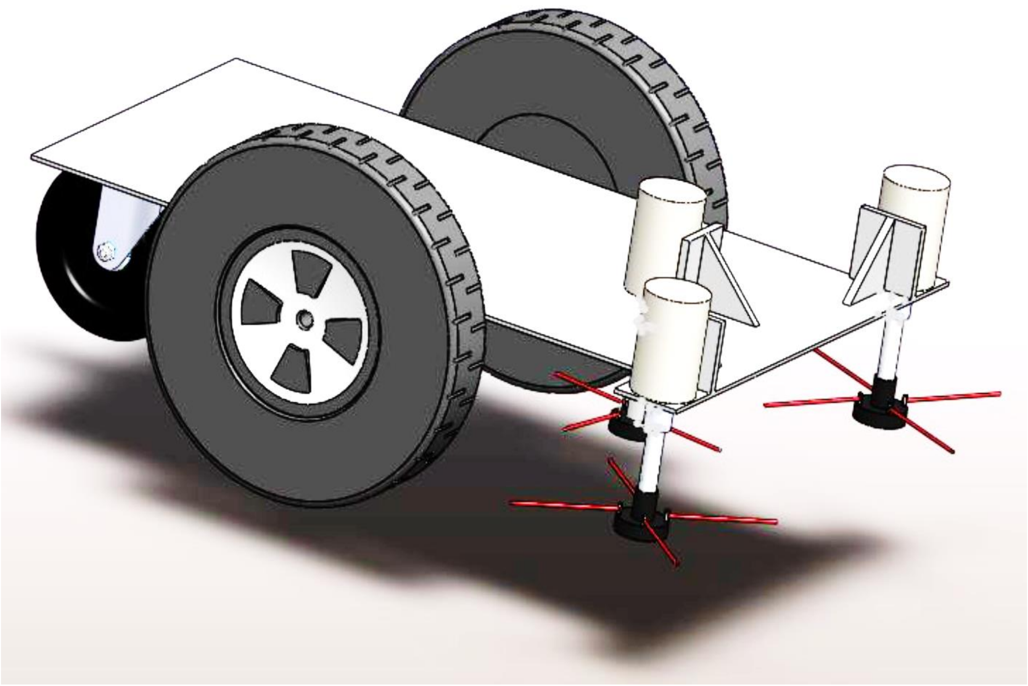
Articulated Autonomous AI-Assisted Solar Farm Grass Cutter



Department of Electrical Engineering and Computer Science

University of Central Florida

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Sponsored By: Orlando Utility Commission and Duke Energy

Senior Design II

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Group 19

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Motivation

According to Duke Energy and Orlando Utility Commission, maintaining the property of the Solar Farms costs roughly 150-200 thousand dollars per year to maintain about 500 acres of land. Our sponsors have given us a budget of $1,500 to design and create a prototype of an Articulated Autonomous AI-Assisted Solar Farm Grass Cutter in order to reduce solar farm maintenance costs. The motivation behind this project is to reduce the carbon footprint when compared to current solutions. By producing a low-cost autonomous solution, our sponsors will create more revenue on their solar farms and, in return other utility companies will be encouraged to create more solar farms.

Goals and Objectives

The goals and objectives of this project are to design and implement a power efficient, functional and prestige Autonomous AI-Assisted Solar Farm Grass Cutter. The main goal is to cut the grass areas under, around and below the Solar PV Structures without damaging or having any contact with the structures, humans, obstacles and/or objects that might be in the way. The Grass Cutter should stay in the boundaries of the set areas and cut the grass in an efficient matter in a reasonable time frame.

Interdisciplinary Teams

Three teams will work together with various different tasks and roles.

The focus of the Electrical and Computer Engineering team will be on the hardware, software, power systems, electrical designs and implementations of the overall grass cutter system. This includes specifications for the components, the design and implementation of the hardware and software and the integration of components to create a fully functional prototype that meets all the engineering standards and requirements.

The focus of the Mechanical Engineering team will be on the framework, wheels, string-based blade, motion and size of robot design and implementations.

The focus of the Computer Science team will be on the Laptop application for the robot, path planning, mapping, self-localization and communication to the electrical designs.

Sponsors Project Requirements

Robotic rovers must use an off-the-shelf battery, charger, remote controlled system and battery powered trimmer (no metal blade – must be string-based) to cut grass.
Provide math model to estimate how much grass area the robot can cut per hour. Teams will be provided total size of a typical solar farm. Assume grass cutting of entire site on a monthly basis and provide analysis based on season/weather/location for purposes of this evaluation.
The robotic grass cutting rovers must be equipped with a remote kill switch that can turn off the cutting system and locomotion at a distance of approximately 50 feet.
The system must maintain grass at acceptable height (3 to 6 inches) so as not to interfere with PV panels.
The rover must be capable of safely navigating in uneven terrain (~ 3 inch terrain differential over ~ 2 foot span in any direction) without capsizing while avoiding a series of obstacles. System must fit below and between rows of PV panels. Assume system package of less than 2 feet in all directions.
The system must be able to cut large areas, trim around PV support structures and cut grass under obstacles that are as low as 2 foot above ground with avoiding any damage to surrounding infrastructure, the environment and humans. The system must operate independently and have no attachments to existing solar farm array structures.
The system must operate independently and have no attachments to existing solar farm array structures. System to provide a secondary safety protocol to deal with rogue objects, in addition to the remote kill switch. System also to include location beacon with independent power supply (the beacon should be able to operate for a defined period of time after the main battery is completely drained).

Technical Requirements

Number	Technical Requirement	Target	Technical Difficulty
1	Provide an articulated sweeping motion needed to move the weed whacker across the terrain and cut grass	≥90% Efficiency	2
2	To identify grass areas that need attention	≥90% Efficiency	3
3	Obstacle Avoidance	≥2 feet Range	3
4	Motion Control	≥90% Efficiency	3
5	Defined battery storage technology with charging capability	≥90% Efficiency	1
6	Nylon String-Based Blade to cut grass	≥90% Efficiency	2
7	Kill Switch that can turn off the cutting system and locomotion	≥50 ft.	4
8	Safely Navigating through uneven terrain without capsizing while avoiding a series of obstacles	≥3 in. differential over	4
9	Cut grass under obstacles	≤2 ft. above the ground	2
10	Maintain acceptable grass height	≤6 in.	2
11	Must cut large areas and trim around PV Support Structures	≥500 sq. ft.	5
12	Size of Robot	≤2x2x2 ft.	1
13	Obstacle Detection	< 5 inches	1
14	Avoid any damage to surrounding infrastructure, the environment and humans	≥90% Efficiency	3
15	Time to charge from 25% level to 100%	≤3 Hours	3
16	Uniformity of cut	≤6 in.	4
17	Percent of total grass area cut and time	≥500 sq. ft. in 15 minutes	2
18	Stay in Boundaries	≥90% Efficiency	3
19	System Weight	≤40 lbs.	2
20	System Cost	≤$1500	3
21	Torque of Blade Motors	≥1 N·m	5
22	Force of Blade Motors	≥2N	5

ABET Design Constraints

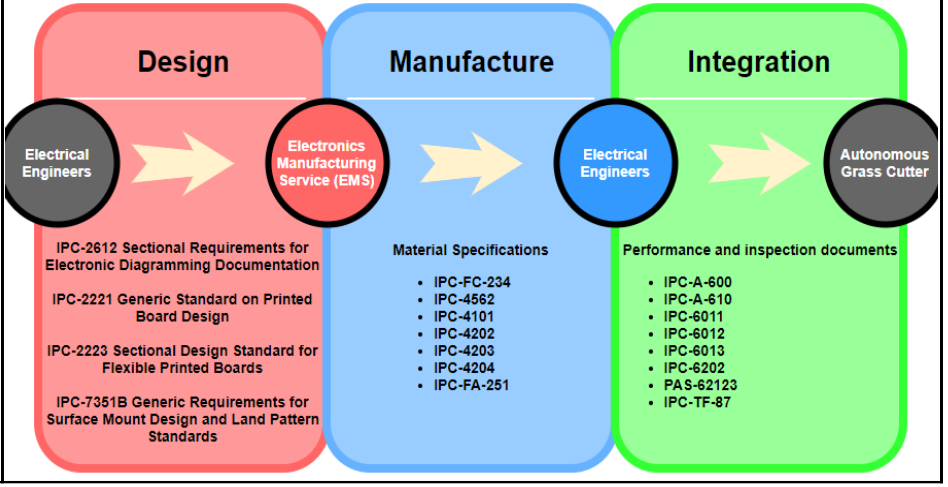
- Accreditation Board for Engineering and Technology (ABET)
- According to the ABET Design Requirements, students in Senior Design should be able to attain an ability to design a system, components, or process to meet desired needs within the realistic design constraints. These realistic design constraints, named: time, economic, environmental, weight, size, ethical, health and safety, manufacturability, and power, are design constraints that must be addressed when it comes to designing the autonomous grass cutter. This includes finding information on the design constraints in professional publications in the areas related to this project.

Constraint	Requirement / Limitation
Time	30 weeks or 2 Semesters time
Economic	1500 dollar budget set by OUC and Duke Energy. Prototyping costs $$. Research is Free.
Environmental	Thermal (Up to 110F) + Humidity (Daily Avg 70%) + Rain; Electronics in Florida. Terrain Differential of up to 3 inches.
Weight	Lightest possible, but has inverse relationship with economic/power/size constraints.
Size	< 2 cubic feet. Must fit underneath and between solar panels.
Ethical	Fairness within competition. Project integrity (standards/safety).
Health and Safety	Prioritize avoiding accidents (people and objects). String based blades required.
Manufacturability	Prototype needs to be reproducible for future iterations. Commercial off the shelf (COTS) parts.
Power	Must complete demonstration and competition at a minimum.

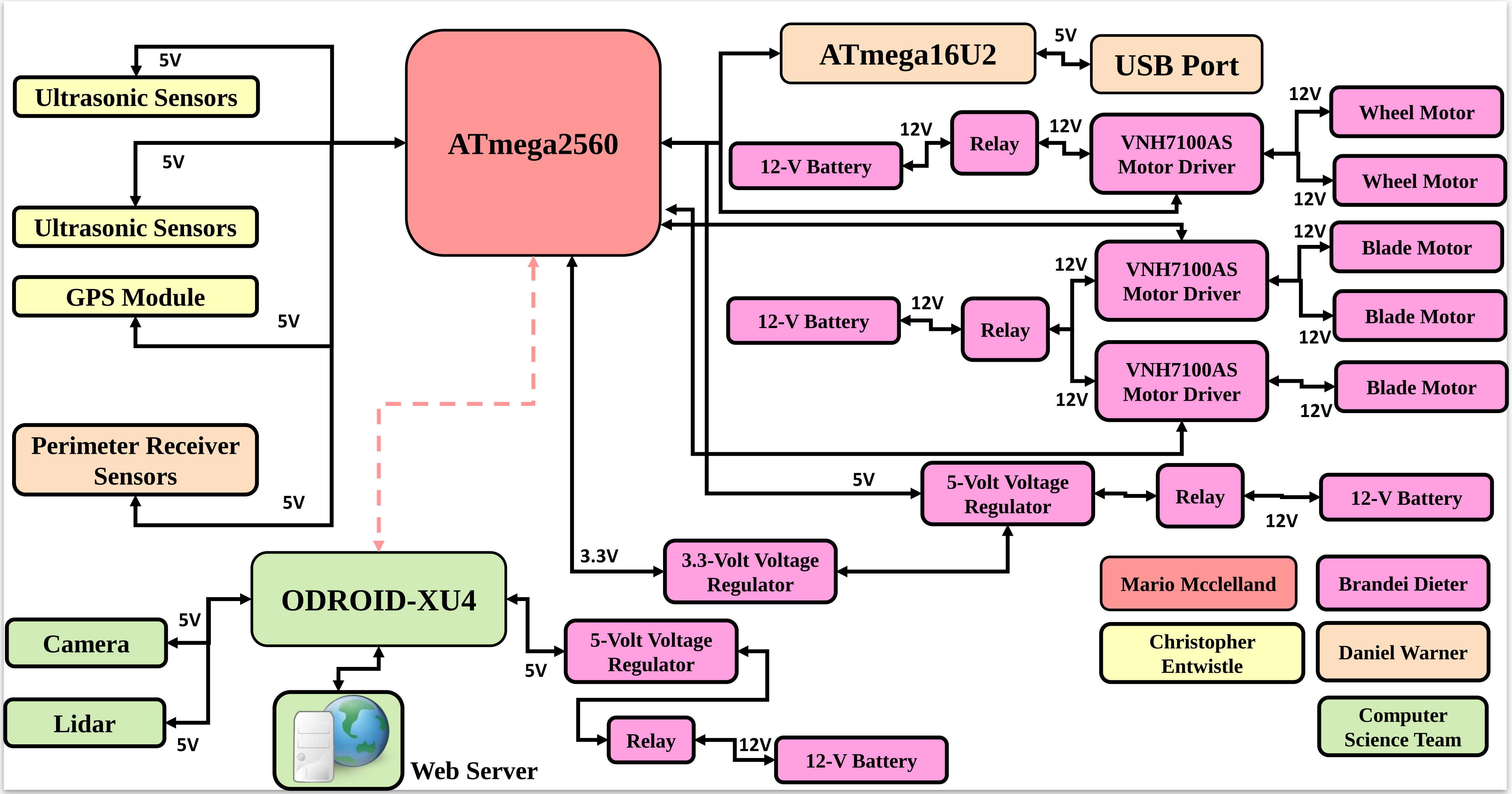
Standards

- Institute of Electrical and Electronics Engineers (IEEE)
- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
- The Institute of Electrical and Electronics Engineers (IEEE) Standards Association provides a wide range of technical and geographic points of origin to facilitate standards development and standards related collaboration. IEEE is one of the biggest publishers of standards, especially in the subject of electronics. IEEE forms committees to decide how a product, process, or service should be standardized.

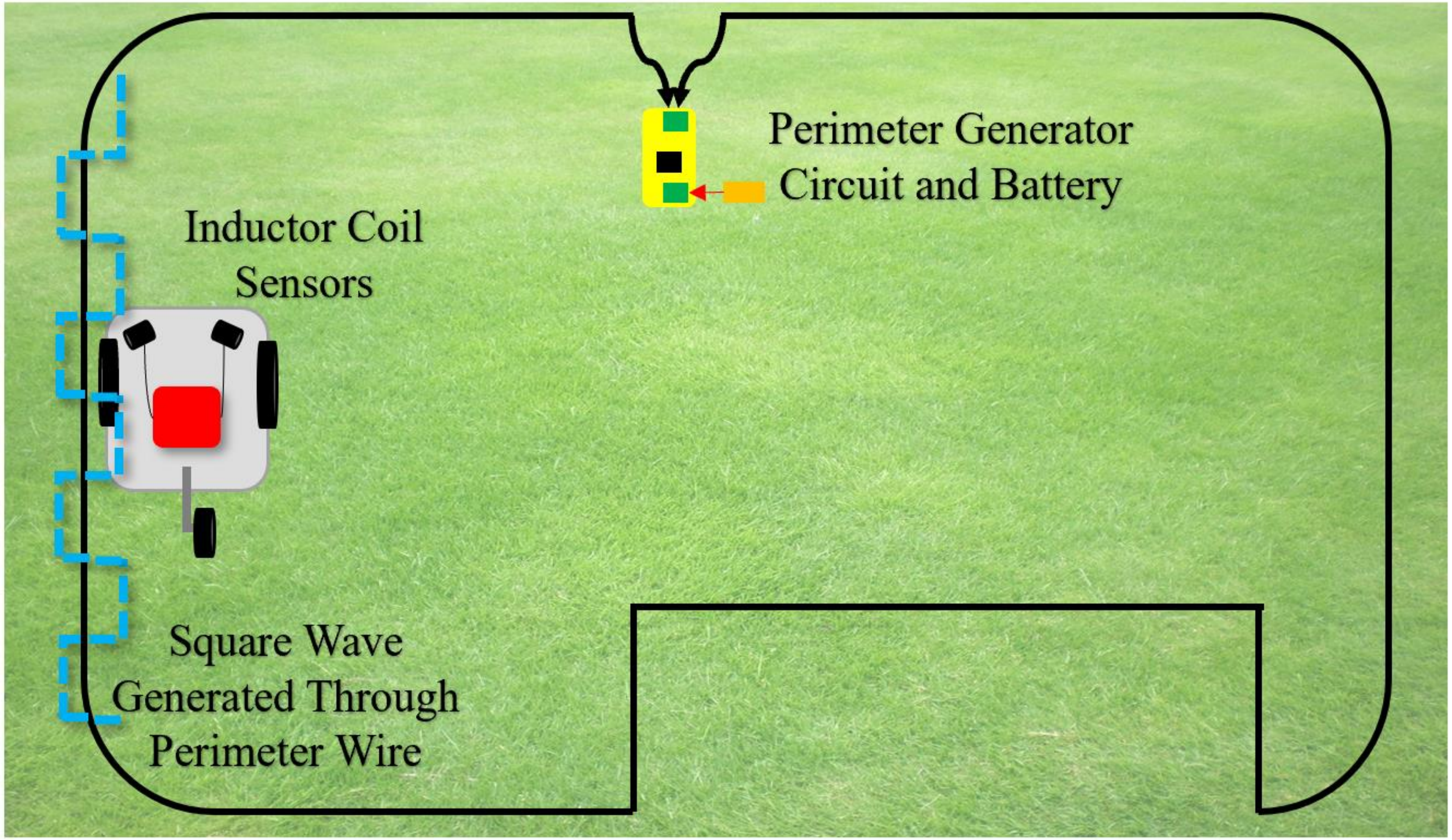
IEC ISO IEEE

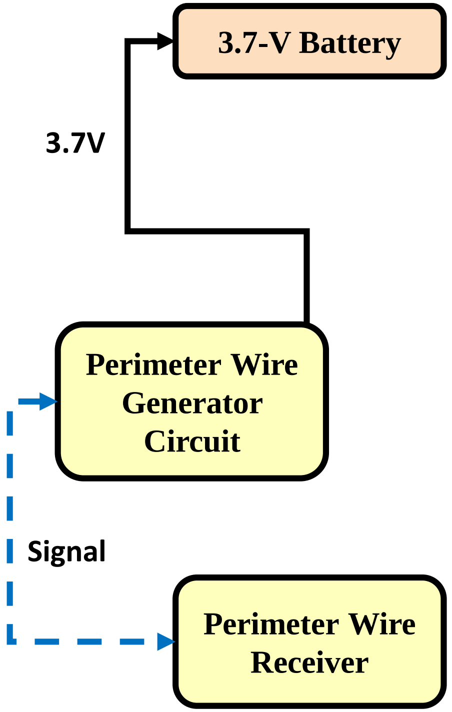
Component/Protocol	**Applicable Standards**
Battery	IEEE 1625, IEEE 1679.1
C Language	ISO/IEC 9899
Wireless	IEEE 802.11b/g/n
Software and Systems Engineering – Software Testing	ISO/IEC/IEEE 29119 Suite
Robot Map Data Representation for Navigation	IEEE 1873
Robotics	ISO 8373, ISO 9283, ISO 9787, ISO 10218-1, ISO 10218-2, ISO 18646-1
Inter-Integrated Circuit (I2C)	I2C Bus Specification (NXP Semiconductors)
Universal Serial Bus (USB)	IEC 62680 Suite
Electromagnetic Compatibility (EMC)	IEC CISPR 14-1, IEC CISPR 14-2, IEC 61000, IEC 61000
Institute for Printed Circuits (IPC) PCB	

Overall Hardware Block Diagram

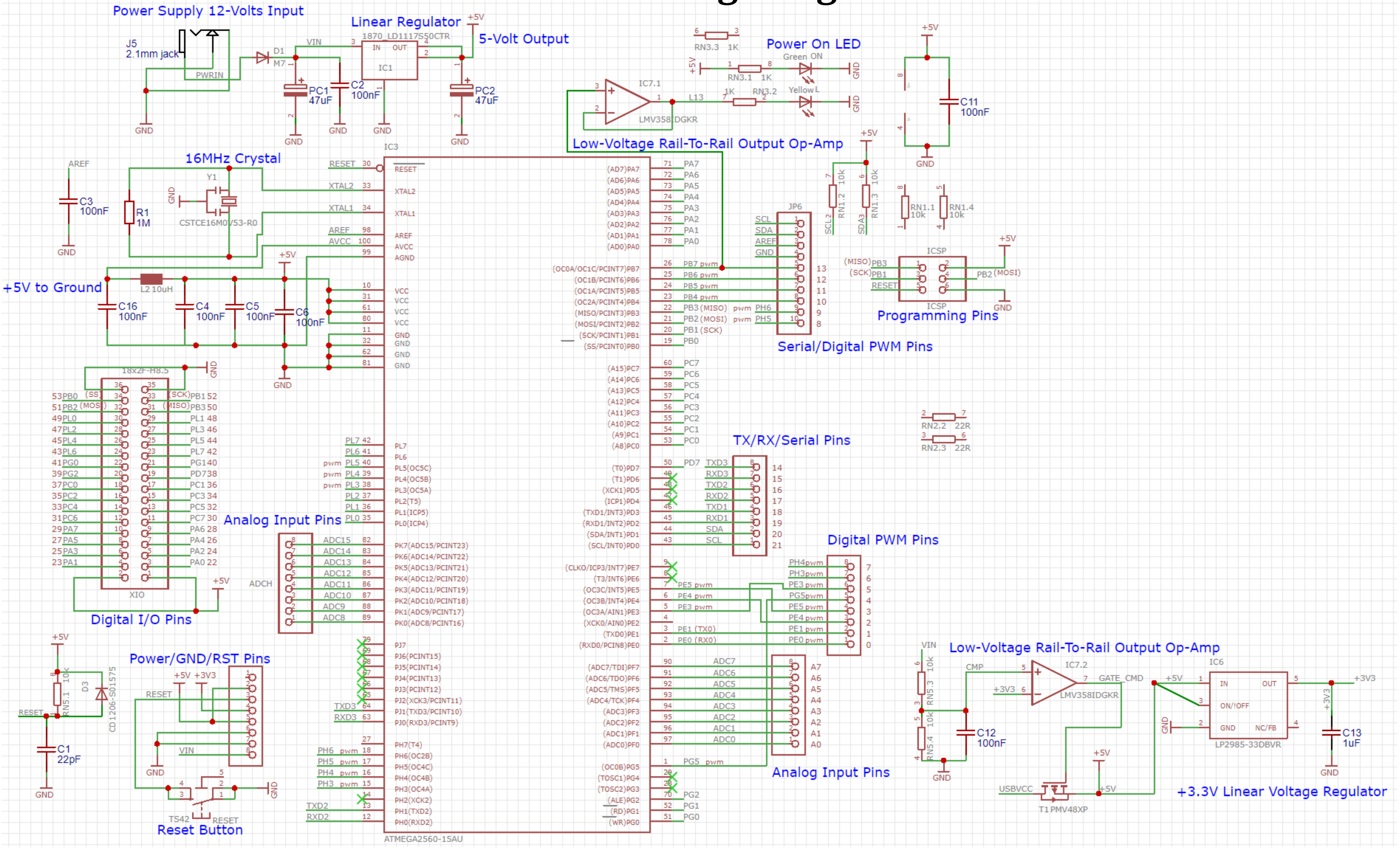


Boundary System Hardware Block Diagram and Functionality

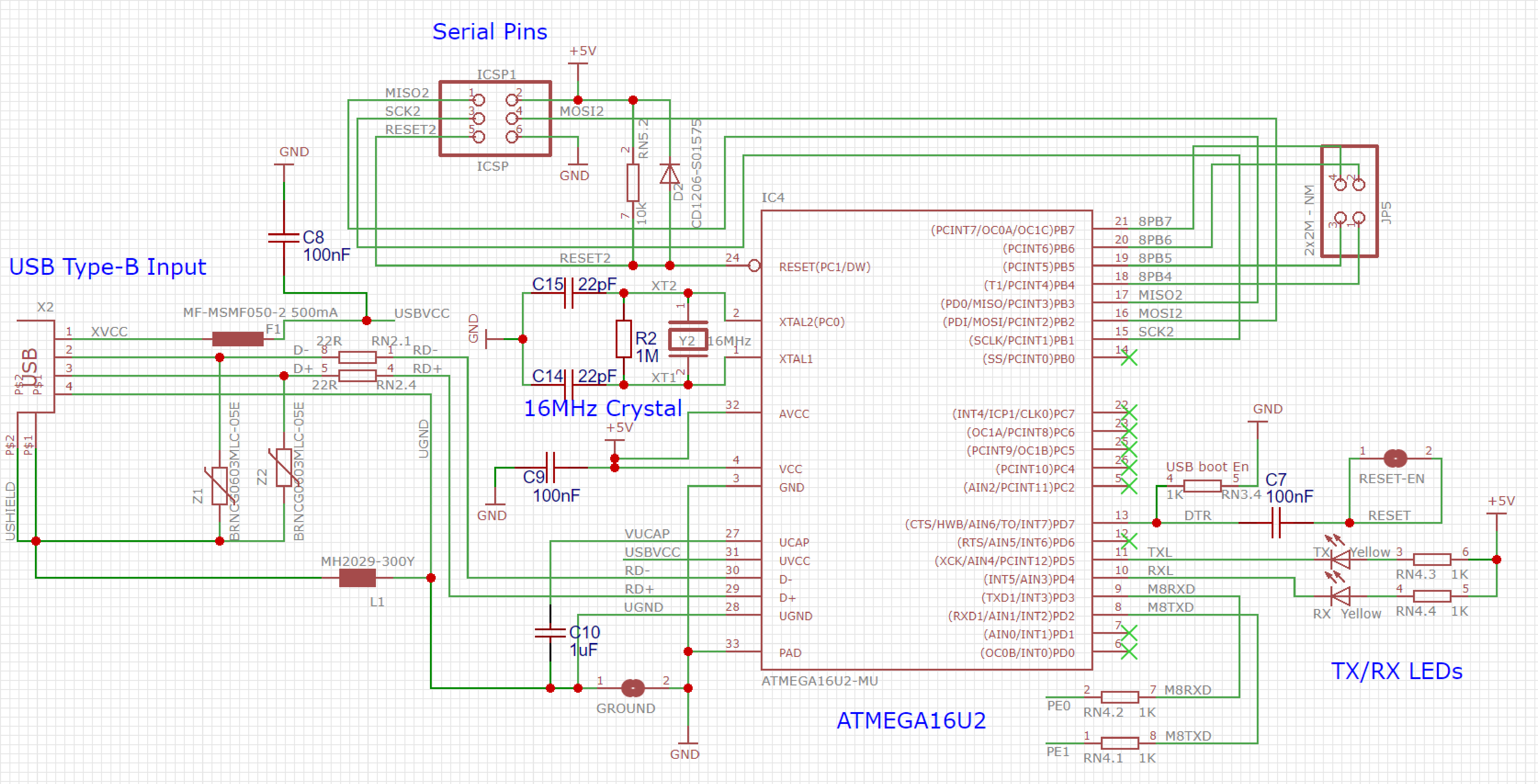




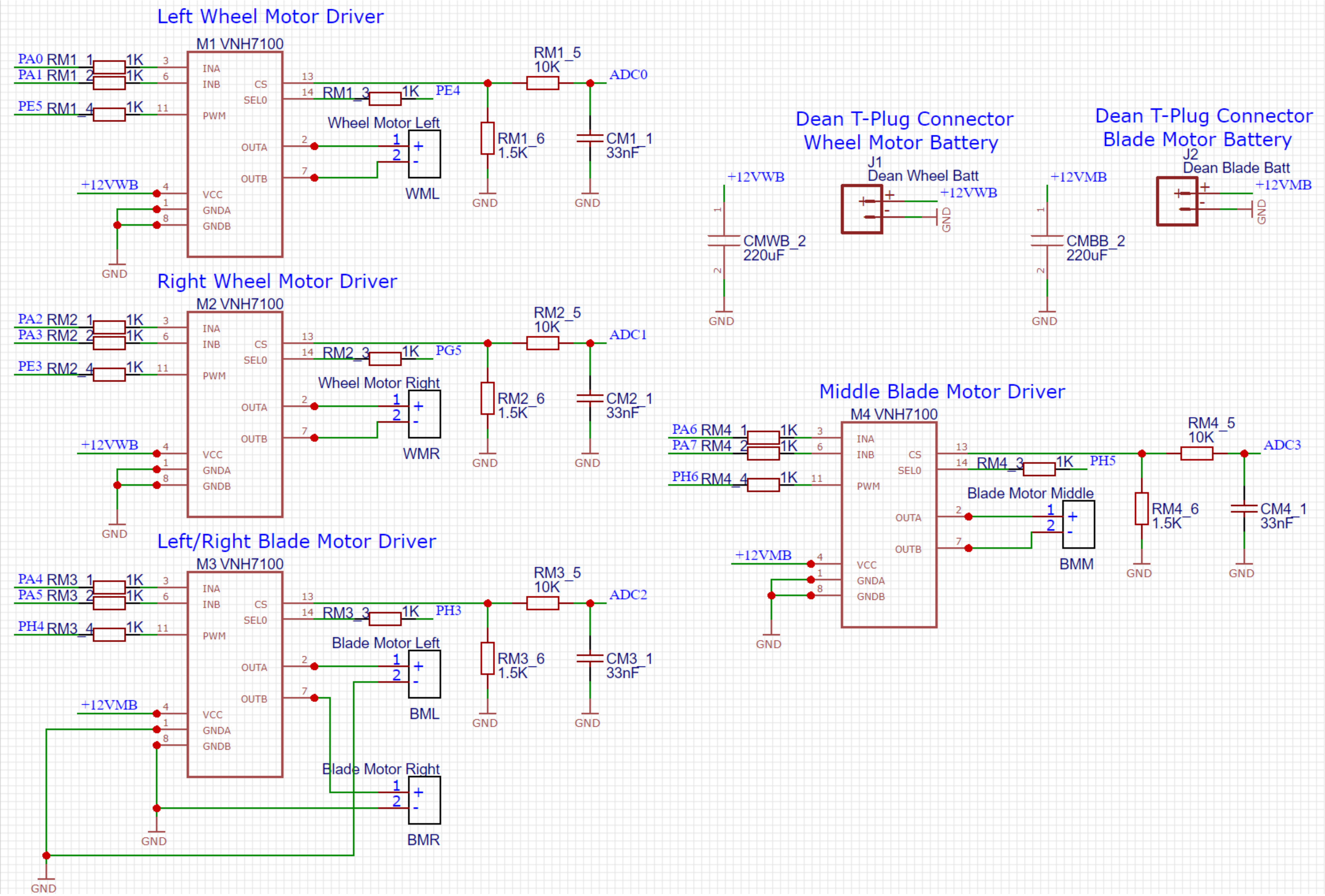
ATMEGA2560 and Voltage Regulators Schematic



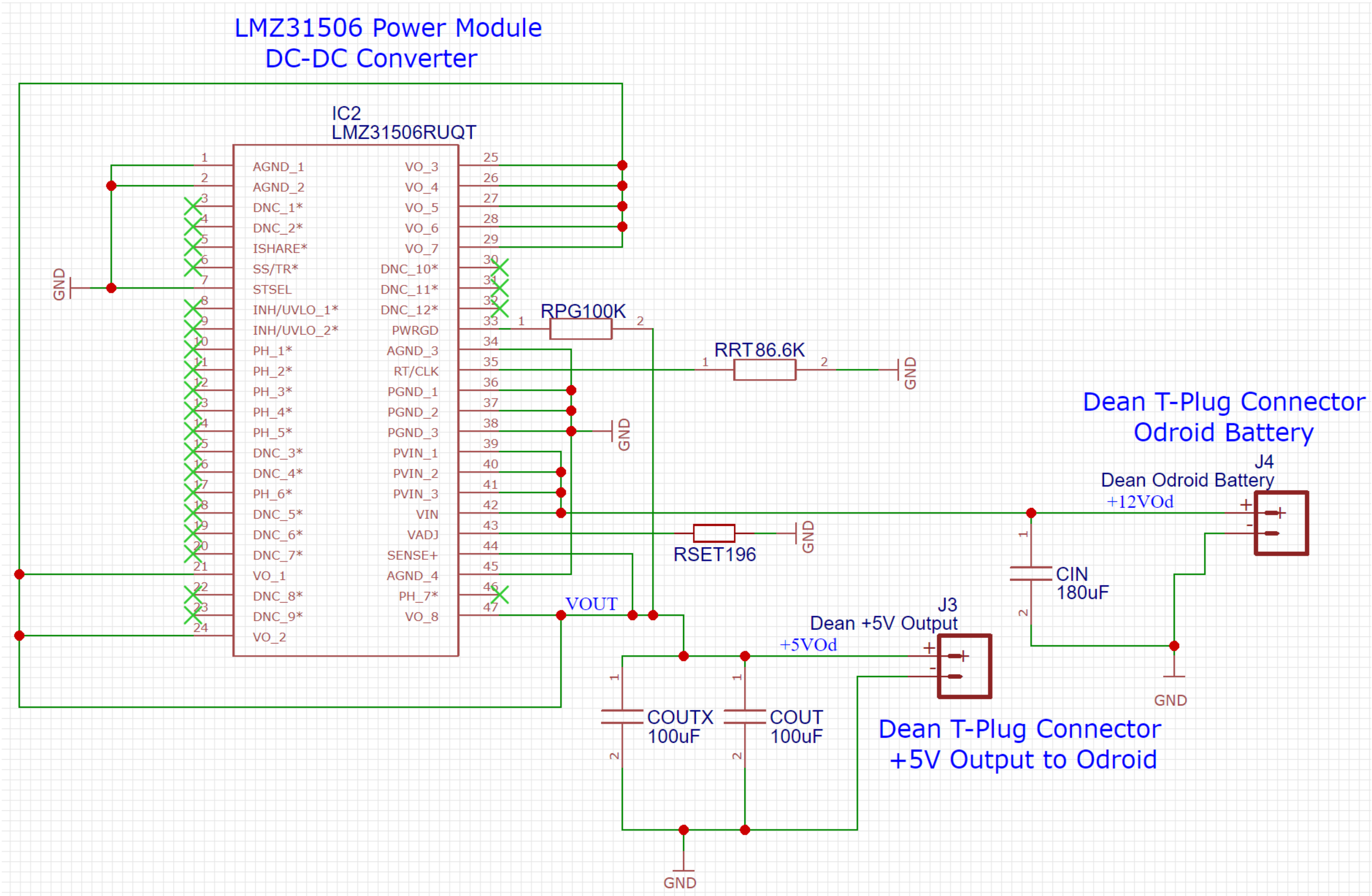
ATMEGA16U2 and USB Connection Schematic



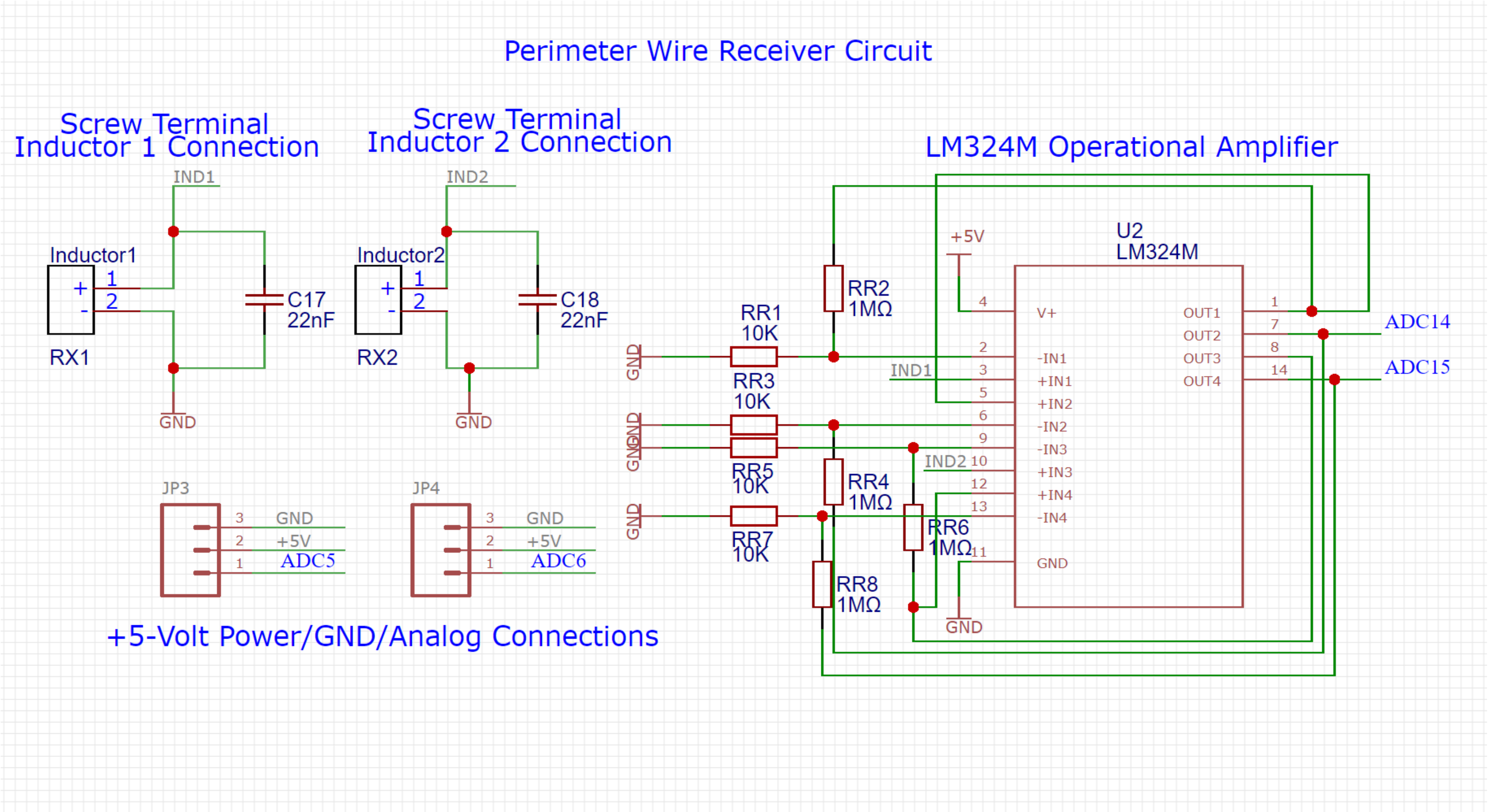
Wheel and Blade Motor Drivers Schematic



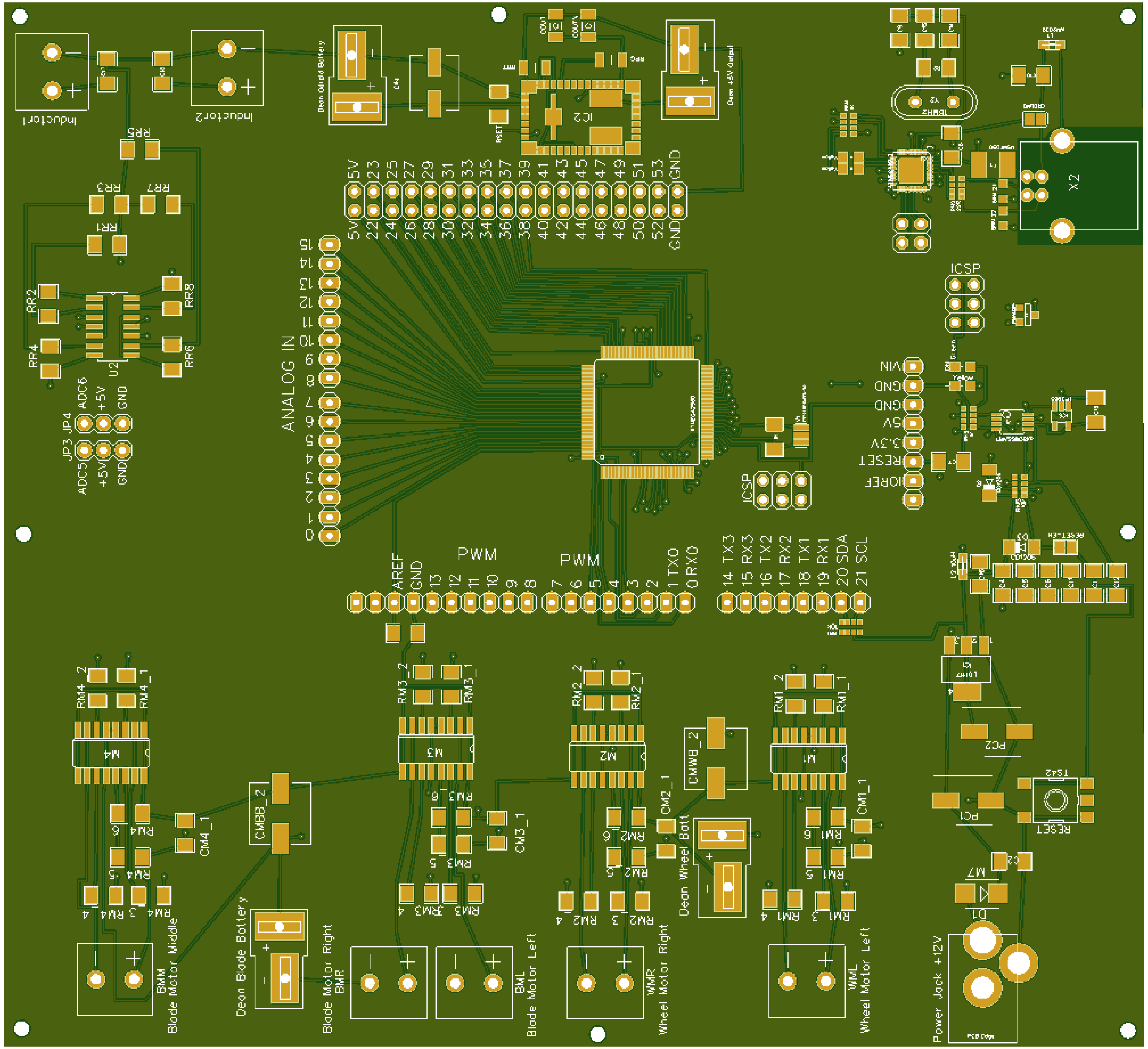
Voltage Regulator for Odroid Schematic



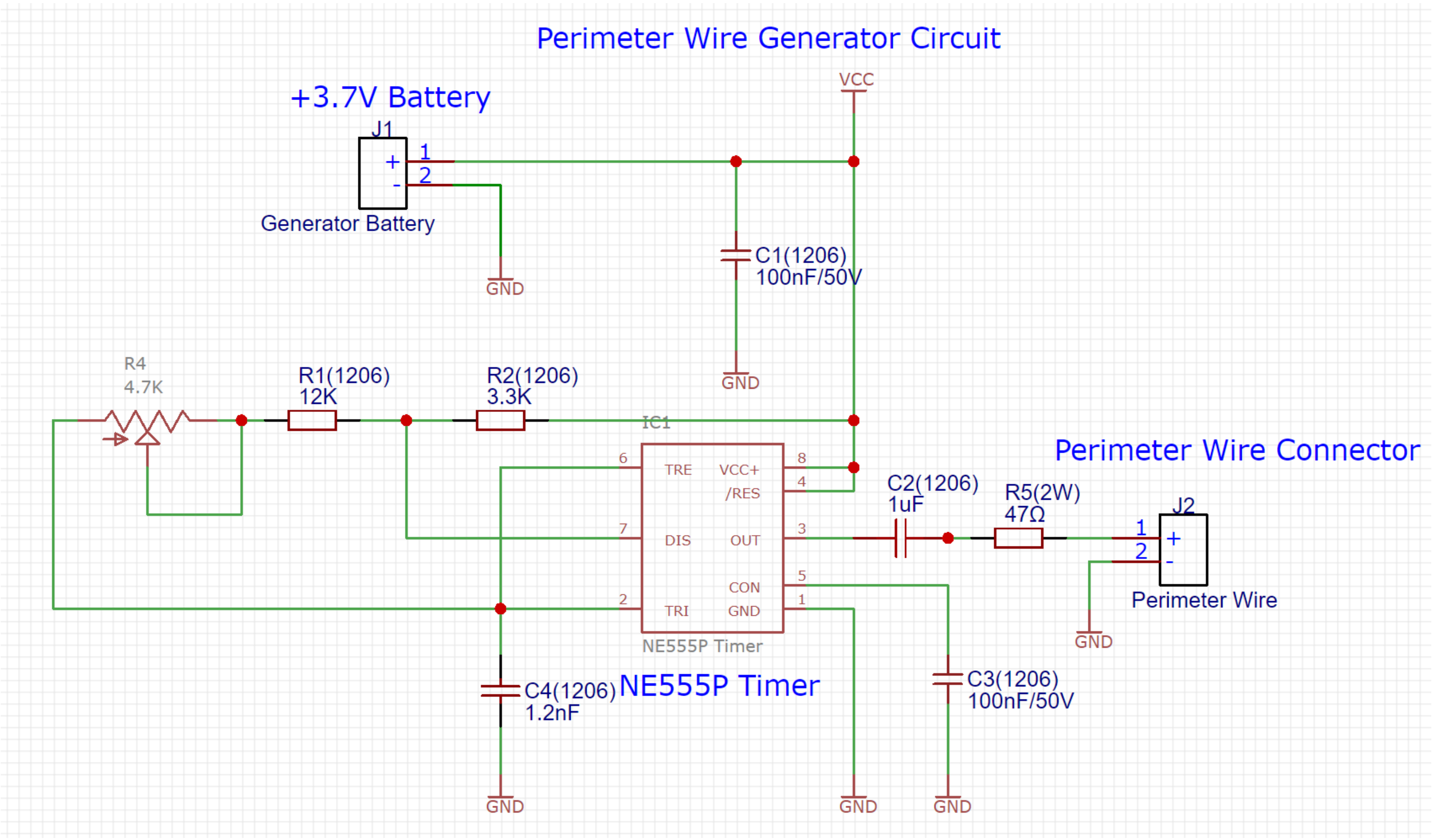
Perimeter Wire Receiver Schematic



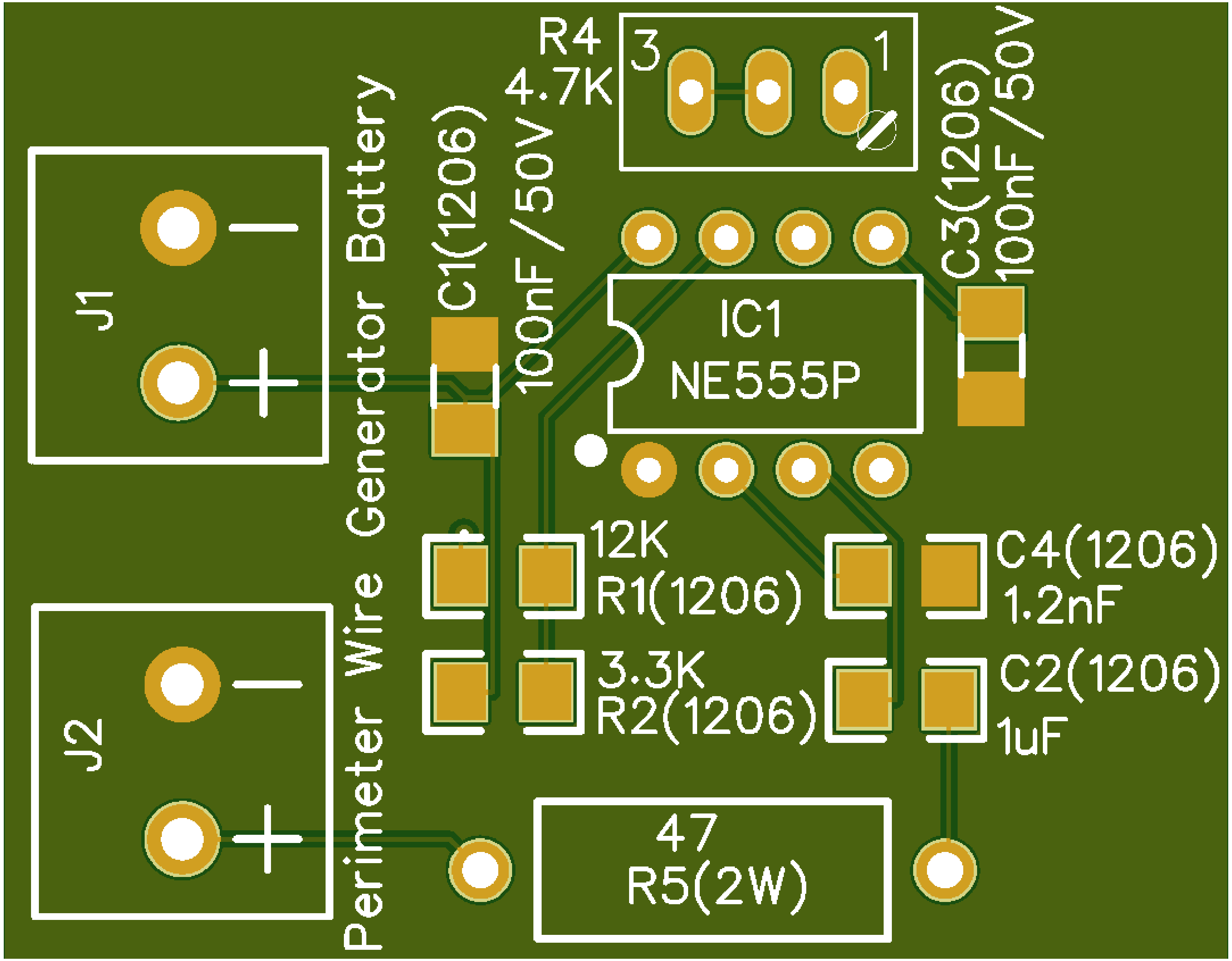
Overall PCB



Perimeter Wire Generator Schematic

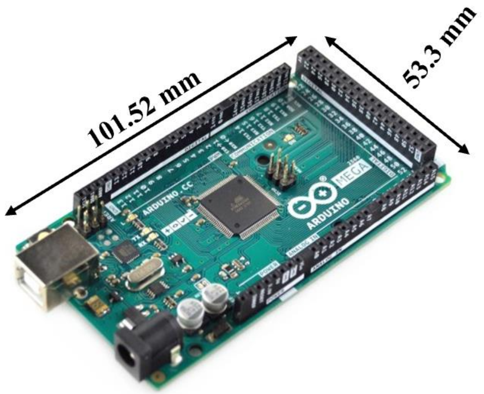


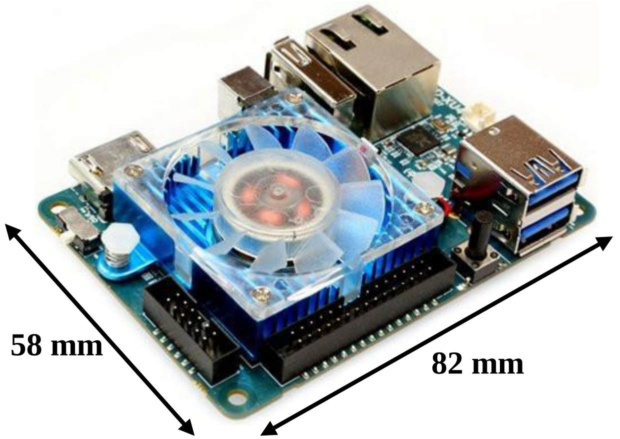
Perimeter Wire Generator PCB



Development Board Selection

- The Arduino Mega 2560 Development Board was selected for testing the overall system of the robot. The ATMega2560 and ATMega16U2 will be integrated onto the PCB design.
- The ODROID-XU4 was selected for the Computer Science team for all the image processing, lidar, computer vision and path planning software. The ODROID has 7 times faster processing power than the Raspberry Pi 3.

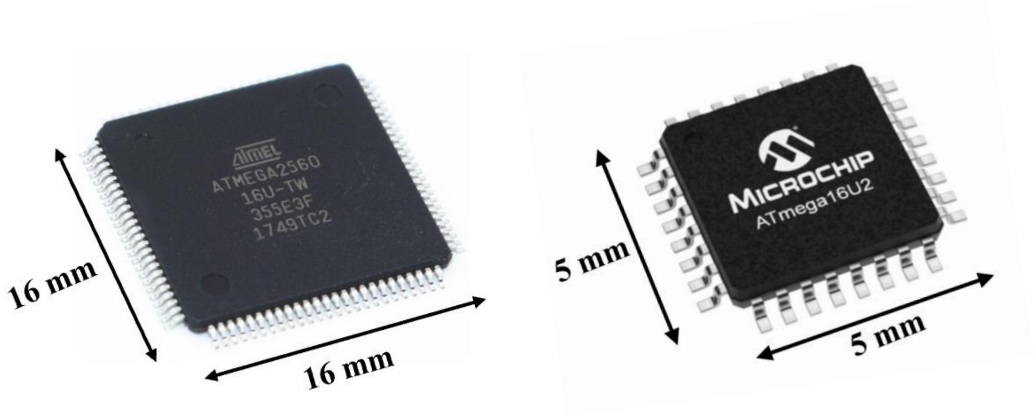




	Raspberry Pi 3 Model B	Arduino Mega 2560	ODROID-XU4
Price	$35.00	$38.50	$51.95
Size	87.1x56mm	101.52x53.3mm	82x58x22mm
Key Elements	-BCM43428 Wireless LAN and BLE on board -40-pin extended GPO -CSI camera port -DSI display port -1GB of Ram -Quad Core 1.2GHz Broadcam BCM2837 64-bit CPU	-54 Digital I/O pins -15 PWM outputs from Digital I/O Pins -16 Analog Input Pins -256KB of Flash Memory -8KB of SRAM -4KB of EEPROM -16MHz Clock speed -ATmega2560 Microcontroller	-Samsung Exynos5422 Cortex-A15 2GHz and Cortex-A7 Octa Core CPU -Mali-T628 MP6 -2GB LPDDR3 RAM PoP stacked -eMMC5.0 HS400 Flash Storage -Gigabit Ethernet Port

Microcontroller Selection

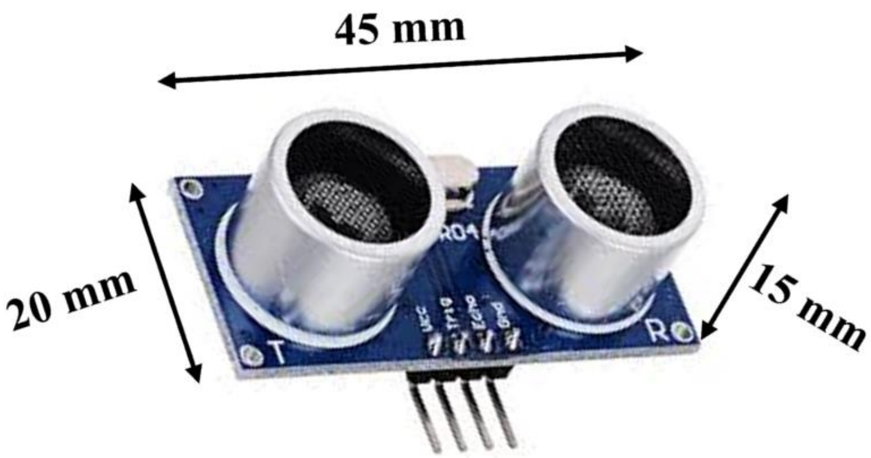
- The ATMEGA2560 was selected for the high compatibilities with controlling the overall system of the robot. This chip will be used on the custom-made PCB design for the overall grass cutter system.
- The ATMEGA16U2 was selected for the high compatibilities with communicating with the USB port and the ATmega2560. This chip will be used on the custom-made PCB design for the overall grass cutter system.
- The ATMEGA328P was not selected due to not enough pins and memory available that is required for this project.



	Atmel ATMEGA2560	Microchip ATMEGA16U2	Atmel ATMEGA328P
Price	$12.00	$2.53	$1.95
Size	16x16x1mm	5x5x0.95mm	34.79x7.49x4.57mm
Key Elements	-54 Digital I/O pins -15 PWM outputs from Digital I/O Pins -16 Analog Input Pins -256KB of Flash Memory -8KB of SRAM -4KB of EEPROM -Operating Voltage of 5-Volts -Input Voltage of 6-20-Volts -16MHz clock speed -5 SPI pins for SPI communication -2 TWI pins for TWI communication -4 hardware UARTs and 8 Serial pins for TTL serial data communication	-16KB of In-System Self-Programmable Flash -512B of EEPROM -512 of Internal SRAM -126 powerful instructions -32x8 general purpose working registers -22 Programmable I/O lines -Operating Voltage range of 2.7 to 5.5-Volts -1 UART and 2 SPI Digital Communication Peripherals	-32x8 General Purpose Working Registers -32KB Program Memory Size -2KB Data RAM Size -23 Input and Output Pins -1KB EEPROM ROM Size -8-bit Microcontroller

Ultrasonic Sensor Selection

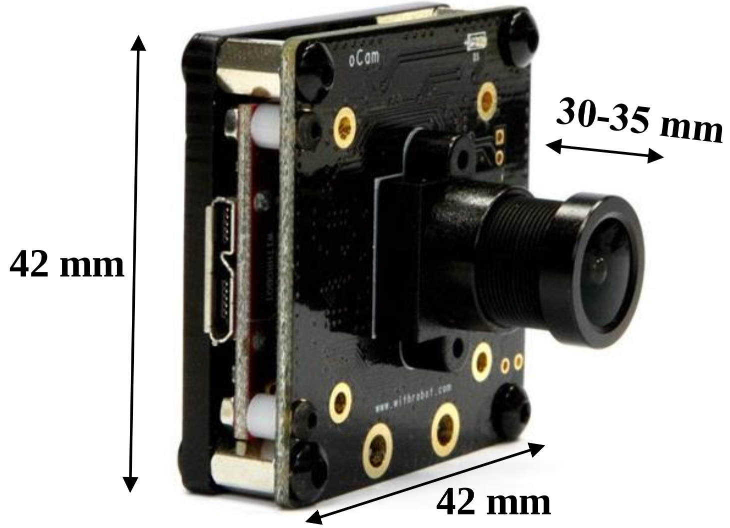
- The Arduino HC-SR04 Ultrasonic Sensor was selected due to the lower costs, higher maximum range and accuracy. Two of these Ultrasonic Sensors will be used for obstacle avoidance. Both of the ultrasonic sensors will be located on the front of the robot for object avoidance.



	Arduino HC-SR04 Ultrasonic Sensor	Parallax PING Module
Price	$2.50	$18.00
Size	40x20x15mm	22x46x15mm
Key Elements	-5V DC Operating Supply Voltage -15mA Operating Current -15 Degrees Measuring Angle -40kHz Operating Frequency -Minimum range of 2cm -Maximum range of 4m -Sends out eight 40kHz frequency signals -Operates using sonar	-5V DC Operating Supply Voltage -35mA Operating Current -Narrow, less than 15 Degrees Measuring Angle -Sends out short ultrasonic bursts at 40kHz -Minimum range of 2cm -Maximum range of 3m -Operates using Sonar

Camera Selection

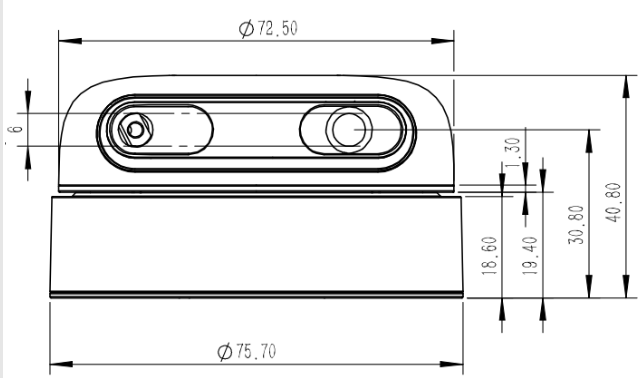
- The oCam 5MP USB3.0 Camera was selected due to the high resolution and compatibility of running computer vision software in conjunction with the ODROID-XU4. The Arducam Noir Camera was our first choice with the Raspberry Pi but the oCam and ODROID-XU4 has extremely better qualities that would be very useful for our project. This camera will be used by the Computer Science team for image processing, image segmentation, and computer vision.



	Arducam Noir Camera for Raspberry Pi	oCam 5MP USB 3.0 Camera
Price	$33.98	99.95
Size	36x36x4mm	42x42x30mm
Key Elements	-OmniVision 5647 Sensor in a Fixed-Focus Module -M12x0.5 Lens Holder -5MP Sensor -Still Picture Resolution 2592x1944 -Maximum Video Resolution of 1080p -Maximum Frame Rate of 30fps -LS-2717CS Lens -15-Pin MIPI Camera Serial Interface (CSI)	-OmniVision OV5640 CMOS image sensor -Standard M12 Lens with Focal Length of 3.6mm -FOV of 65 Degrees -Electric Rolling Shutter -Camera Control includes brightness, contrast, hue, saturation and white balance -Various Frame Rates available from 7.5-120 frames per second

Lidar Selection

- The SLAMTEC RPLidarA2M8 360° Laser Scanner was selected due to the high capabilities, greater range and 360 degree rotational scan for self localization and mapping using Lidar. This will be used in conjunction with the Computer Science Team with the ODROID-XU4 to effectively map the area and path plan.



	SLAMTEC RPLidar A2M8 360° Laser Scanner	SLAMTEC RPLidar A1M8 360° Laser Scanner
Price	$299.00	$99.00
Size	75.7x75.7x40.8mm	70.28x70.28x51mm
Key Elements	-Sample Frequency of 2000-4100 Hz -Scan Rate of 5-15 Hz -0.15-8-meter range -Angular Resolution of 0.45-1.35° -0-360° Laser Scanner -4000 samples of laser ranging per second with high rotation speed -5V Operating Voltage	-Sample Frequency of ≥2000-2010 Hz -Scan Rate of 1-10 Hz -0.15-6-meter range -Angular Resolution of less than equal to 1° -0-360° Laser Scanner -Samples 360 points each round at 5.5Hz -5V Operating Voltage

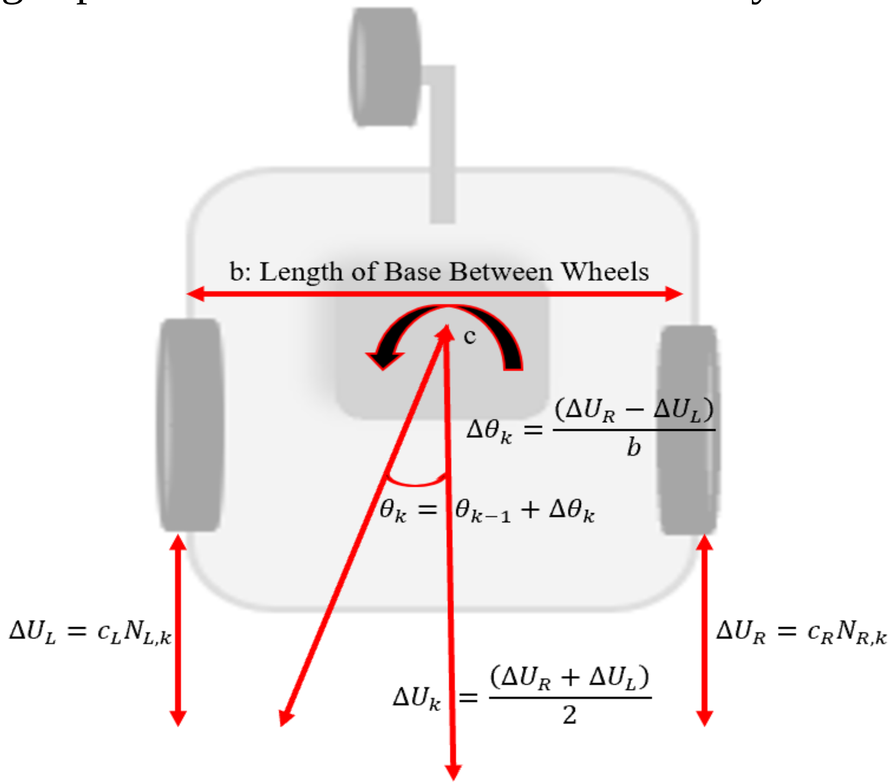
GPS Module Selection

- The Holybro Micro M8N GPS Module was selected due to the backup lithium ion battery for the GPS module that is required in this project and specifications of this device. This chip will aid in the use of location, positioning, mapping and odometry for the software.

	Holybro Micro M8N GPS Module	RadioLink SE100 GPS Module
Price	$36.99	$30.00
Size	38x38x11mm	48.5x48.5x15.3mm
Key Elements	-167 dBm navigation sensitivity -Update rate up to 10Hz -Cold starts at 26s -LNA MAX2659ELT+ -Rechargeable 3 Volt backup battery for warm starts -Low noise 3.3 Volt regulator -HMC5983L Built-in Compass -Ceramic Path Antenna	-167dBm sensitivity -Cold starts at 26s -Hot starts at 1s -Maximum update rate up to 18Hz -2.5 dbI high gain and selectivity ceramic antenna -MMIC BGA715L7 IC power amplifier -SAWF double filter -Radiolink M8N GPS with U-Blox UBX-M8030(M8)

Software Control System and Technologies

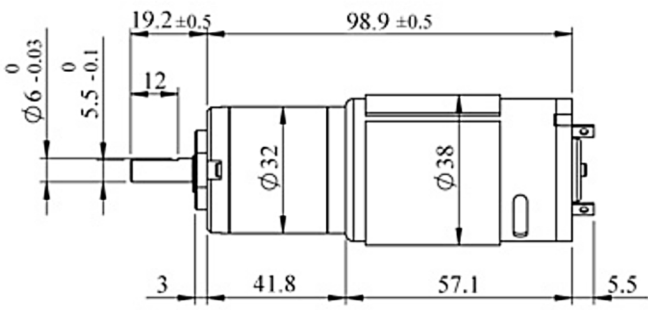
Odometry is a vital element in using the data from the sensors to estimate the change in position over time. It can be used to estimate the robot's location relative to a starting point and keep track of where the robot is at any time. Since the robot is driven by the two front wheels on either side of the grass cutter with one caster wheel following, the unicycle model of control can be implemented. This odometry will shift over time without a method to correct it. An optimization method that can be used is Borenstein's method. It can be used in modeling and estimating the error of odometry of a robot. A planned arbitrary test route is needed to calibrate and optimize the odometry. The model will calculate repeatedly by taking the robot along a path several times until the odometry is fully optimized and accurate.



$x'(t) = v(t)\cos(\theta t)$	Robot's state of x with respect to (x, y, θ)
$y'(t) = v(t)\sin(\theta t)$	Robot's state of y with respect to (x, y, θ)
$\theta'(t) = \omega(t)$	Robot's state of θ with respect to (x, y, θ)
$v_r(t) = \frac{v_r(t) + v_l(t)}{2}$	Velocity of the right wheel
$v_l(t) = \frac{v_r(t) - v_l(t)}{b}$	Velocity of the left wheel b is the length of the base from each wheel
$\Delta U_L = c_L N_{L,k}$	Incremental distance for the left wheel $N_{L,k}$ is the left pulse increment for the wheel encoders for a sample time k c_L is the conversion factor that translates the encoder's pulses into linear wheel displacement for the left wheel
$\Delta U_R = c_R N_{R,k}$	Incremental distance for the right wheel $N_{R,k}$ is the left pulse increment for the wheel encoders for a sample time k c_R is the conversion factor that translates the encoder's pulses into linear wheel displacement for the left wheel
$\Delta U_k = \frac{(\Delta U_R + \Delta U_L)}{2}$	Incremental displacement of the center point c
$\Delta\theta_k = \frac{(\Delta U_R - \Delta U_L)}{b}$	Incremental angular displacement b is the length of the base from each wheel
$\theta_k = \theta_{k-1} + \Delta\theta_k$	Robot's kinematic state of θ_k with respect to (x_k, y_k, θ_k)
$x_k = x_{k-1} + \Delta U_k cos\theta_k$	Robot's kinematic state of x_k with respect to (x_k, y_k, θ_k)
$y_k = y_{k-1} + \Delta U_k sin\theta_k$	Robot's kinematic state of y_k with respect to (x_k, y_k, θ_k)

Wheel Motor Selection

- The Planetary Gear Brush Motor by Robot Zone was chosen because of it's high torque capability.
- The torque fulfills weight requirement of a max of 40 pounds and provides a 30% positive power margin.
- 23 RPM was calculated as sufficient when using 8 inch wheels for surface area coverage.
- The disadvantage is that these motors require can require high amounts of power.



	Uxcell Self-Locking DC Worm Gear Motor with Encoder	Robot Zone Model # 638266 DC Planetary Gear Brush Motor (includes encoder)
Price	$34.99	$59.99
Size	40x36x125mm	38mm diameter x 97.6mm
Key Elements	-12V Operating Voltage -No-Load Speed of 55 RPM -Torque of 7.4 lb-in -Reduction Ratio of 1:72 -8mm D-Type Output Shaft -15mm Output Shaft Length -Bidirectional Capability -Overall, not strong enough	-12V Operating Voltage -No-load speed of 23 RPM -Rated-Load Current 1.2A -Max Stall current 20A -Torque of 260 lb-in -Reduction Ratio of 1:369 -6mm D-Type Output Shaft -12mm Output Shaft Length -Bidirectional Capability -Overall, strong enough, but LOTS of power

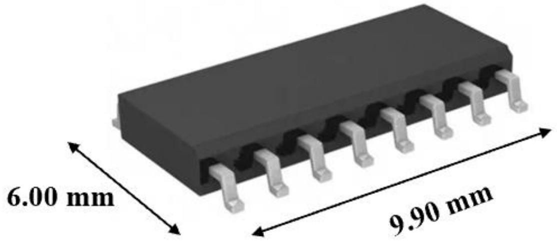
Blade Motor Selection

- The Guang Wan XD-3420 Permanent Magnet DC Motor was selected for the low costs, high torque and speed specifications. Three of these motors will be used for the three blades of the grass cutter system.
- The Machifit 895 DC Gear Motor was a good consideration but was not selected due to the parts being out of stock when it was time to purchase parts.

	Machifit 895 DC Gear Motor	Guang Wan XD-3420 Permanent Magnet DC Motor
Price	$15.99	$26.29
Size	Not Available	50.8x114.3mm
Key Elements	-Shaft Diameter of 5mm -Rated Voltage of 12-24V -Rated Speed of 3000rpm -Rated Torque of 0.51 N-m	-12V Operating Voltage -High Torque -No-Load Speed of 3000rpm -No-Load Current of 2.42A -Rated Revolution of 3000rpm -Rated Current of 3.1A -Rated Power of 30W -Copper Wire Stator Windings -CW/CCW Control

Motor Driver Selection

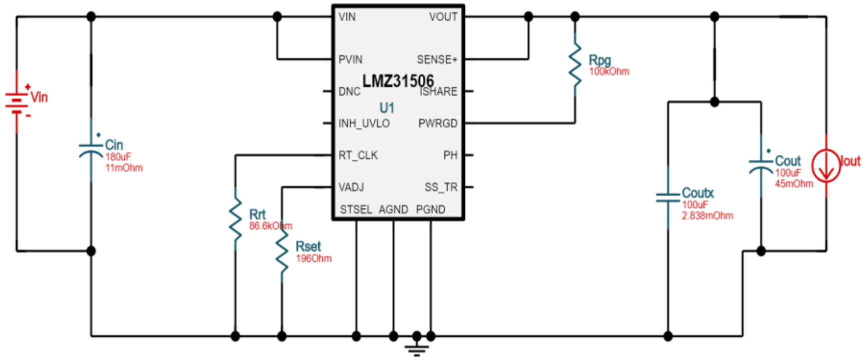
- The VNH7100AS Automotive Fully Integrated H-Bridge Motor Driver was selected due to the higher current ratings per channel. Although the DRV8432 was a good choice, this specific part was out of stock. This motor driver is important to support the high current needs that the motors will pull under load. The L293DNE motor driver was originally selected for this project but after testing the motors, we quickly realized that chip was not equipped to handle large loads and high currents per channel.



	VNH7100AS Automotive Fully Integrated H-Bridge Motor Driver	DRV8432 Dual Full-Bridge PWM Motor Driver	L293DNE Quadruple Half-H Drivers
Price	$4.65	$10.75	$3.68
Size	9.90x6.00mm	15.90x11mm	19.80x6.35mm
Key Elements	-Automotive Qualified -Maximum Operating Voltage of 41 V -Output Current of 20A -PWM operation up to 20kHz -5 Multi-sense diagnostic functions -Half-bridge and Multi-Motors Configuration -Incorporates a dual monolithic high-side driver and two low-side switches -Can monitor motor current by delivering a current proportional to the motor current value	-High-Efficiency Power Stage up to 97% -Maximum Operating Voltage of 52 V -Up to 2x7Amp Continuous Output Current with a 2x12Amp Peak Current in Dual Full-Bridge Mode -Undervoltage, Overtemperature, Overload and Short Circuit Protection	-Maximum Operating Voltage of 36V -High-Noise-Immunity Inputs -Output Current 1A Per Channel -Peak Output Current 2A Per Channel -Output Clamp Diodes for Inductive Transient Suppression

Voltage Regulator Selection

- The LMZ31506 Power Module DC-DC Converter was selected due to the higher power efficiencies at an output of 5-Volts and 4-Amps. The other selections were cheaper, but they were less efficient and did not meet required specifications. The simulation shown was created on Texas Instrument Webench Power Designer. This will be used in the power systems to convert a 12-Volt battery to an output of 5-V and 4A to power the Odroid-XU4, Lidar and Ocam.



	LMZ31506 Power Module DC-DC Converter	LM2596-ADJ Step-Down Voltage Regulator	LM2673S-ADJ Step-Down Voltage Regulator
Price	$11.76	$4.73	$4.86
Size	15.2x9.2x2.9mm	42x24mm	27x16mm
Key Elements	-Greater than 92.5% efficient -Adjustable output versions from 0.6-5.5V -Adjustable Switching Frequencies of 250-780kHz -High efficiency at 5-V, 4A output -Offers Flexibility and feature-set of a discrete point-of-load design -Over-Current and Temperature Protection	-Greater than 80% efficient -3.3 V, 5V, 12V and Adjustable output versions available -150kHz Fixed-Frequency Internal Oscillator -Low power standby mode ~80μA -Thermal Shutdown and Current-Limit protection -Maximum 3A output load current	-Greater than 90% efficient -Fixed output versions of 3.3, 5 and 12-Volts and 1.2 to 37-Volts -260kHz fixed-frequency internal oscillator -Soft-start capability -Built-in thermal shutdown -Resistor programmable current limit of the power MOSFET switch -Maximum 3A output load current

Batteries Selection

- The Ovonic 11.1V LiPo Battery was selected due to its lower costs, fast shipping time and specifications. The other battery selection would take too long to ship from China and may be unreliable. Four of these batteries will be used to power the Electrical Components, Wheel Motors and Blade Motors.
- The 3.7V MXJO Lithium Ion Battery will be used to power the low power perimeter generator circuit.

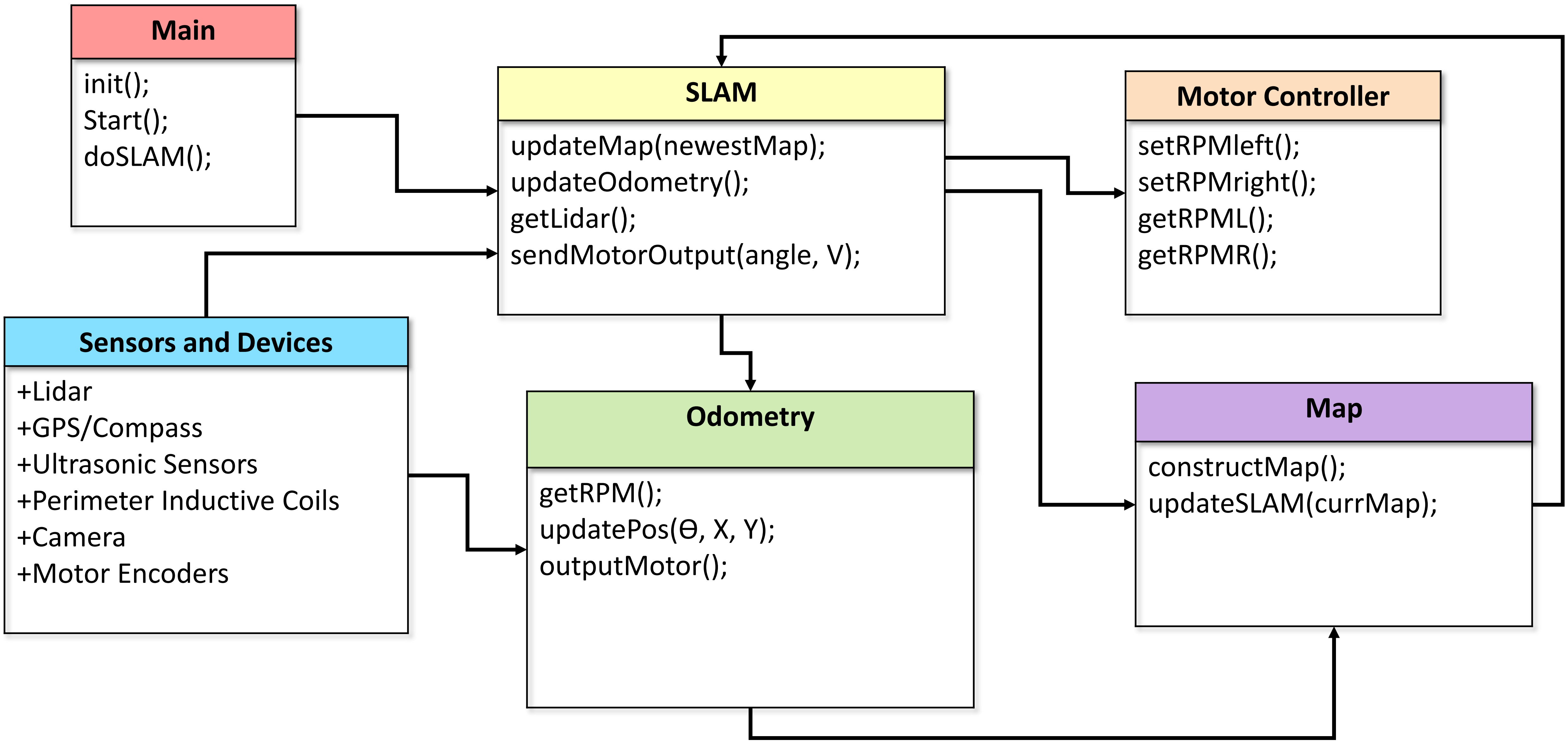
	Ovonic 11.1V LiPo Battery	DMD 100Ah/12V Li-Ion Battery	3.7V MXJO Lithium Ion Battery
Price	$49.99	$169.00	$10.00
Size	130x40x31mm	260x260x60mm	65mmLx18mmD
Key Elements	-11.1V LiPo Battery -High Discharge Rate of 50C -3 Series -Single Cell of Capacity to reach 8000mAh -Deans Plug Connection -Weighs 0.93476 pounds -Widely used for RC cars and 4WD Racing Trucks	-12V Li-Ion Battery -Seven smart security features -Cycle life of 2000 times or more times -Disadvantage is that it ships from China	-Current Rating of 20A -3.7V Lithium Ion -3500mAh Battery Capacity

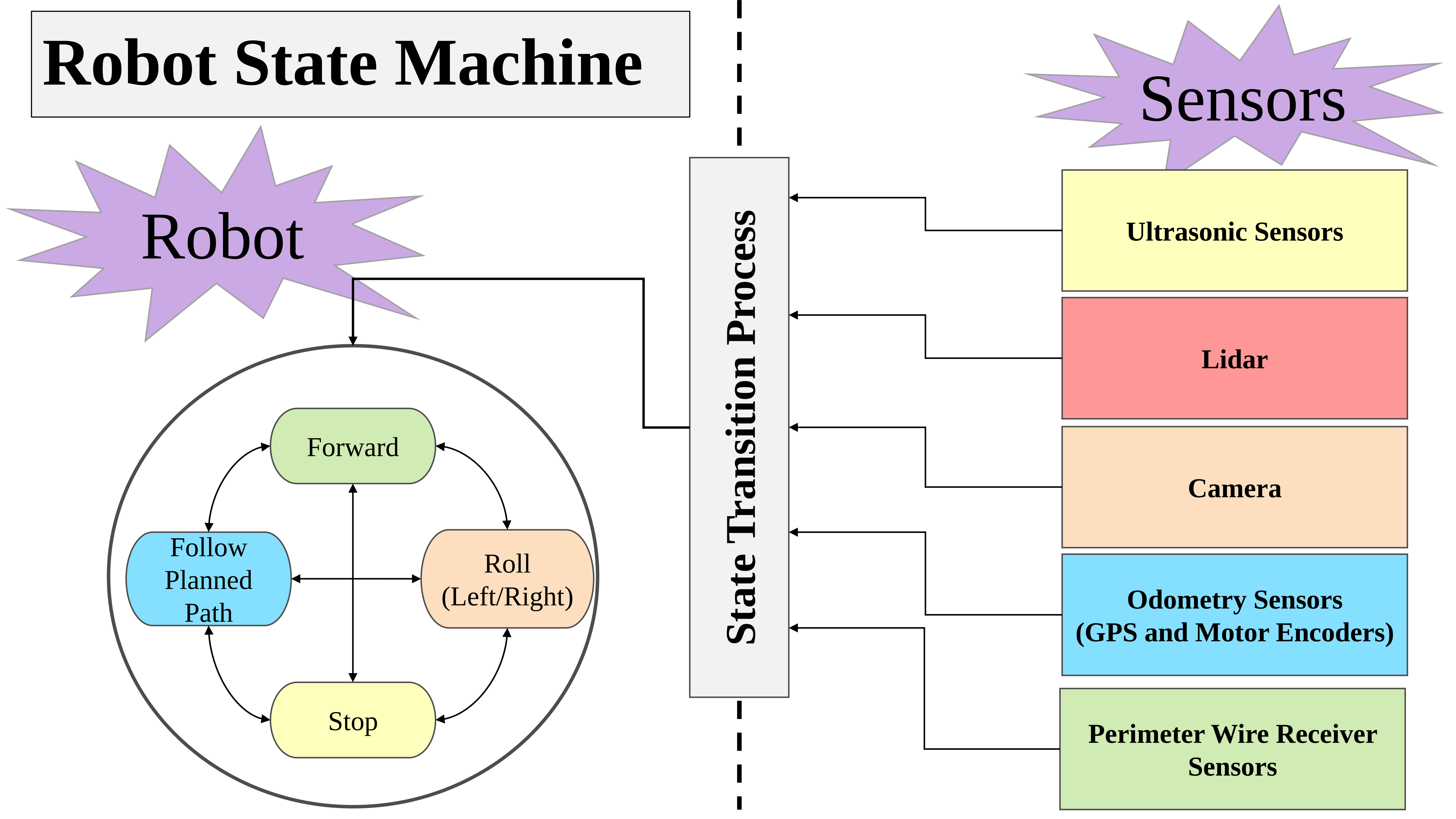
Relay Selection

- The eMylo relay uses radio frequency technology with long remote control distance. This product meets the sponsor requirement of a 50 ft remote controlled shut off.
- The maximum current that the eMylo relay is capable of handling (10A) is greater than the maximum current rating for the PCB (8.5A).

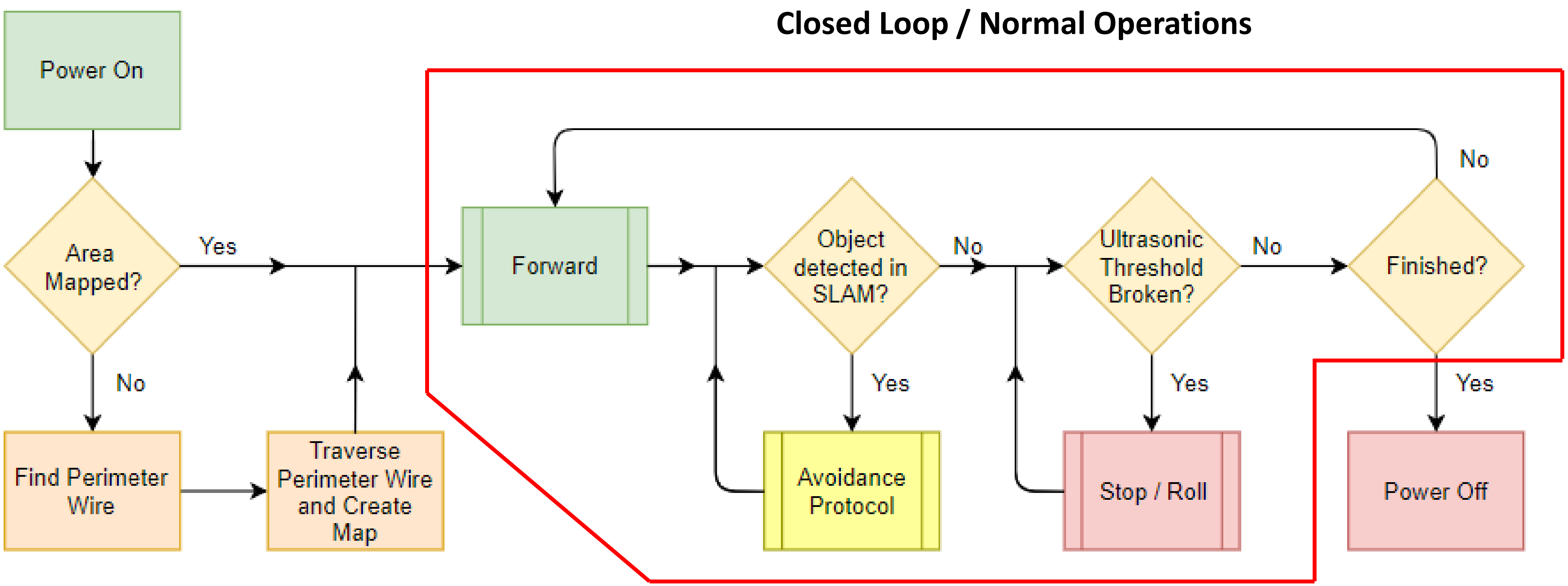
	eMylo DC 12V 6x 1 Channel RF Relay Wireless Remote Control Switch	DONJON Wireless Remote Switch
Price	$29.99	$20.99
Size	105x48x15mm	66x43x30.48mm
Key Elements	-12V Operating Voltage -Operating distance of up to 492.126ft. -Operating frequency of 433MHz -maximum current load of 10A -6 available channels for 6 different relays -3 alternative programmable outputs. -Overall, fulfills requirements but expensive.	-12V Operating Voltage -Operating distance of up to 328ft. -Operating frequency of 433MHz -maximum current load of 30A -2 available channels for 2 different relays -2 separate remotes -compact design

Software Class Diagram




Robot State Machine
Robot
Forward
Follow Planned Path
Roll (Left/Right)
Stop
State Transition Process
Sensors
Ultrasonic Sensors
Lidar
Camera
Odometry Sensors (GPS and Motor Encoders)
Perimeter Wire Receiver Sensors

System Software Flowchart



Software Tools and Designs

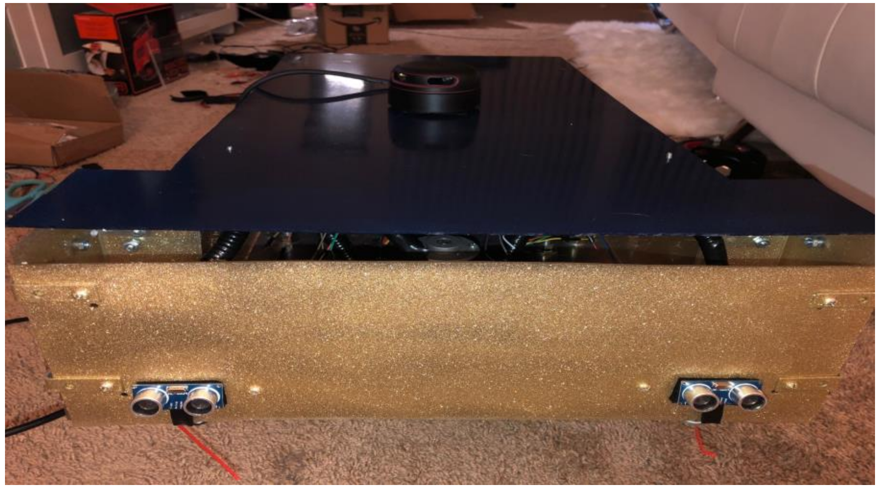
-The Arduino IDE will be used to program the ATmega2560 for all the electrical components.

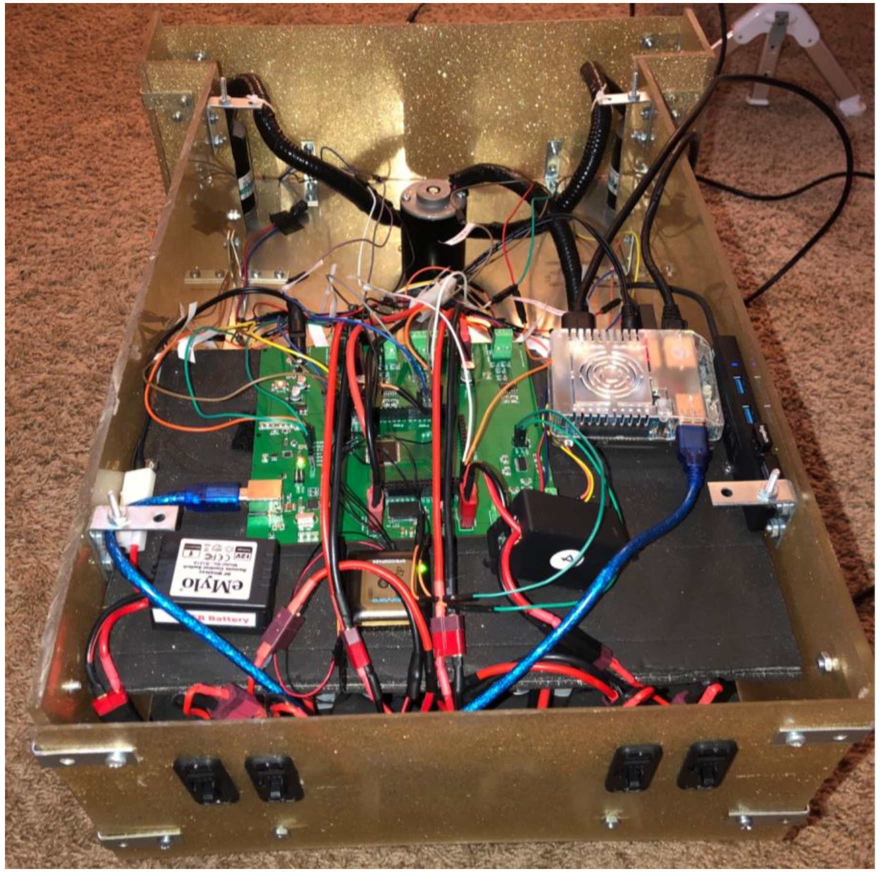
-The programming languages that will be used are C++ and Python.

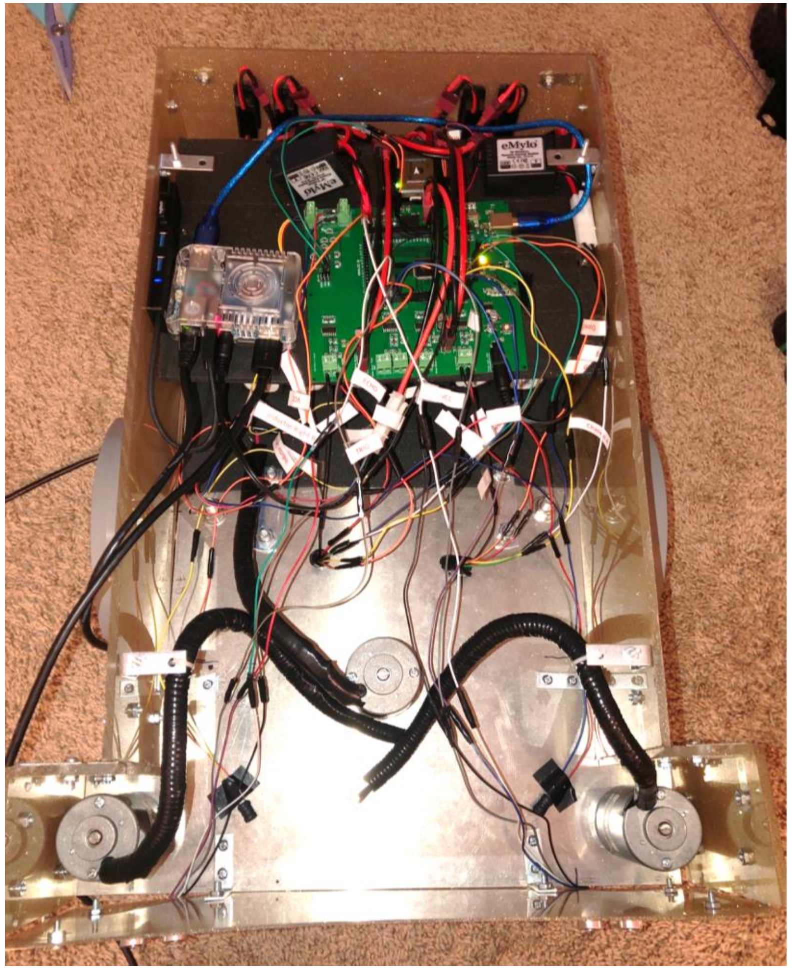
-A Linux Operating System will be used on the Odroid-XU4 in conjunction with the Computer Science Team. This will include the camera, path planning, Lidar, Breezy SLAM and image processing software.

-OpenCV will be used for all the camera image processing software in conjunction with the Computer Science Team.

Final Prototype







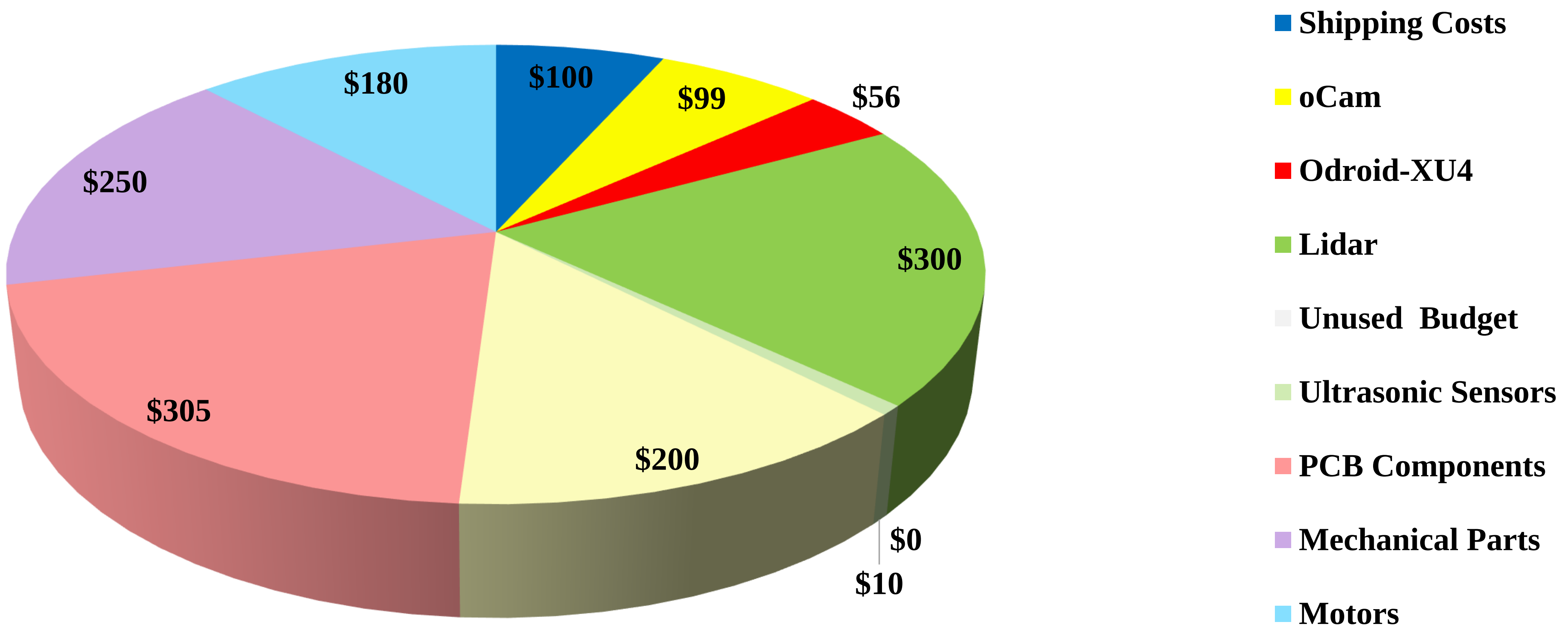
Primary Roles and Work Distribution

	Brandei Dieter	Christopher Entwistle	Mario Mcclelland	Daniel Warner
Ordering Parts	Primary			
PCB Design and Implementation	Primary			Secondary
Software Design and Implementation		Secondary	Primary	
Integration of Software with CS Team		Secondary	Primary	
Boundary System		Secondary		Primary
Drive System	Primary			Secondary
Sensor System		Primary	Secondary	
Power System	Primary			Secondary
USB Interface			Secondary	Primary
Overall Testing	All Team Members	All Team Members	All Team Members	All Team Members

Administrative Content

Spring 2019- Senior Design II Milestones					
Num.	**Task**	**Start**	**End**	**Status**	**Responsible**
1	Schematic Design Finalized	01/01/19	01/30/19	Completed	Group 19
2	PCB Design Finalized	01/01/19	01/30/19	Completed	Group 19
3	Electrical Components Ordered	11/20/18	01/30/19	Completed	Group 19
4	Batteries Ordered	12/03/18	01/30/19	Completed	Group 19
5	Prototype Equipment Bought	12/03/19	01/30/19	Completed	Group 19
6	CDR Presentation	01/11/19	02/08/19	Completed	Group 19
7	CDR File Submission	01/11/19	02/15/19	Completed	Group 19
8	Ordered trial #1 PCB Board from JLCPCB	01/01/19	02/08/19	Completed	Group 19
9	Assemble Trial#1 Prototype	02/10/19	02/20/19	Completed	Group 19
10	Test Trial#1 Prototype	02/10/19	02/29/19	Completed	Group 19
11	Improve Prototype	03/02/19	03/10/19	Completed	Group 19
12	Test Prototype Trial #2	03/11/19	03/11/19	Completed	Group 19
13	Improve Prototype	03/13/19	03/14/19	Completed	Group 19
14	Finalize Prototype (Final Trial #3)	03/15/19	04/01/19	Completed	Group 19
15	8 Page Conference Paper and Committee Form	03/25/19	04/05/19	Completed	Group 19
16	Midterm Demo	03/26/19	03/27/19	Completed	Group 19
17	Finished Product	04/10/19	04/15/19	Completed	Group 19
18	Senior Design Day	04/19/19	04/19/19	Completed	Group 19
19	Final Presentation	03/25/19	04/15/19	Completed	Group 19 and committee members
20	Final Documentation	04/08/19	04/22/19	Completed	Group 19

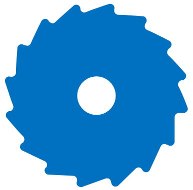
Project Budget and Financing
Overall Budget of $1500



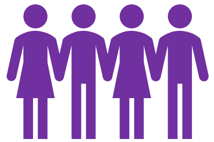
Possible Problems and Issues

The PCB track widths may have problems carrying heavy current loads required by the DC wheel motors.

The String-Based Blades used to cut grass will wear down quickly and need to be replaced. There is also no way to monitor the quality of the strings.



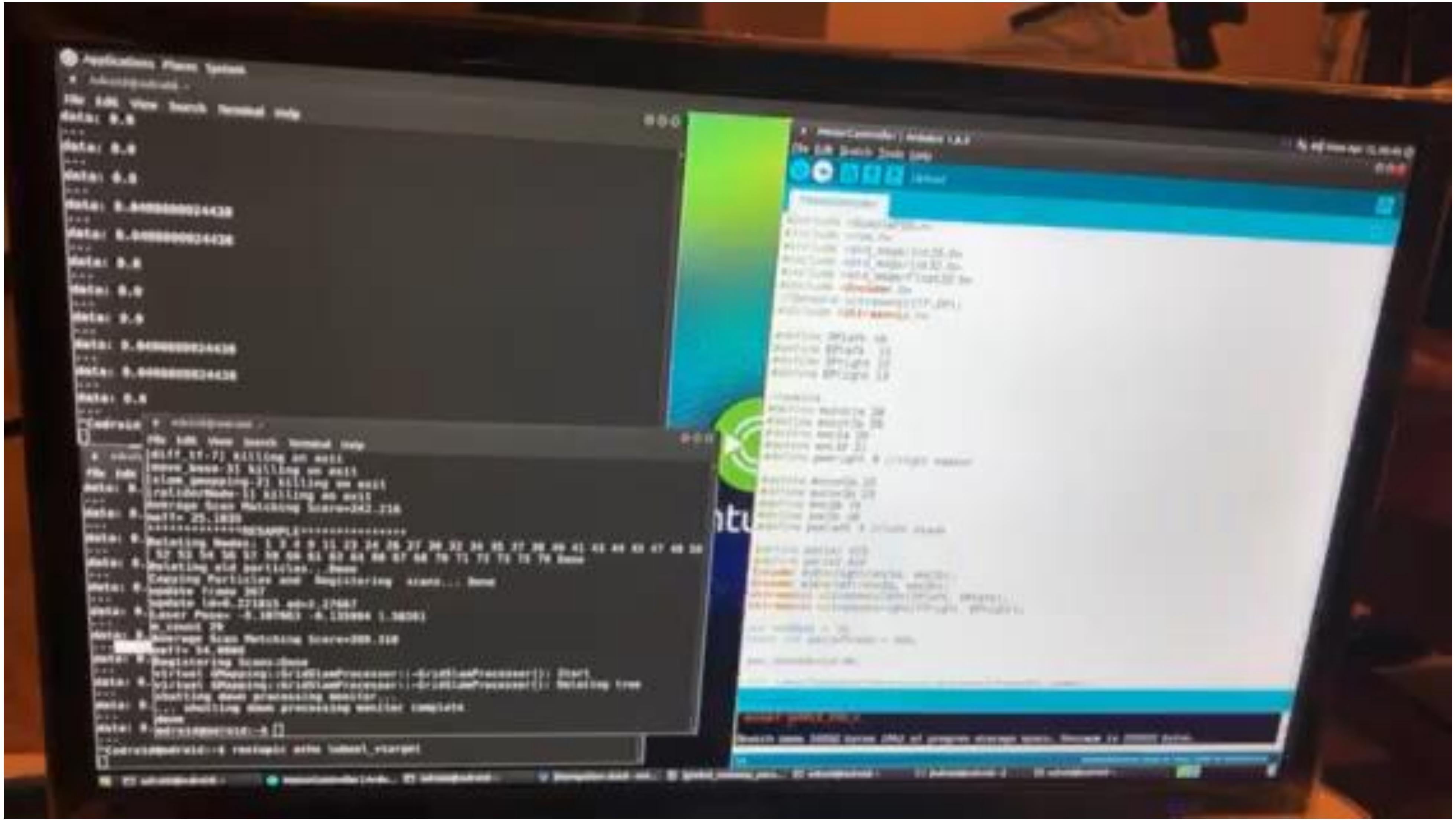
Larger wheels were selected by the mechanical team. However, the large diameter wheels and weight required too much current to supply efficient torque. The caster wheel size was also too heavy.



Team management and communication between three interdisciplinary teams has been difficult.

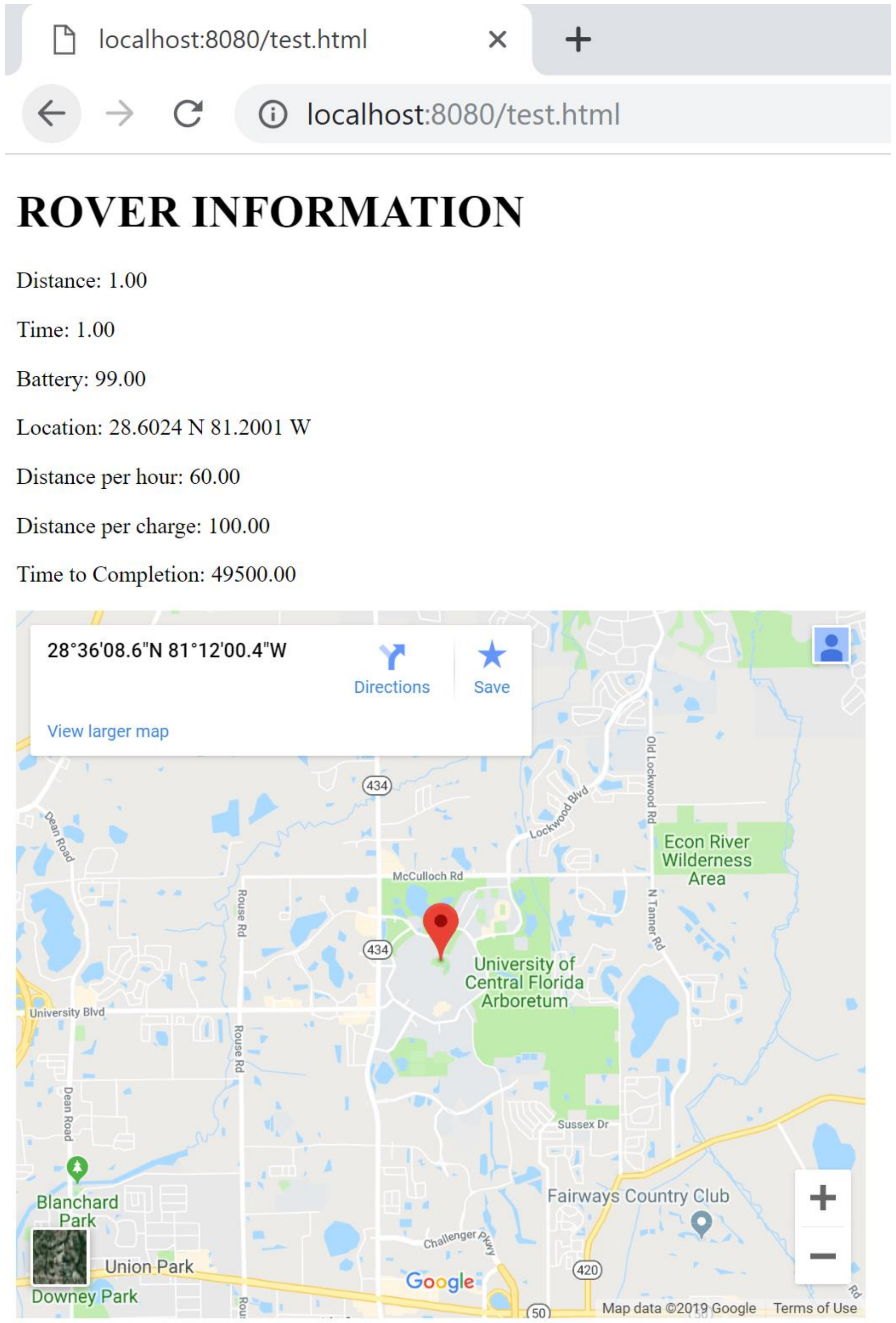
Robot On Grass Avoiding Obstacles Via Ultrasonic Sensors

Lidar Mapping and Path Planning



Web Server with GPS Location

The GPS acts as a location beacon to locate the robot when the main batteries die. This is implemented in conjunction with the computer science team.



Questions