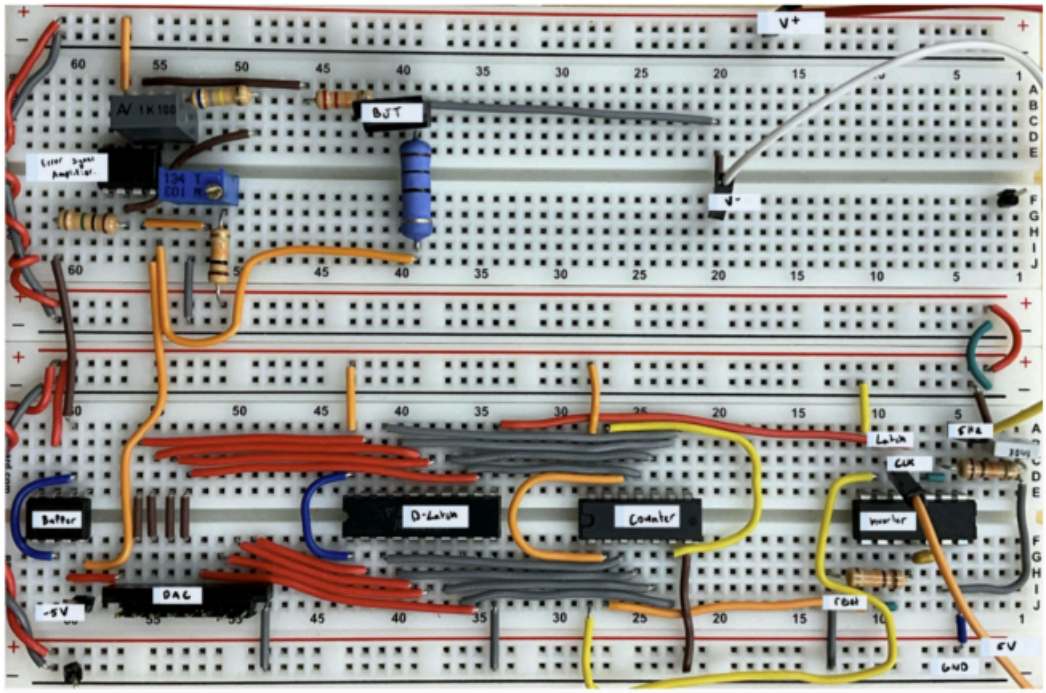
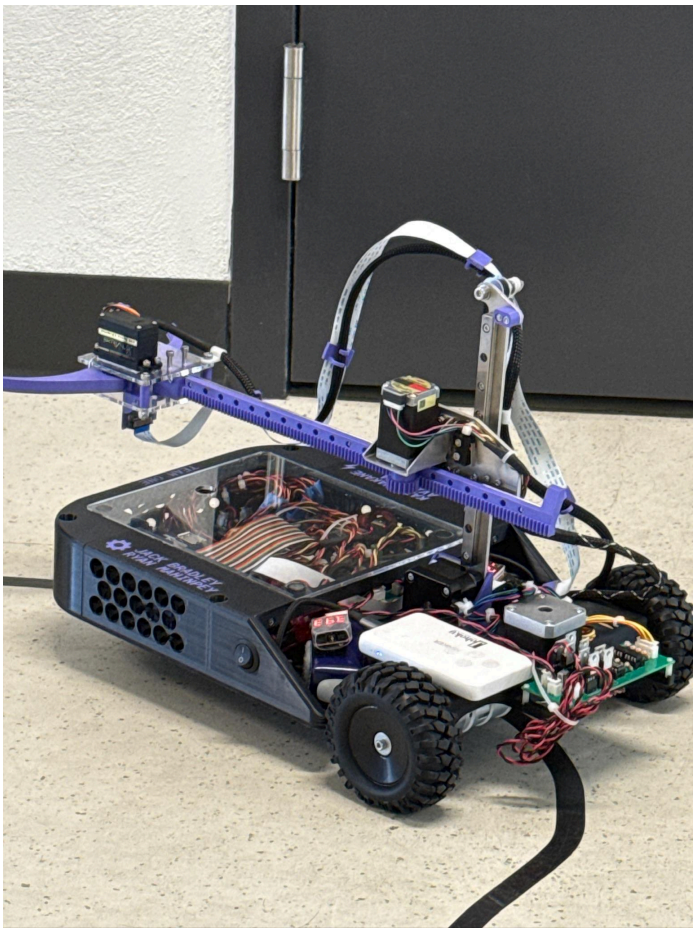


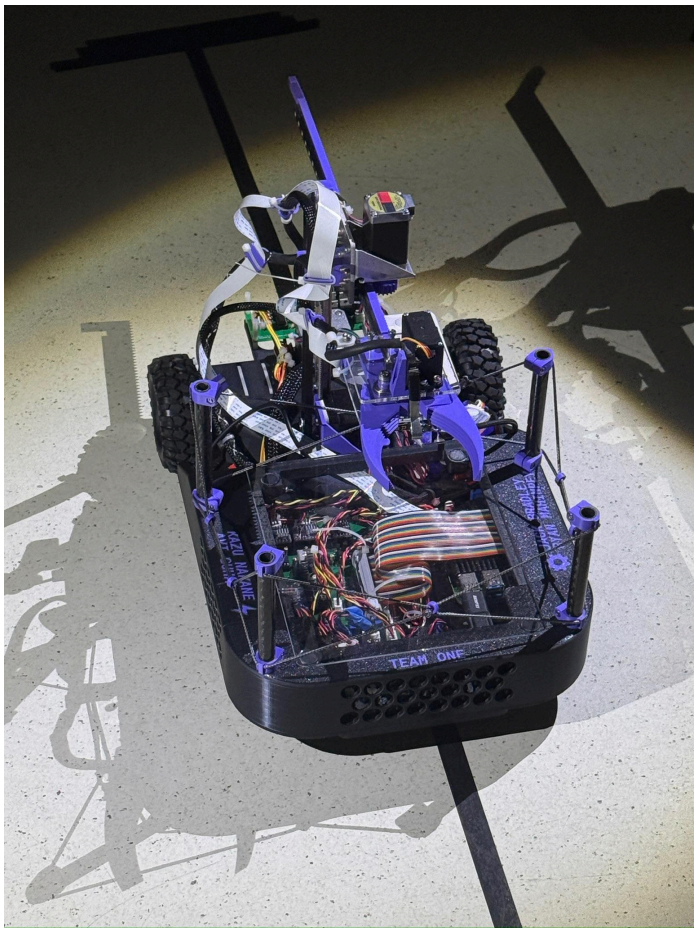
Image 5: Completed Circuit

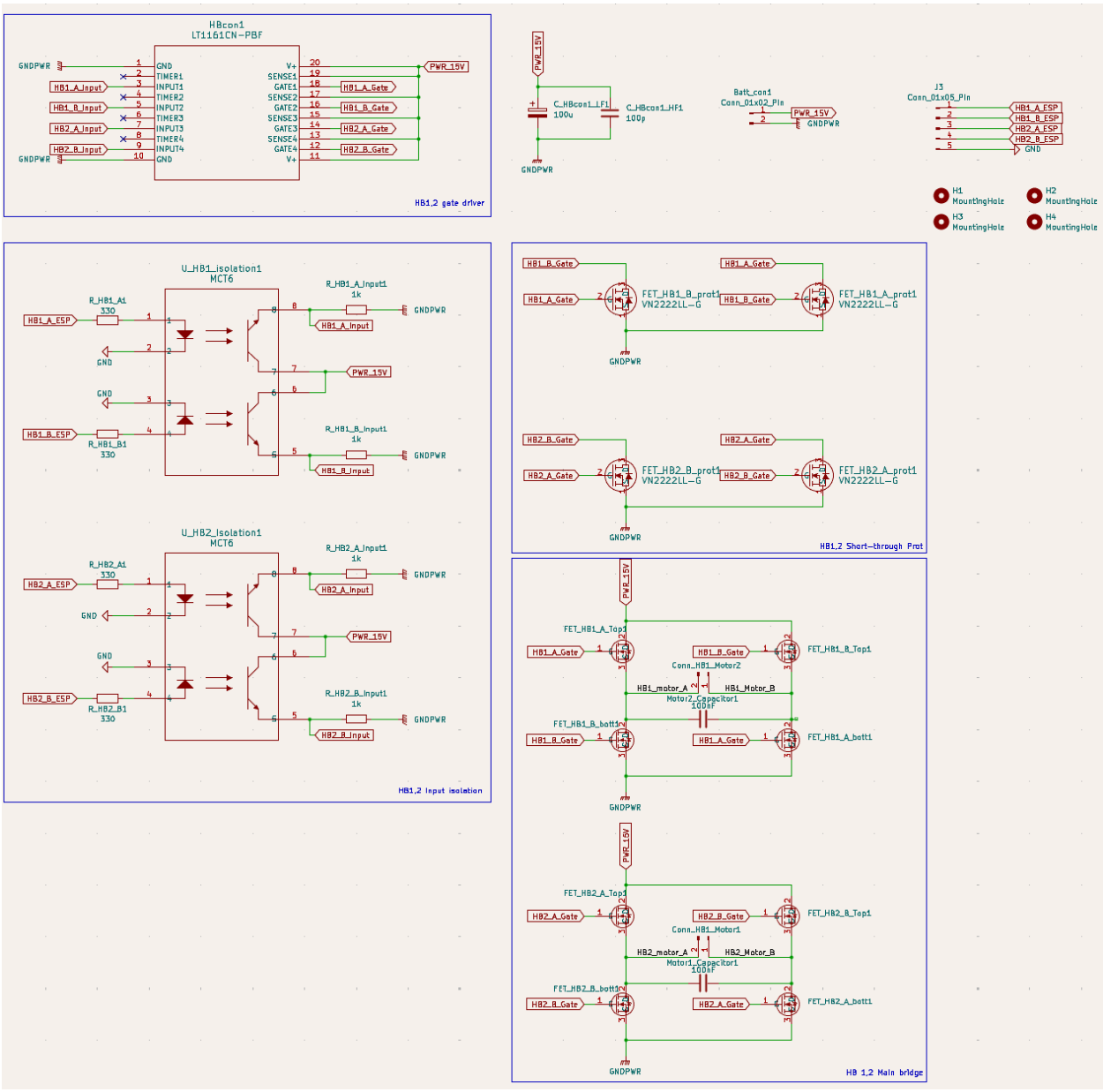


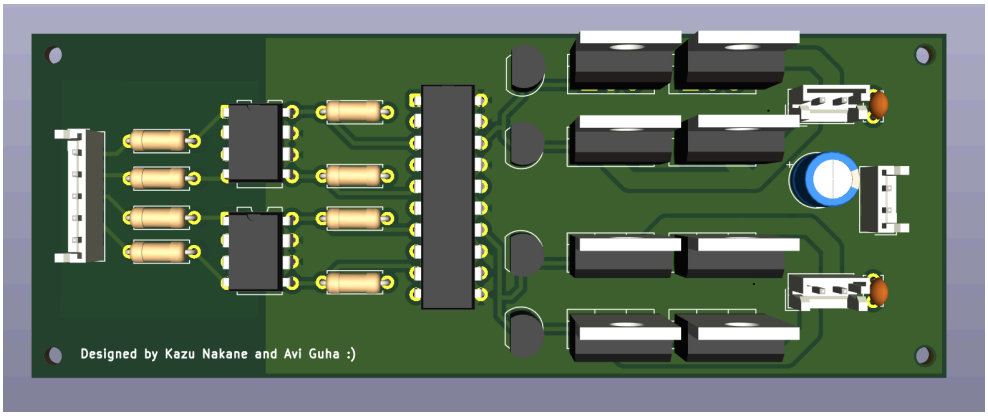
Autonomous Pet Rescuing Robot

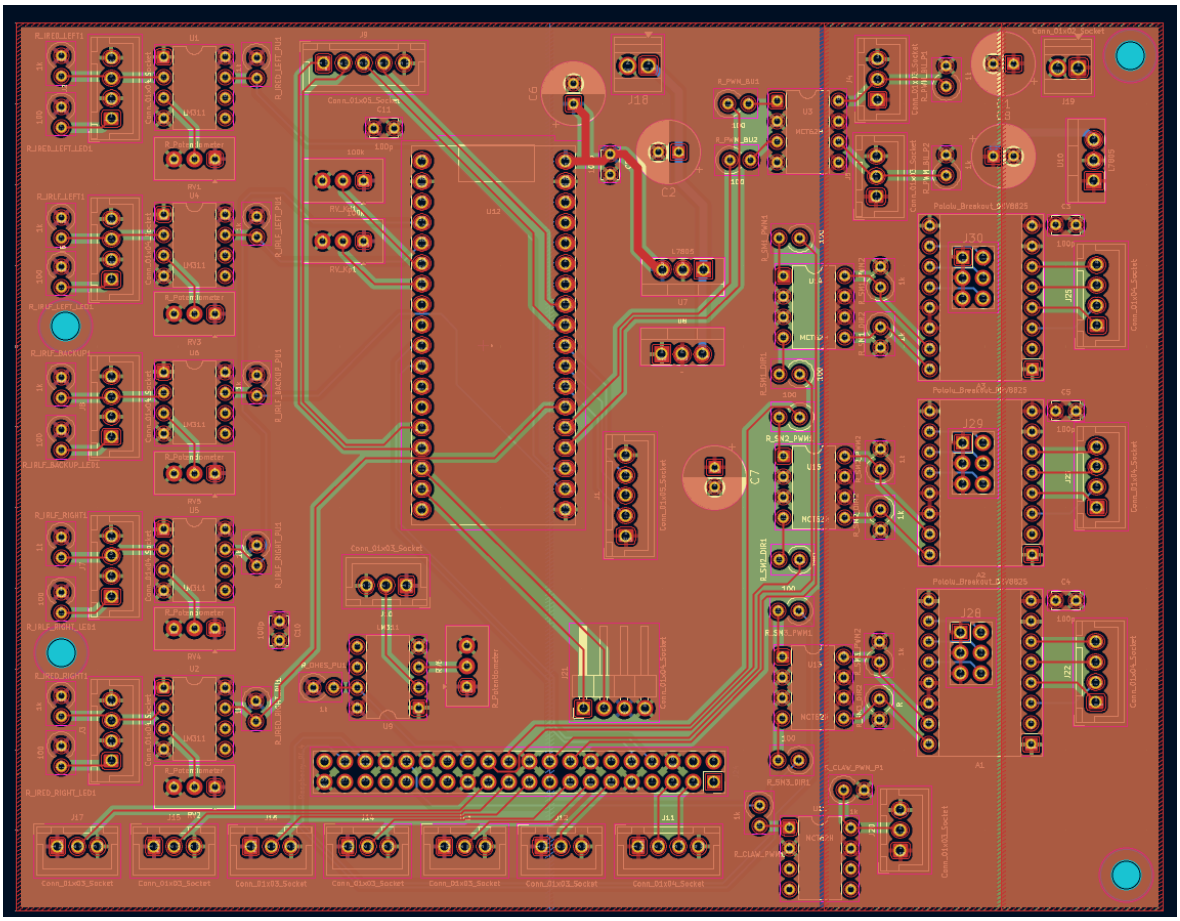
- As part of a competition, alongside three team members, I built an autonomous ‘pet-rescuing’ robot from scratch.
- This project was extremely rewarding in terms of learning, as nearly every component was built from the ground up.
    - My contribution included:
        - Motor drivers
            - Dual H-Bridge motor-drivers for brushed DC motors.
        - A GPIO Motherboard for ESP32 and Raspberry PI.
            - Included UART communication between ESP32 and Raspberry PI
        - RTOS for task handling by the ESP-32
            - Made using FreeRTOS
        - Infrared Line following
            - Dual core data-processing and handling.
        - Pet-detection with computer vision, utilizing YOLOv11
            - < 2 degree angle variation in pet-detection
            - 95% success rate in detecting pets.
        - Stepper motor firmware.
            - S-Curve motion profile, eliminating skipped-steps.

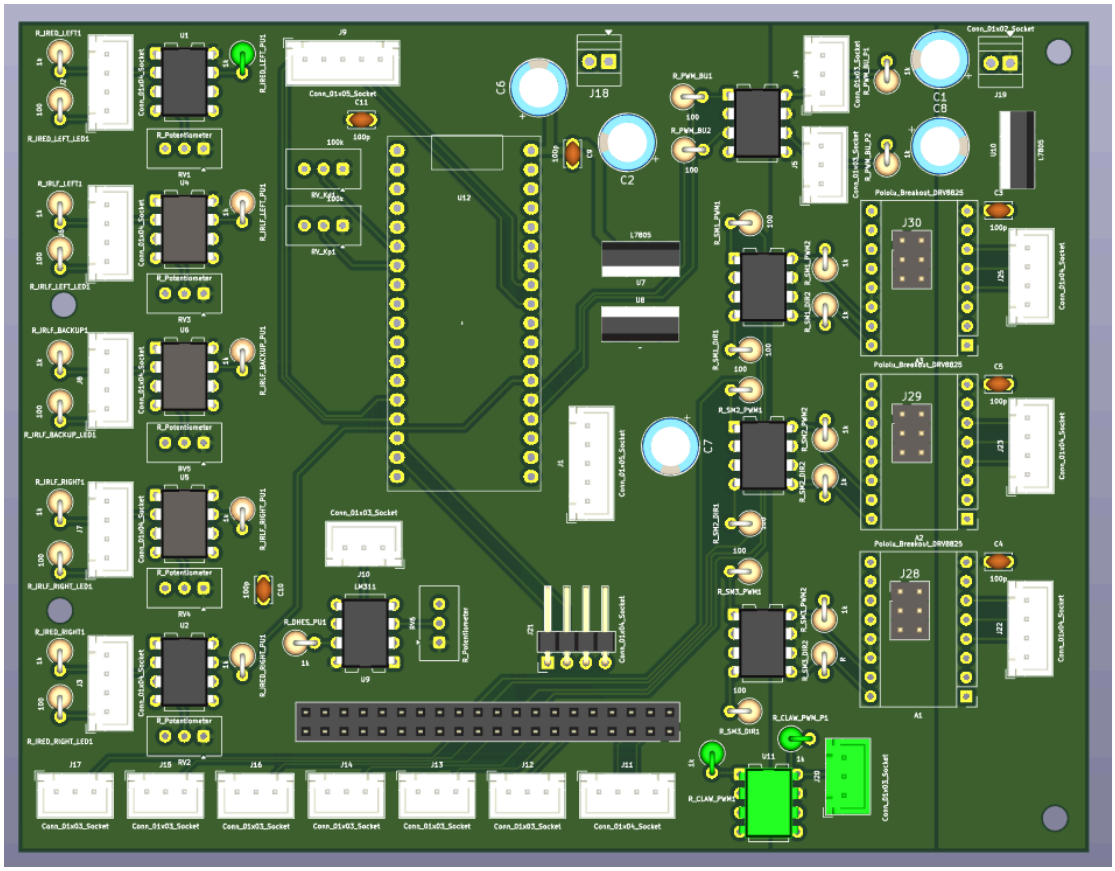





HBcon1
LT1161CN-PBF
GNDPWR
HB1_A_Input
HB1_B_Input
HB2_A_Input
HB2_B_Input
GND
TIMER1
INPUT1
TIMER2
INPUT2
TIMER3
INPUT3
TIMER4
INPUT4
V+
SENSE1
GATE1
SENSE2
GATE2
SENSE3
GATE3
SENSE4
GATE4
PWR_15V
HB1_A_Gate
HB1_B_Gate
HB2_A_Gate
HB2_B_Gate
HB1,2 gate driver
PWR_15V
C_HBcon1_LF1
100u
C_HBcon1_HF1
100p
Batt_con1
Conn_01x02_Pin
J3
Conn_01x05_Pin
HB1_A_ESP
HB1_B_ESP
HB2_A_ESP
HB2_B_ESP
H1
MountingHole
H2
MountingHole
H3
MountingHole
H4
MountingHole
U_HB1_isolation1
MCT6
R_HB1_A1
330
R_HB1_A_Input1
1k
R_HB1_B1
330
R_HB1_B_Input1
1k
U_HB2_isolation1
MCT6
R_HB2_A1
330
R_HB2_A_Input1
1k
R_HB2_B1
330
R_HB2_B_Input1
1k
HB1,2 Input isolation
FET_HB1_B_prot1
VN2222LL-G
FET_HB1_A_prot1
VN2222LL-G
FET_HB2_B_prot1
VN2222LL-G
FET_HB2_A_prot1
VN2222LL-G
HB1,2 Short-through Prot
FET_HB1_A_Top1
FET_HB1_B_Top1
Conn_HB1_Motor2
HB1_motor_A
HB1_Motor_B
Motor2_Capacitor1
100nF
FET_HB1_B_bott1
FET_HB1_A_bott1
FET_HB2_A_Top1
FET_HB2_B_Top1
Conn_HB1_Motor1
HB2_motor_A
HB2_Motor_B
Motor1_Capacitor1
100nF
FET_HB2_B_bott1
FET_HB2_A_bott1
HB 1,2 Main bridge


Designed by Kazu Nakane and Avi Guha :)



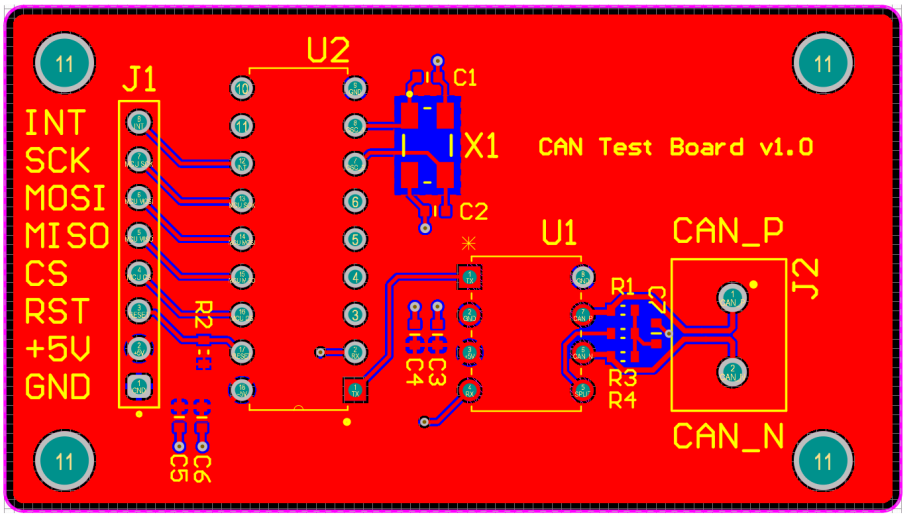


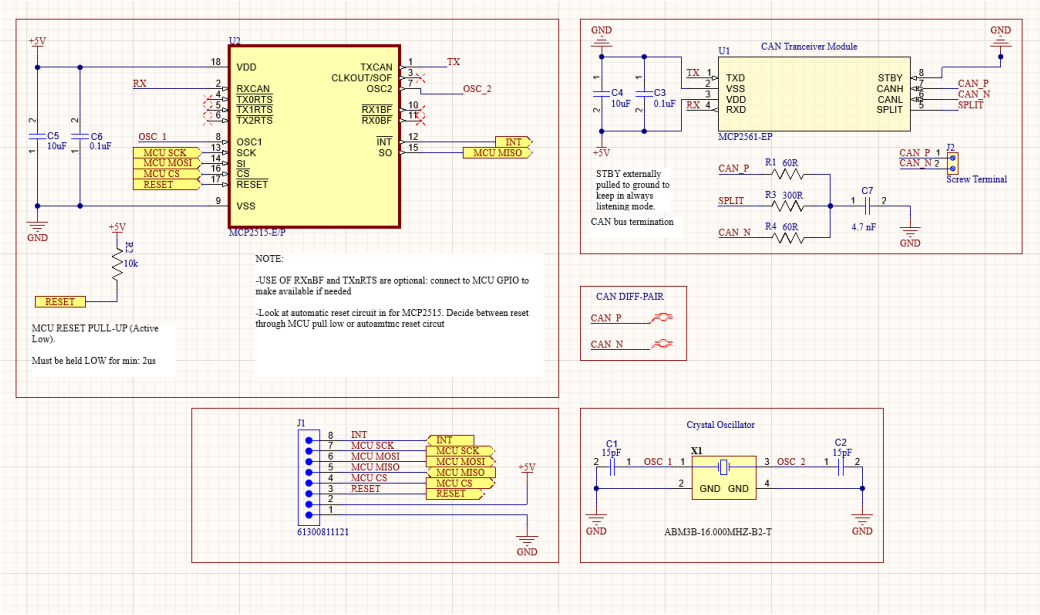
UBC Thunderbots Year 2

- In my second year of UBC Thunderbots, I took more of a leadership role, when working on projects, as I was a more senior member.

<u>CAN Interface Board</u>

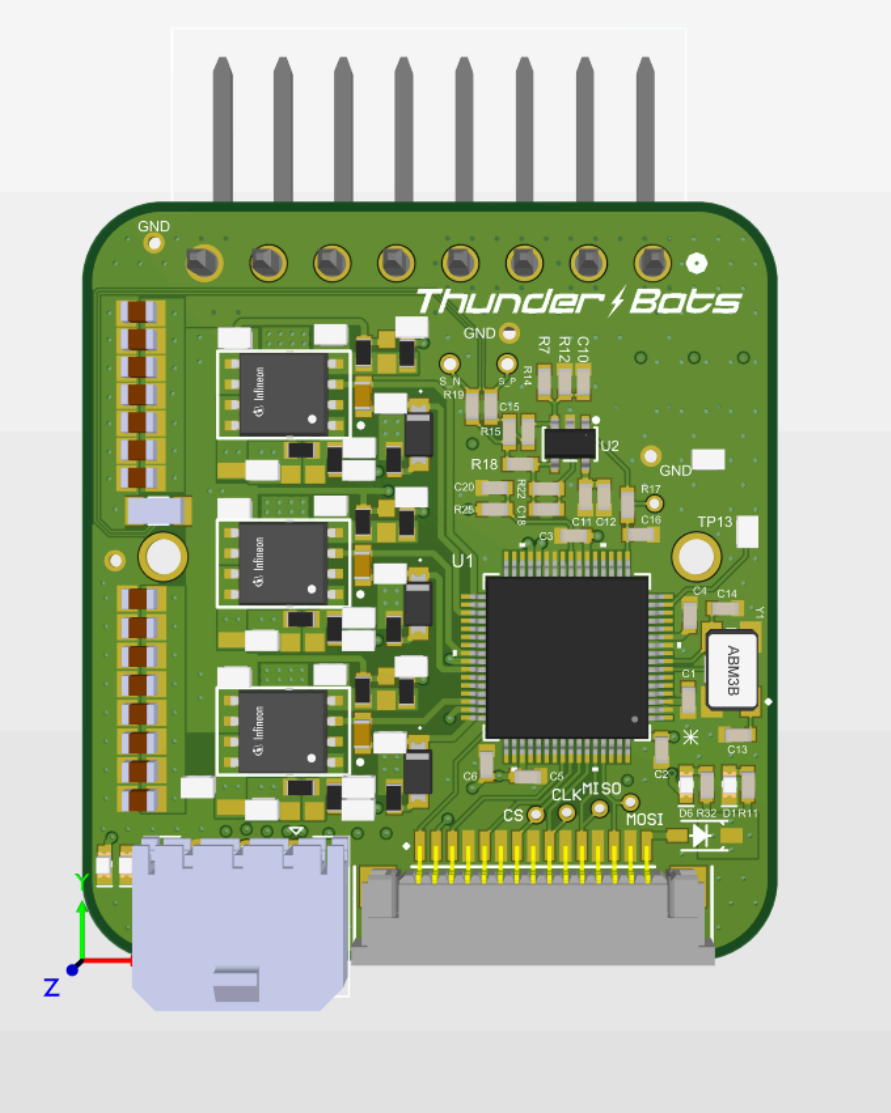
- The first project I worked on this year was converting our motor drivers from SPI to CAN, to minimize the interference from noise.
- The first step in this was designing a prototype board for CAN, though these can be bought online fairly cost effectively, the design of this was invaluable due to introduction to important concepts such as differential impedance matching.





Motor Driver Firmware/Redesign

- Over the recent design cycle, the motor drive was made to be more modular, making it a more ‘hot-swapable’ in the event that one of the drivers malfunctioned.
- There were huge challenges in layout, because we essentially needed to shrink down the previous layout by 10x, while including support for a CAN interface as well.
- I also wrote firmware to drive the motors using sensorless field oriented control (FOC)



ROS Clue Detective

- In a machine learning class, I worked with a partner to develop a robot in a ROS gazebo environment that was capable of following lines, and reading signs.
- I achieved this by training a convolutional neural network on a data set of pre-generated signs, utilizing data augmentation to develop more data and a more accurate model.
- I developed a robust imitation learning model that was capable of avoiding pedestrian and vehicular collisions, utilizing only computer vision.
- Overall, one of the greatest learning experiences of this class was self-teaching imitation learning, as well as learning to implement reinforcement learning through a uniquely implemented reward system.

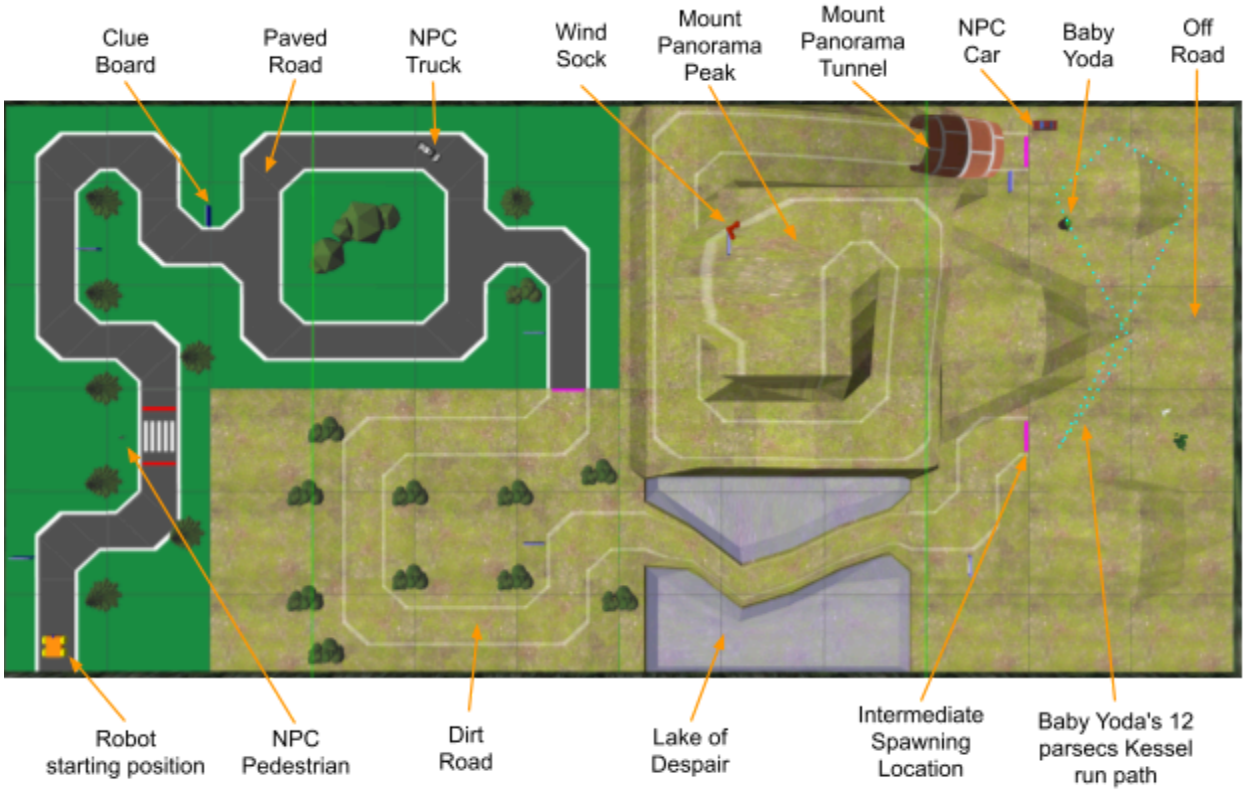


Fig. 1 Simulation playing arena overhead view