Bottom Feeder

Group 2

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Description

A remotely operated underwater vehicle that de-risks aquatic exploration and assists in locating personal effects.

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The Team

John Cope

T Davis

Sarah Reim

Tyler Rose

Motivation

- Underwater exploration creates intrinsic risks
- De-risking aquatic activities is a key business goal
- Valuable objects lost in beaches and waterways are frequently metallic
- De-risking metal detection allows individuals and businesses to locate lost items
- An engaging experience in remote underwater exploration allows for people to become excited about conservation and the environment

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Goals and Objectives

- Create a remote operated vehicle capable of underwater exploration with a live video feed
- ROV will include metal detection in order to locate lost valuables on aquatic floor
- An entry-level price point

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Specifications and Requirements

Component	Parameter	Design Specification
Batteries	Discharge time	1 hour
Metal detector	Detection range	3 cm
Cameras	Field of view	Omnidirectional
Cameras	Image quality	1080p
Lights	Brightness	1000 lm
Housing	Water resistance depth	10 m
Tether	Length	15 m

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Division of Labor

System	John	Tyler	Sarah	T
Printed Circuit Board	Primary	Secondary		Secondary
Lights	Secondary	Primary		Secondary
Tether			Primary	
Propulsion	Secondary			Primary
Power	Secondary	Primary		Secondary
Cameras	Secondary			Primary
Head Mounted Display	Primary			
Surface Station			Secondary	Primary
Metal Detector	Secondary	Primary	Secondary	
Enclosure	Secondary	Secondary	Secondary	Primary

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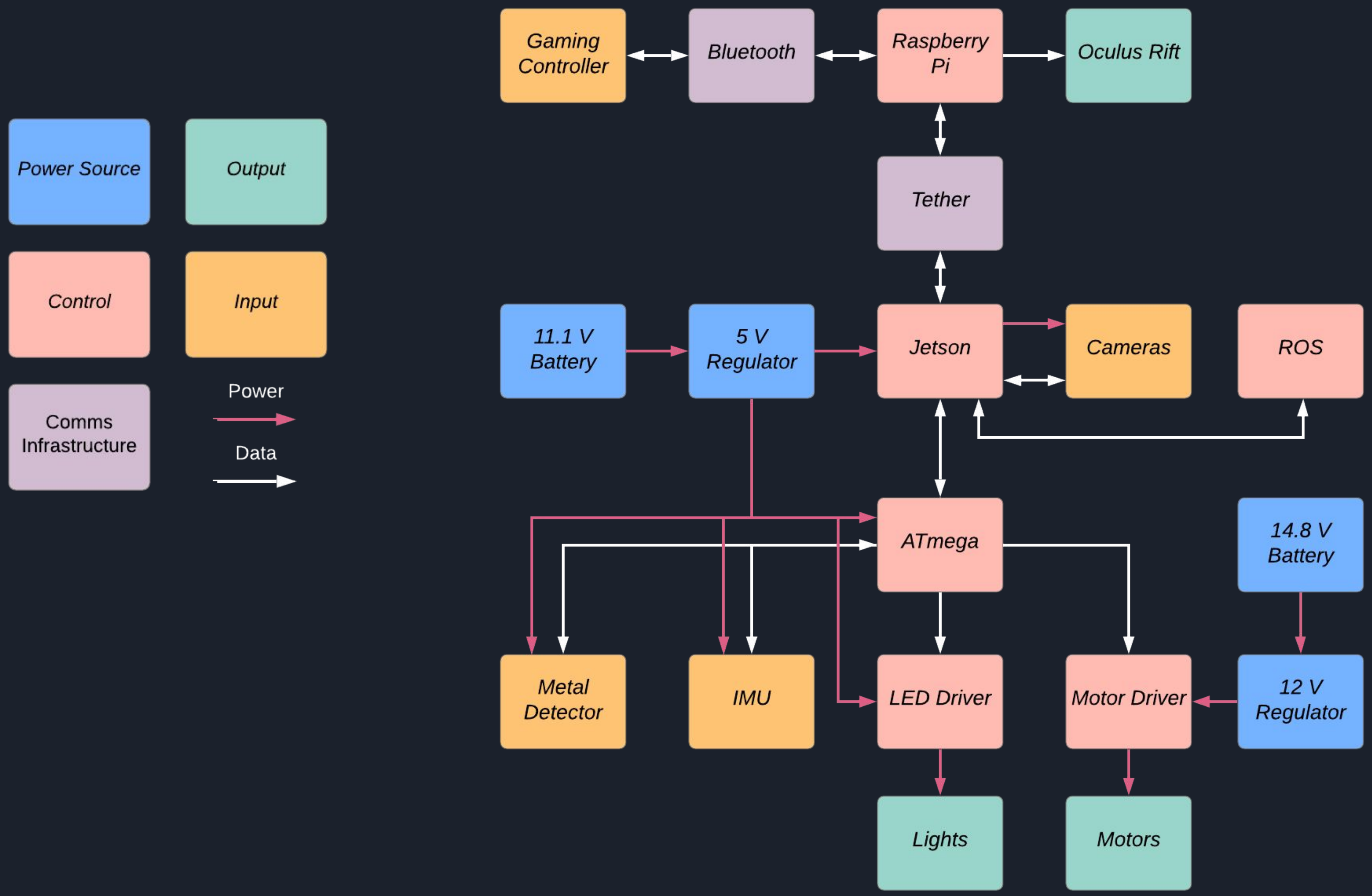
System Block Diagram



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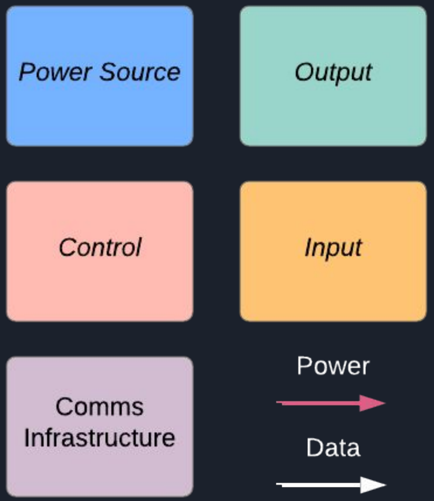
Output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Comms Infrastructure
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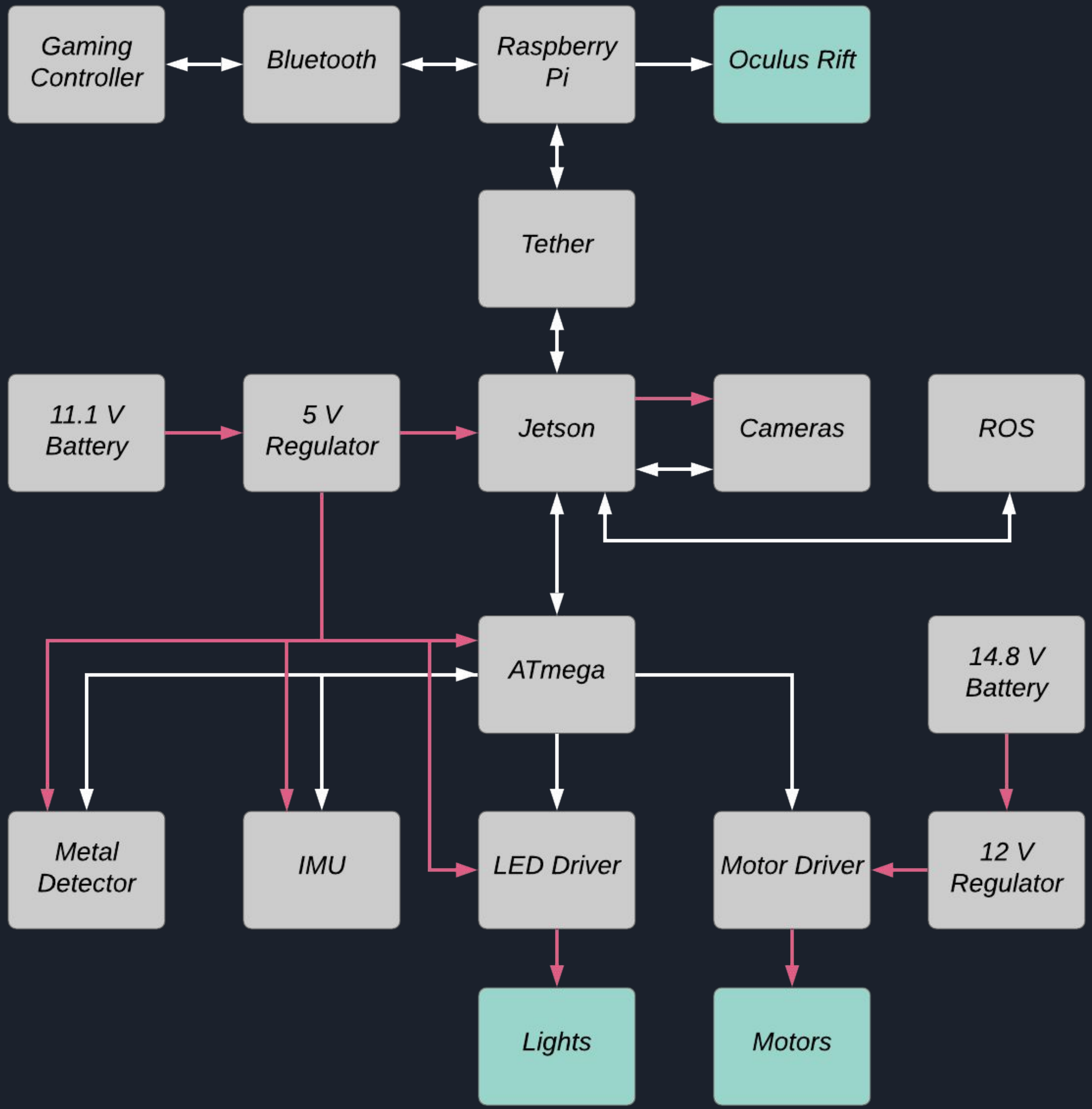
Gaming Controller
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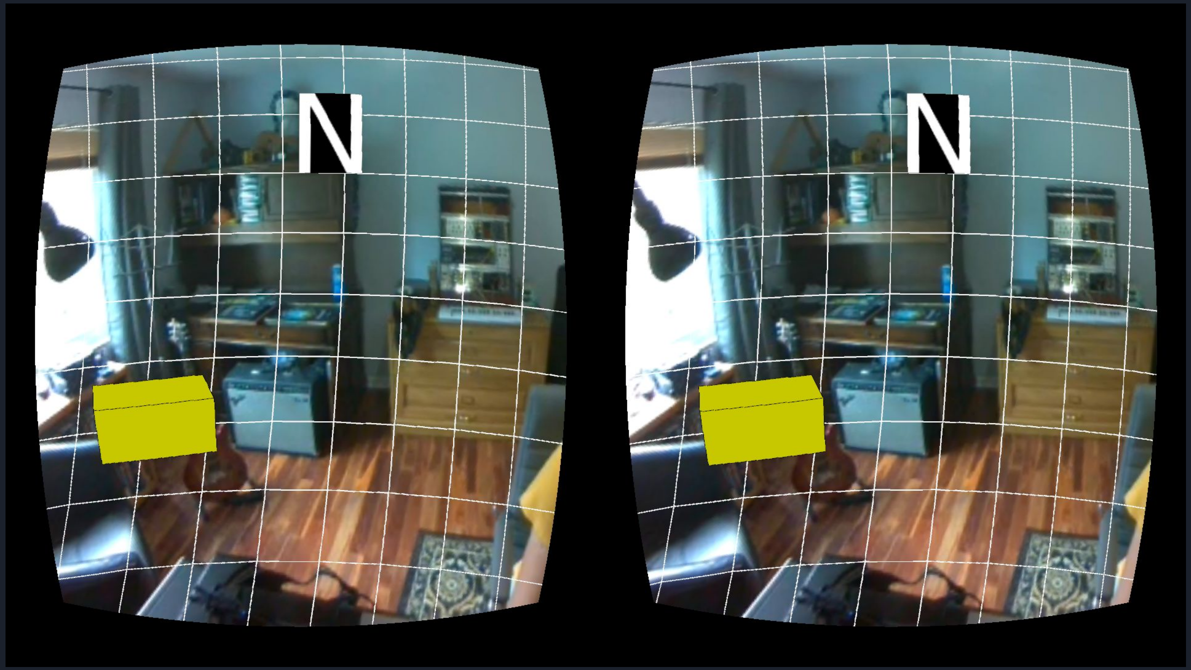
Raspberry Pi
Oculus Rift
Tether
11.1 V Battery
5 V Regulator
Jetson
Cameras
ROS
ATmega
14.8 V Battery
Metal Detector
IMU
LED Driver
Motor Driver
12 V Regulator
Lights
Motors

Oculus Rift

- Integration using the Oculus Rift and the OpenHMD libraries
- Environment built in Java using Processing, and Camera3D libraries
- Heads up display allows the operator to know ROV orientation, metal detector input, as well as other information regarding system status



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Propulsion

- Connects to microcontroller using L2605 H-Bridge motor drivers.
- Uses two Johnson Mayfair 1000 GPH Bilge Pump Cartridges for forwards and backwards movement.
- Uses two 1100 GPH Bilge Water Pumps for vertical movement.

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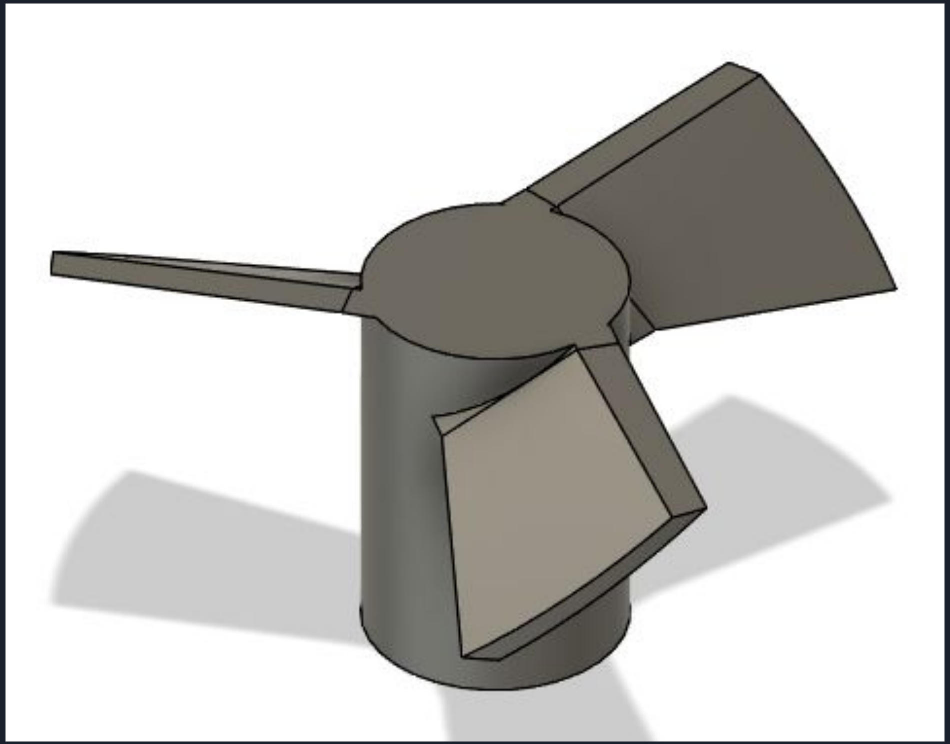
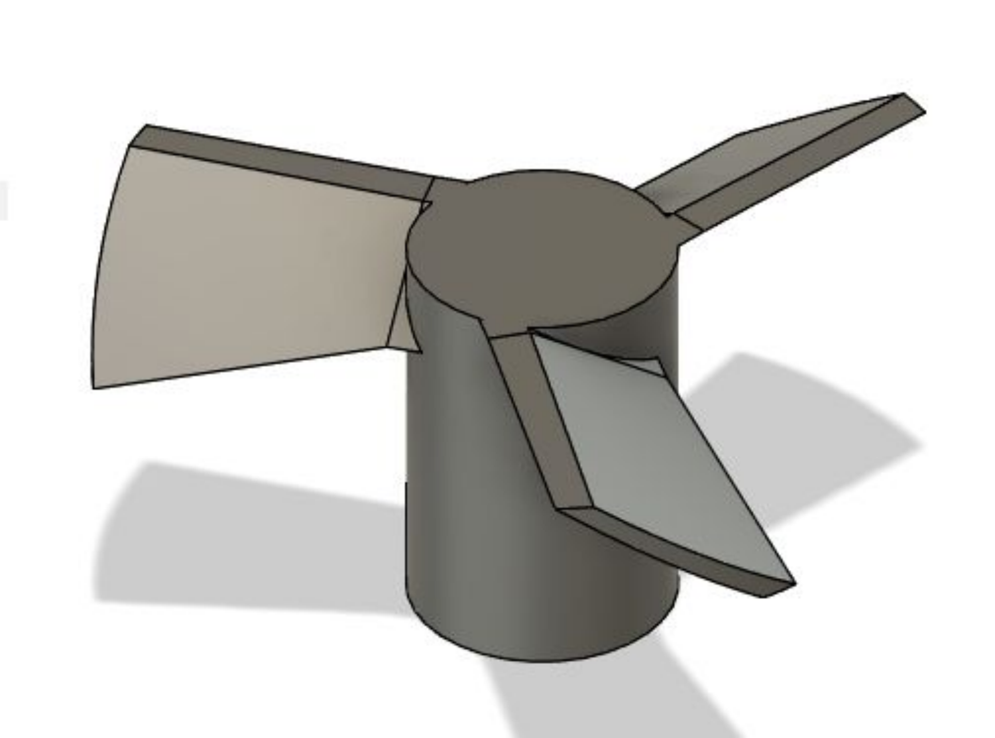
Propellers



Clockwise Propeller



Counterclockwise Propeller

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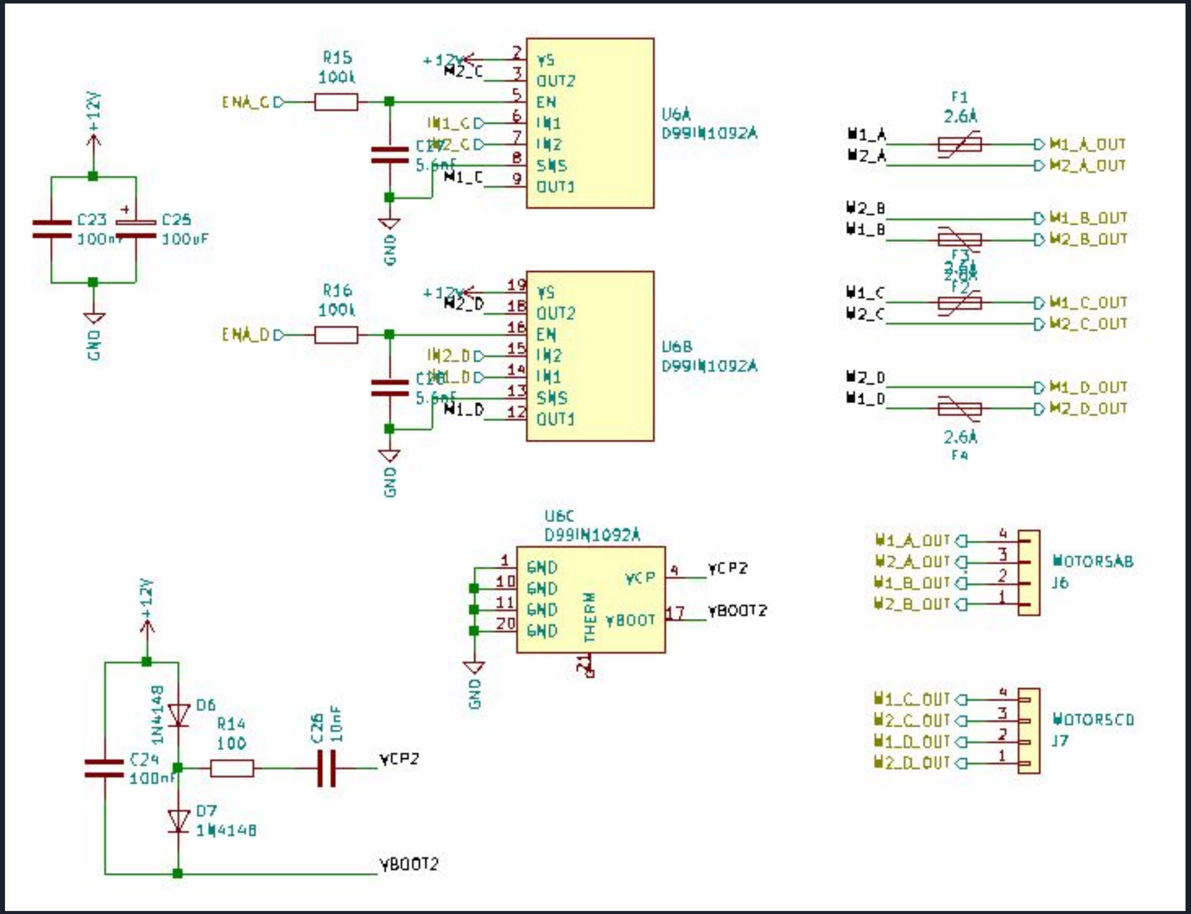
L6205 Motor Drivers

- SMD package has thermal relief available through the PCB
- Large thermal relief plane under IC on both top and bottom copper
- The IC is a dual H-Bridge d



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Lights

Price:

- Two LEDs on either side of ROV
- Each LED produces > 1000 lm for $7
- comparable LEDs produce < 900 lm for $6 or ~1000 lm for over $20

Function:

- User has On/Off control
- Brightness is based on current through LED
- Brightness is controlled by PWM signal

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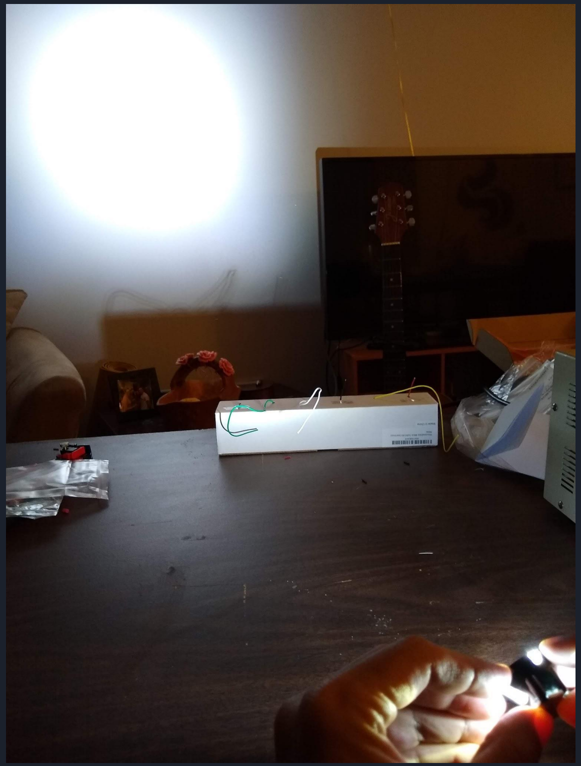
LED Testing

No Reflector

Reflector ($2)



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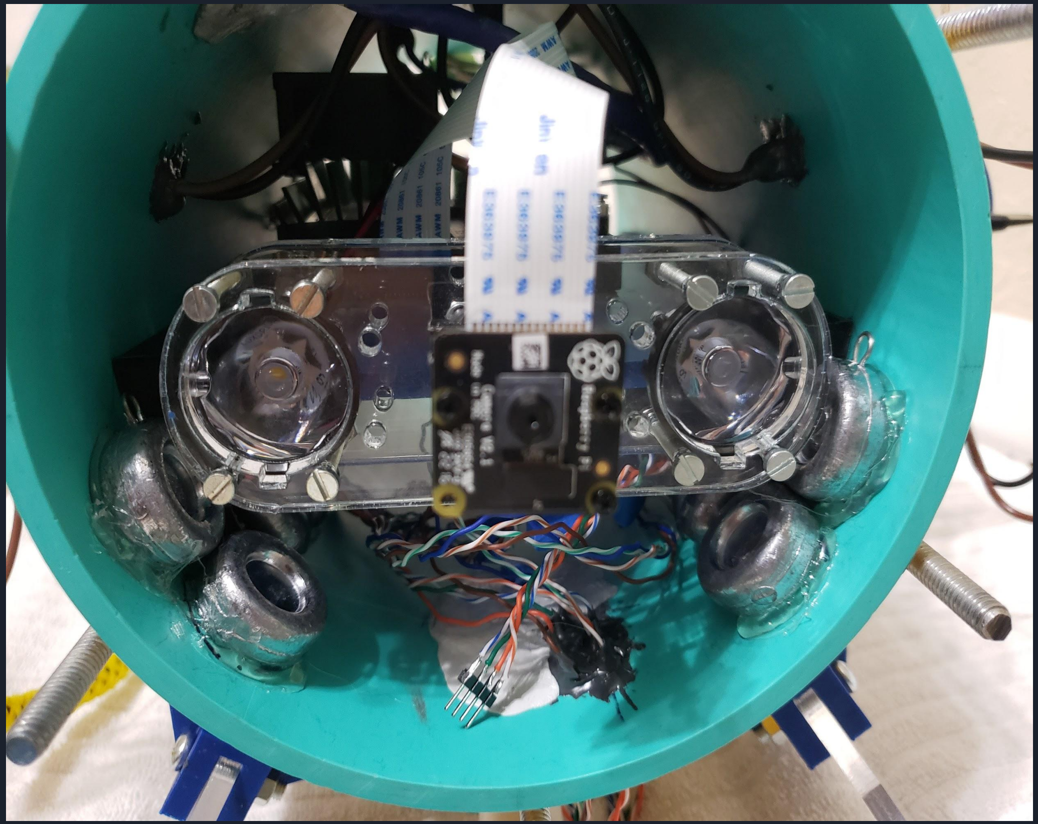
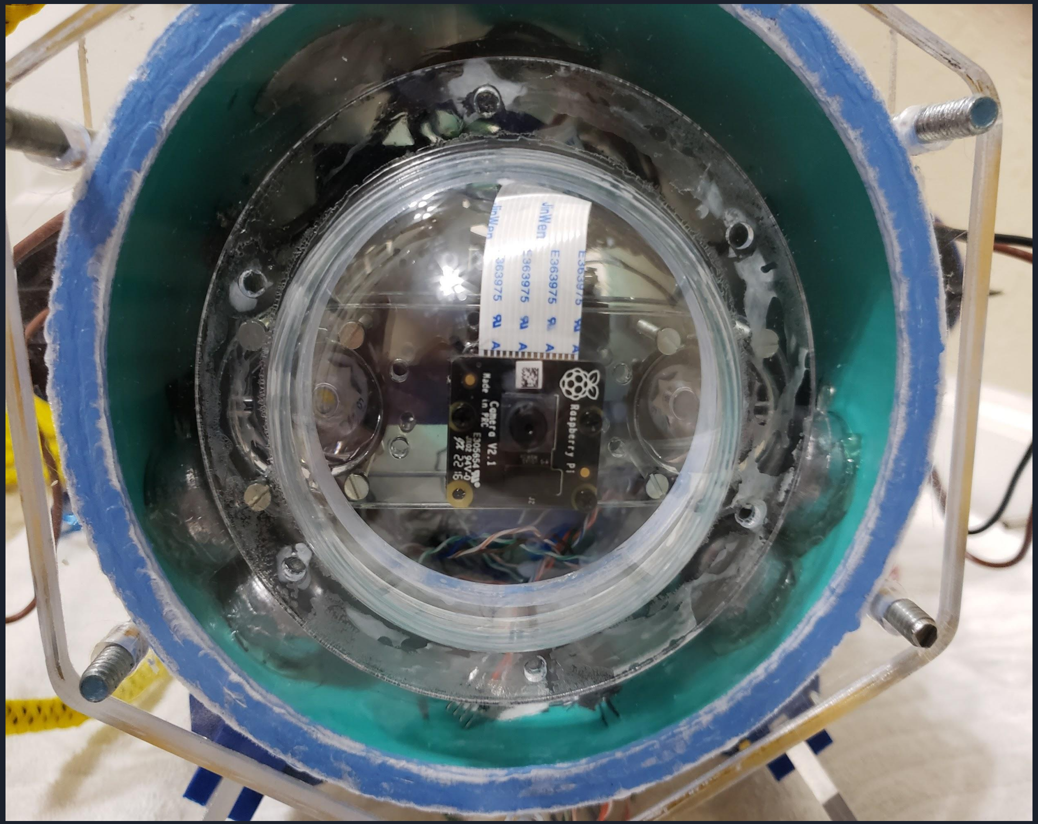
Lights Mounted to ROV





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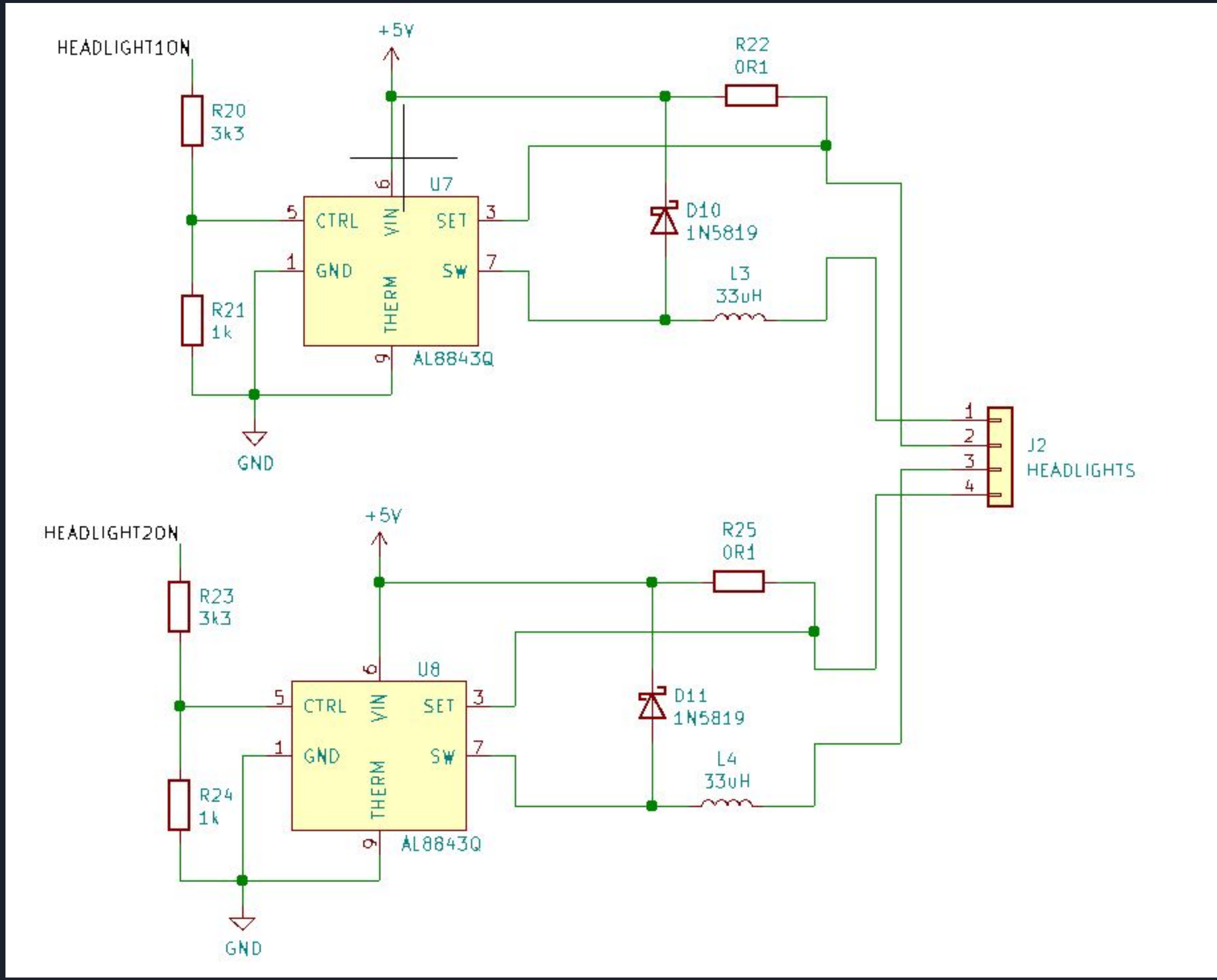
LED Driver Schematic

- Based on the AL8843Q LED driver
- CTRL allows analog current control with inputs from 0.4V to 2.5V
- At maximum output, the current is 3A
- Resistor divider creates range from 0.34V to 3.84V
- Testing showed 1A provided enough lighting
- PWM at 960Hz allows for brightness control without video banding artifacts



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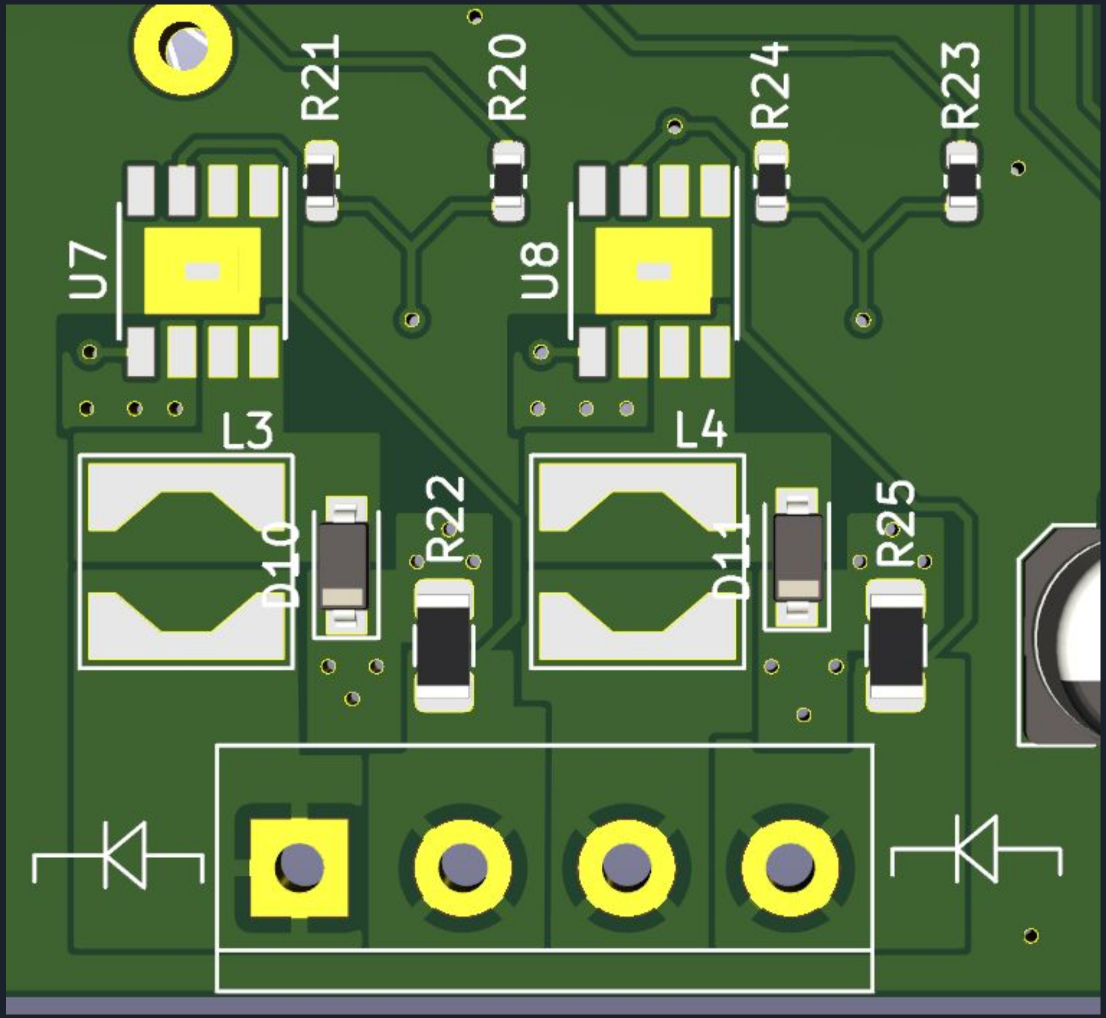
LED Driver

- Following datasheet's advice, we placed the conditioning inductor and freewheeling diode as close as possible to IC
- Four connection points for two series LED circuits
- Two channels allows for independent front and rear lights for the ROV



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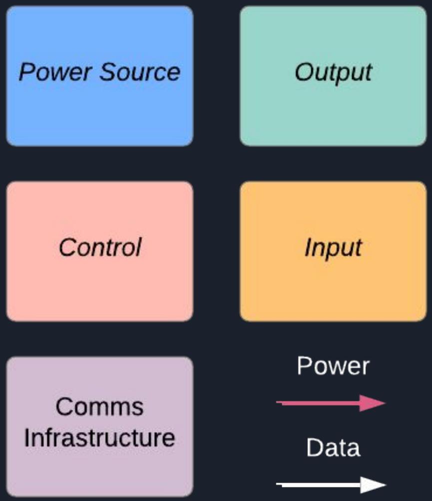
Input



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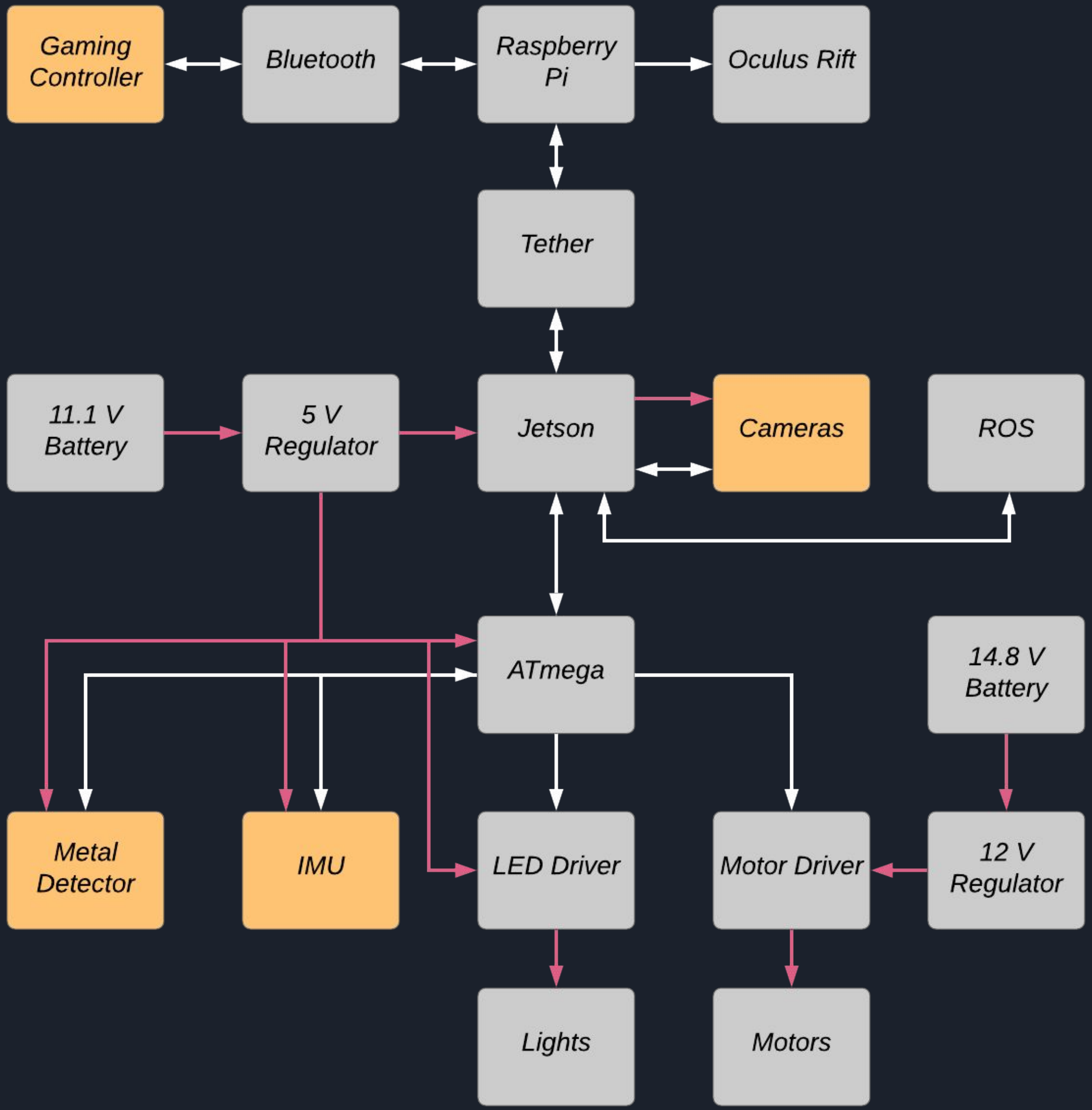

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Cameras

- The Sony IMX219 sensors allow for 3264 by 2464 image capture
- 200 degree field of view on lens
- Allows for omnidirectional video capture with only two cameras

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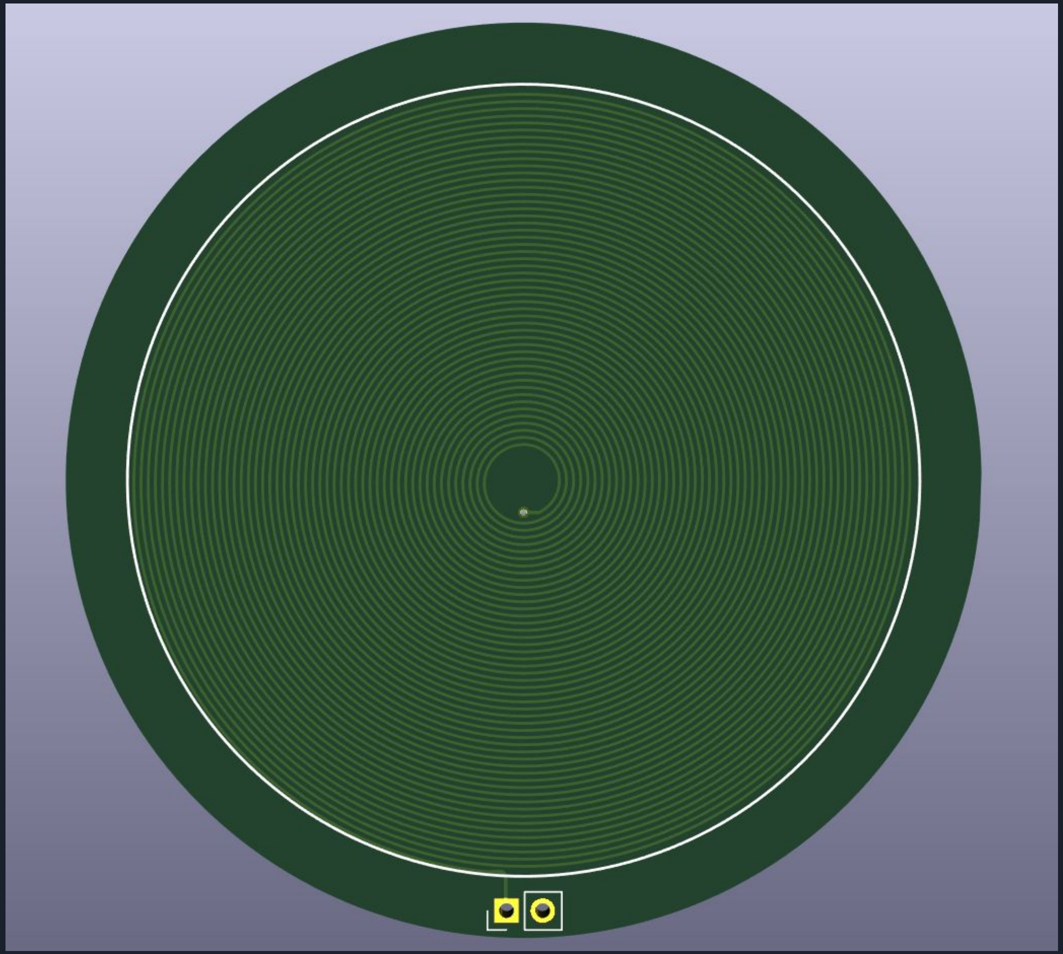
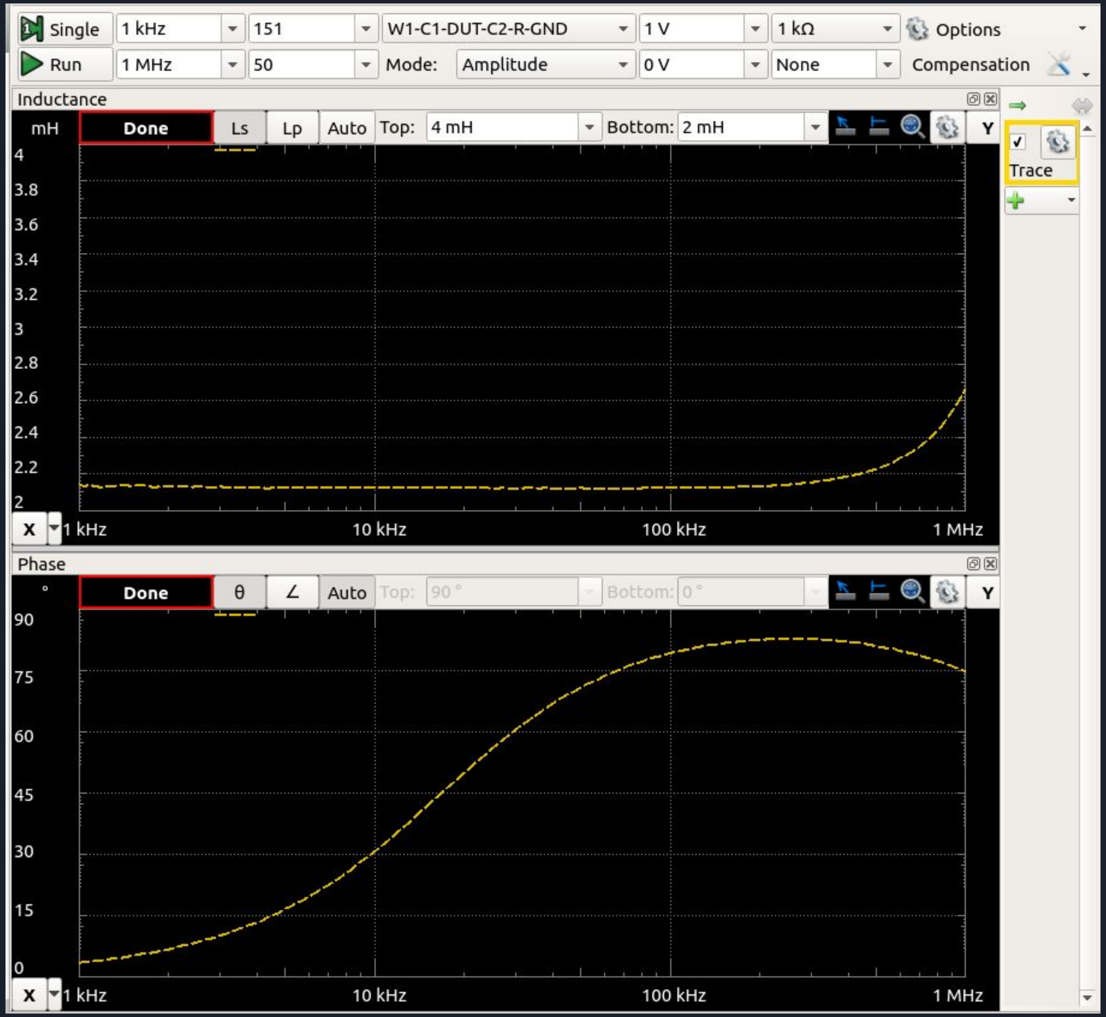
Metal Detector Coil

- A 100 turn coil was laid out to provide a more rigid, repeatable, and uniform test unit.
- A two layer PCB forces us to lay out the coil in a spiral, with each turn being a different radius than its neighbor.
- The inner coils contribute to the system's sensitivity less than the outer coils



Metal Detector PCB Coil Testing

- The PCB coil is shown to have an inductance of 2.12mH
- With a pair of pliers 1cm away, we see an inductance of 2.31mH
- This is an 8% increase in inductance, and should affect a change in the oscillator



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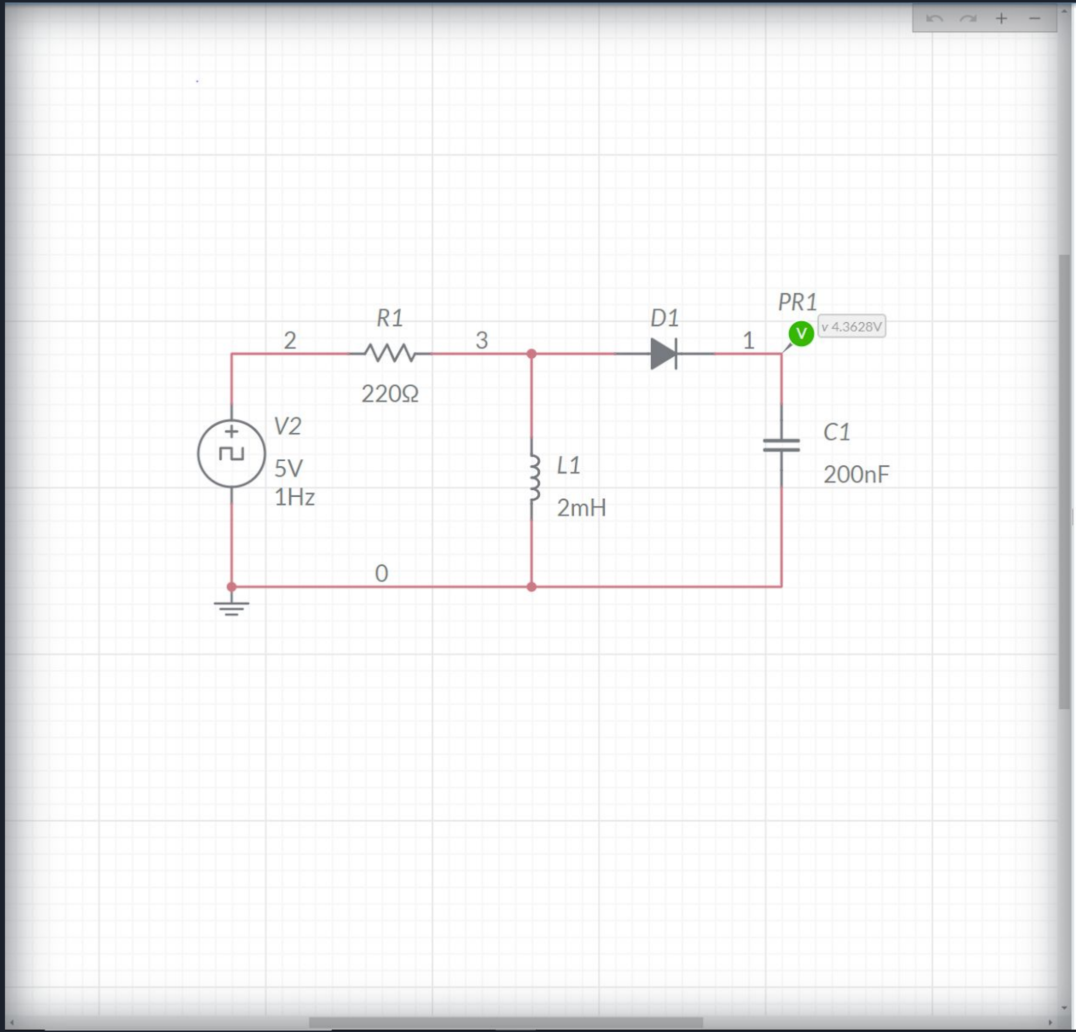
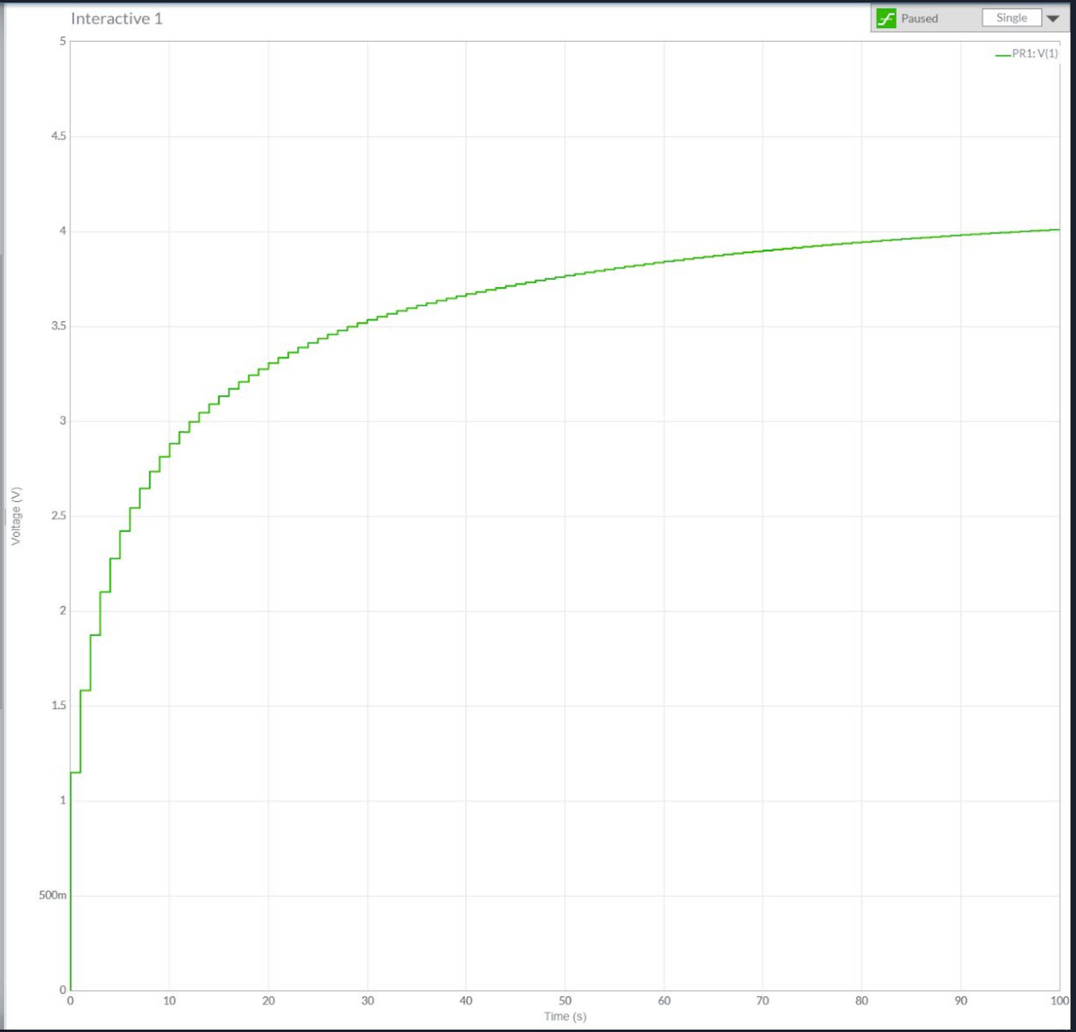
Metal Detector - Design





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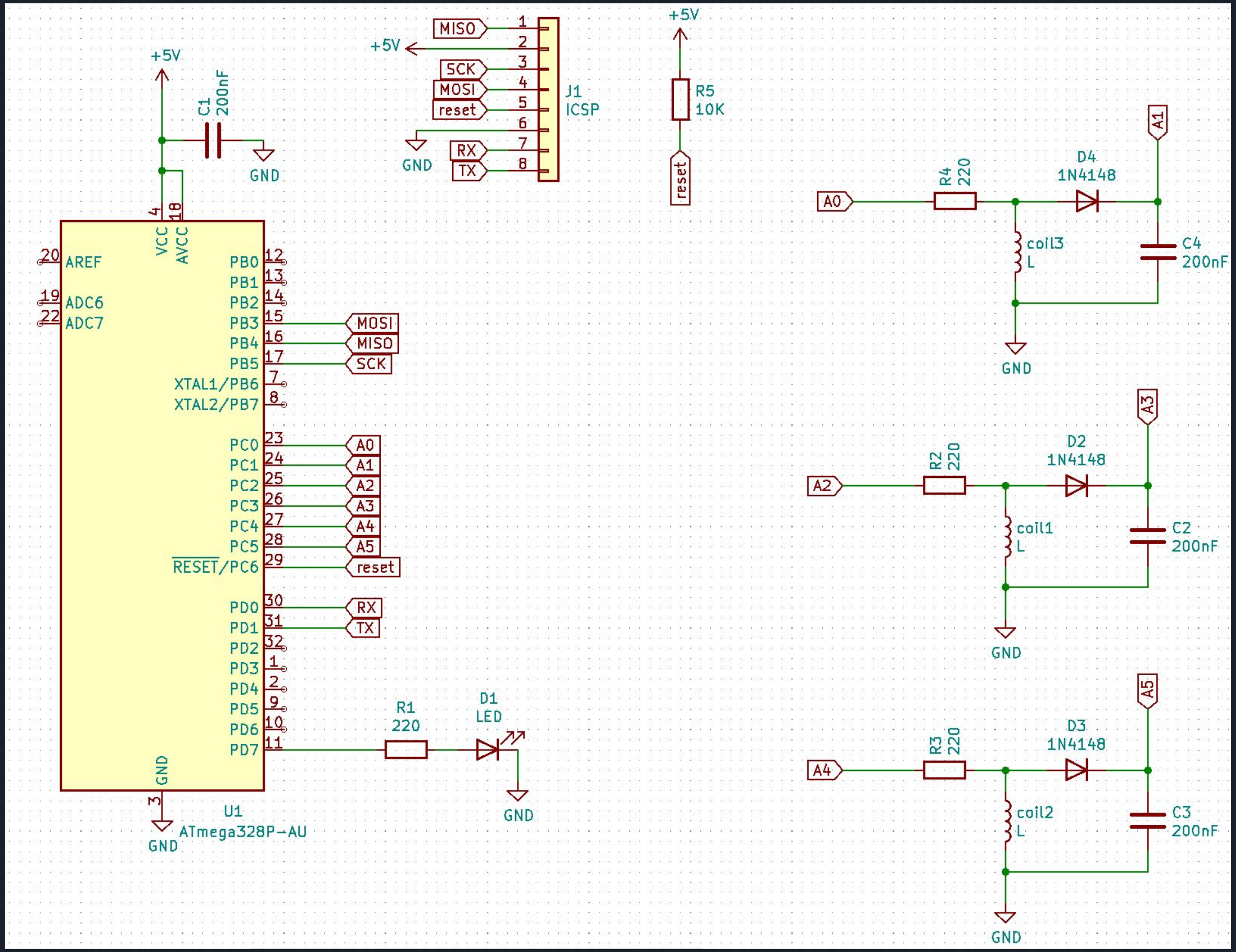
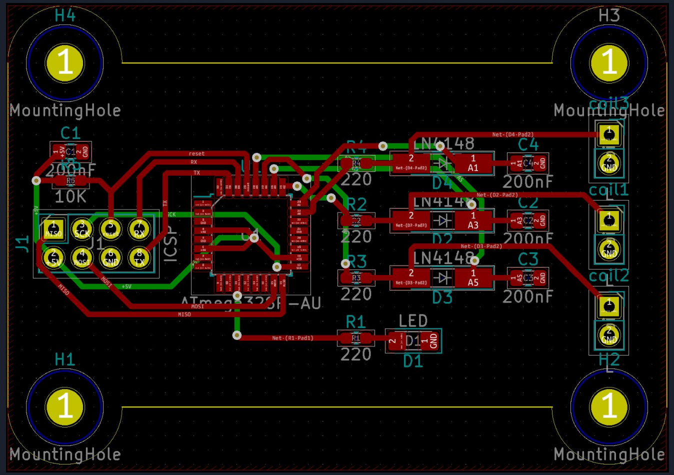
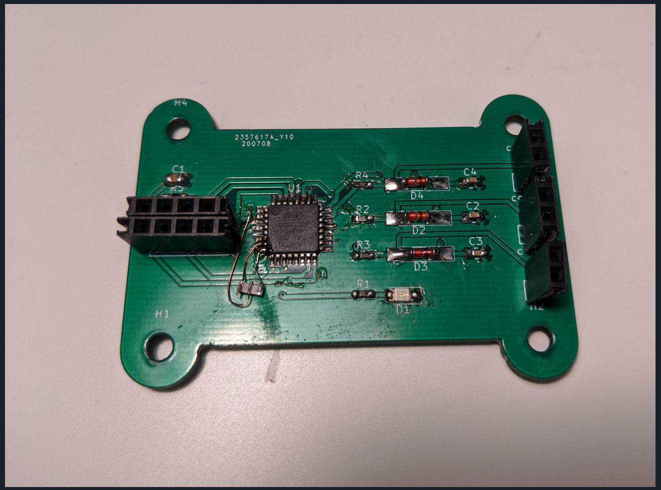
Metal Detector Breakout Driver & PCB







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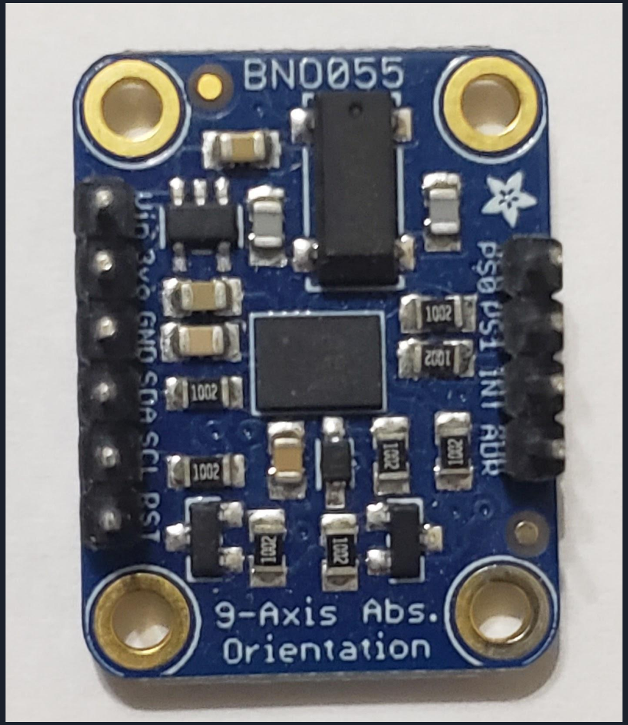
Inertial Measurement Unit - BNO055

- Gives orientation information to help ROV keep level while in use
- I2C communication with microcontroller
- Powered using 5V line from microcontroller



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Inertial Measurement Unit - Testing

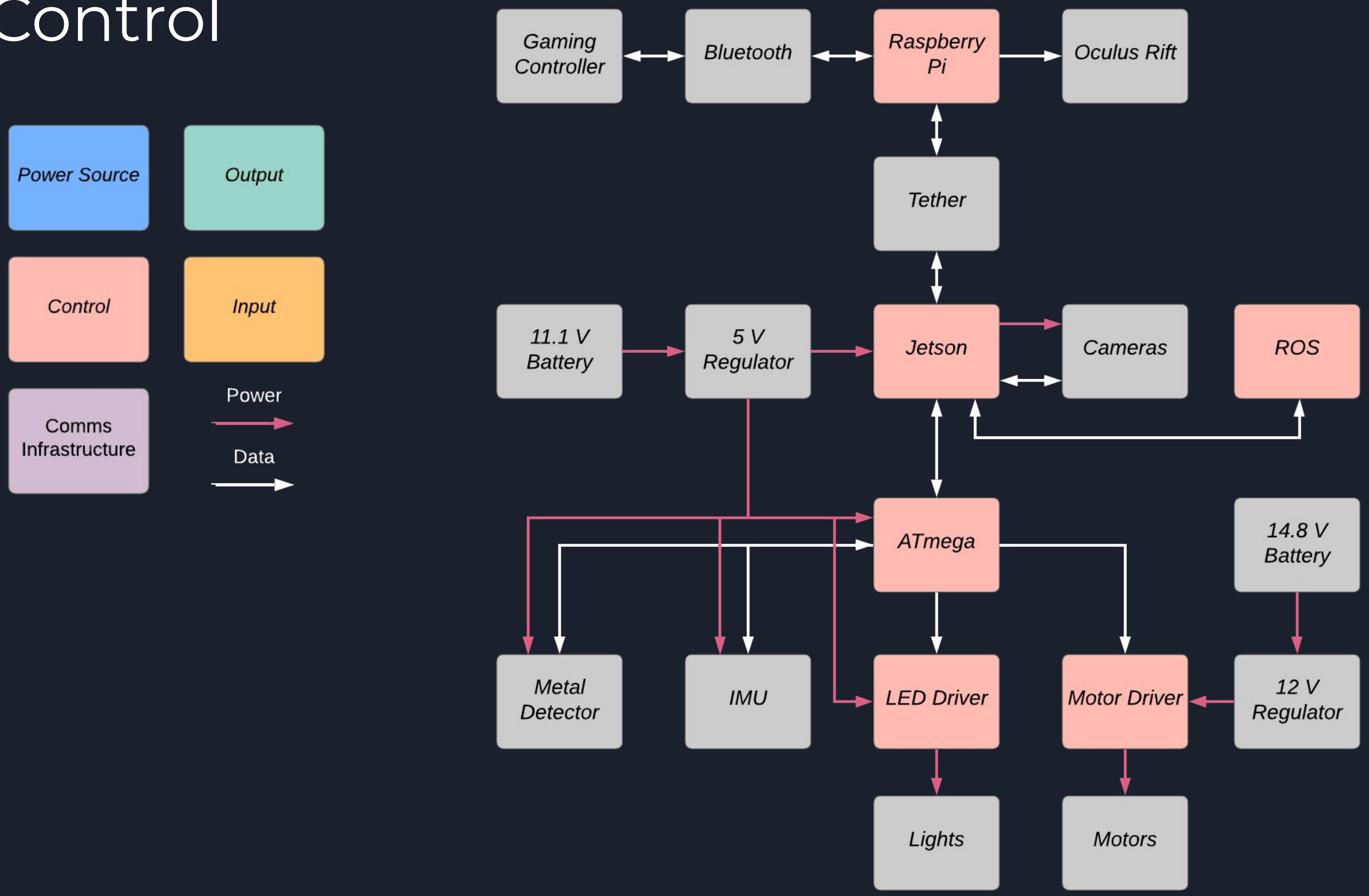
Orientation Sensor Raw Data Test

Current Temperature: 32 C

Calibration status values: 0=uncalibrated, 3=fully calibrated

X: 0.00 Y: 0.00 Z: 0.00	CALIBRATION: Sys=0 Gyro=0 Accel=0 Mag=0
X: 295.19 Y: 2.56 Z: 89.31	CALIBRATION: Sys=3 Gyro=3 Accel=3 Mag=3
X: 285.00 Y: -2.56 Z: 82.31	CALIBRATION: Sys=3 Gyro=3 Accel=3 Mag=3
X: 272.44 Y: -8.94 Z: 73.62	CALIBRATION: Sys=3 Gyro=3 Accel=3 Mag=3
X: 259.50 Y: -15.31 Z: 66.37	CALIBRATION: Sys=3 Gyro=3 Accel=3 Mag=3
X: 243.56 Y: -22.19 Z: 54.75	CALIBRATION: Sys=3 Gyro=3 Accel=3 Mag=3

Control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Data
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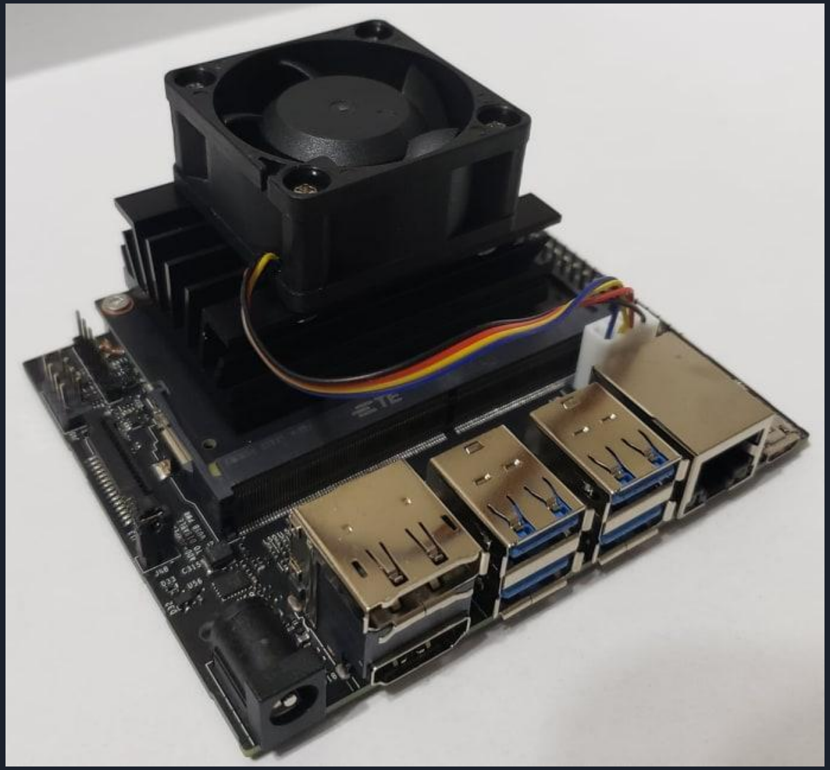
Nvidia Jetson Nano

- Main onboard computer for ROV
- Handles all video capturing and processing
- Sends video feed to surface station
- Receives input commands from surface station and relays them to microcontroller
- Relays sensor information from microcontroller to surface station



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Robot Operating System (ROS)

- Standard for robotics software development
- Low-level framework for interprocess communication
- Plug and play libraries
- Using ROS Melodic Morenia built on Ubuntu 18.04
- ROS code is written using Python or C++

http://wiki.ros.org/melodic

Microcontroller - ATmega2560

- Connects to ROV using UART
- Sends control signal to motor driver boards
- Receives sensor data
- Programmed using an AVR programmer

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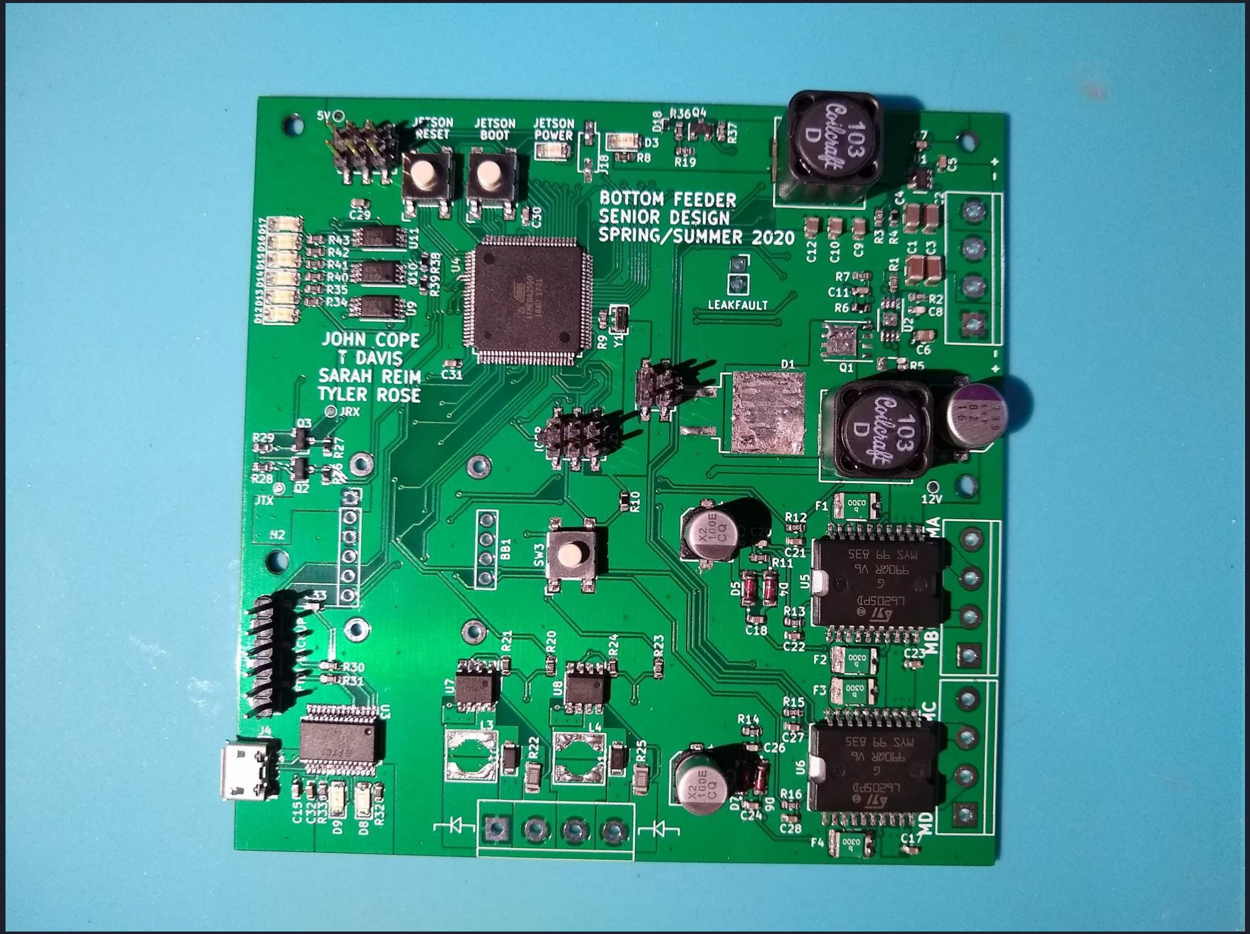
Main Logic Board

- All circuits designed are integrated onto the main logic board
- Debugging LEDs are critically important to testing features and developing software
- ATMEGA and Jetson each have 3 debugging LEDs mapped to their pins
- Jetson boot and reboot features broken out, despite Jetson Carrier not having these as provided buttons



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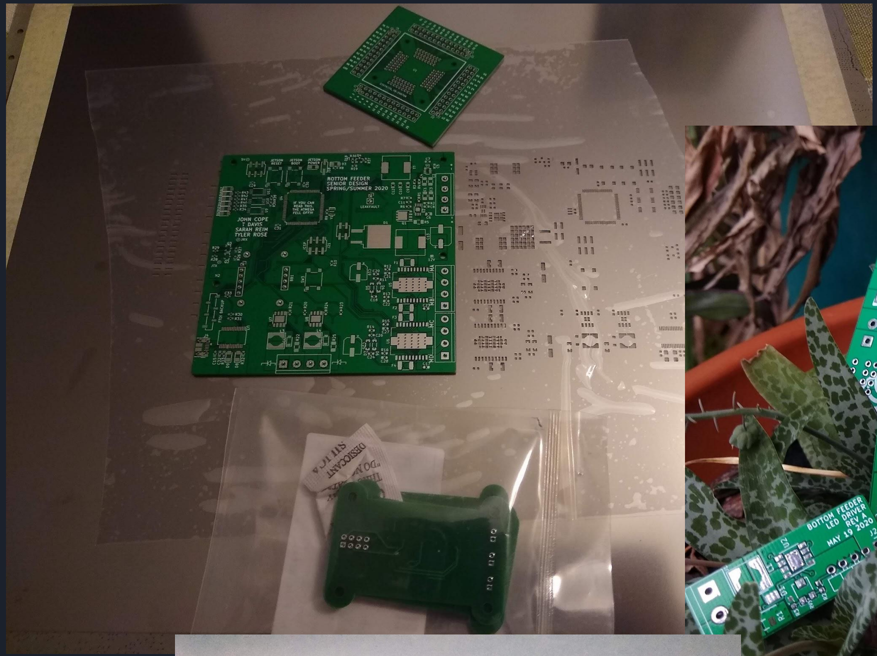
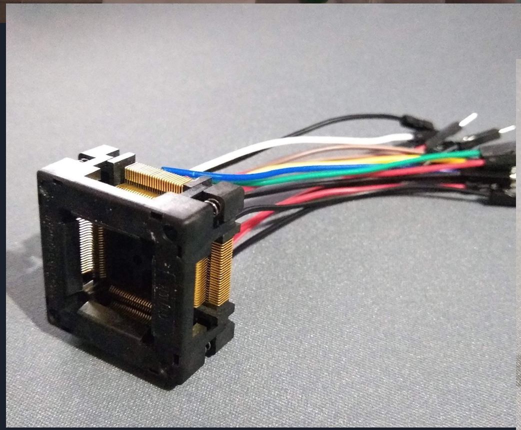
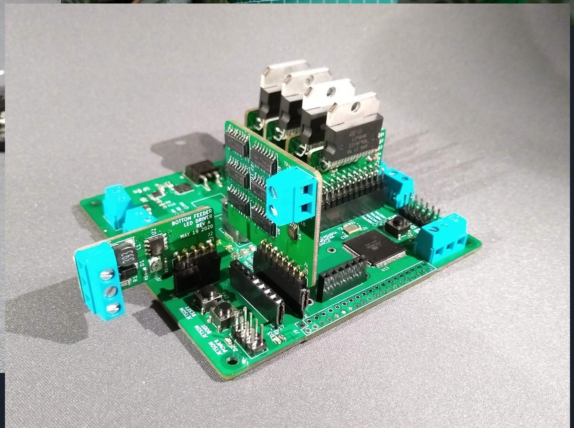
History of PCB Development

- Modular Development has allowed for multiple designs to be explored in parallel
- Designs include
  - 3 distinct motor drivers
  - LED driver
  - 2 Metal Detectors
  - PCB coil
  - Main board prototype
  - QFP100 programmer breakout
- In total, 10 PCBs were designed and fabricated
- SMT Stencils improved solder reliability
- QFP100 breakout allowed us to program ICs before soldering







Tether

- More than 15 meters of stranded Cat 6 Ethernet cable used for signaling
- Wrapped in polypropylene hollow braided rope
- Chosen for cost-efficiency

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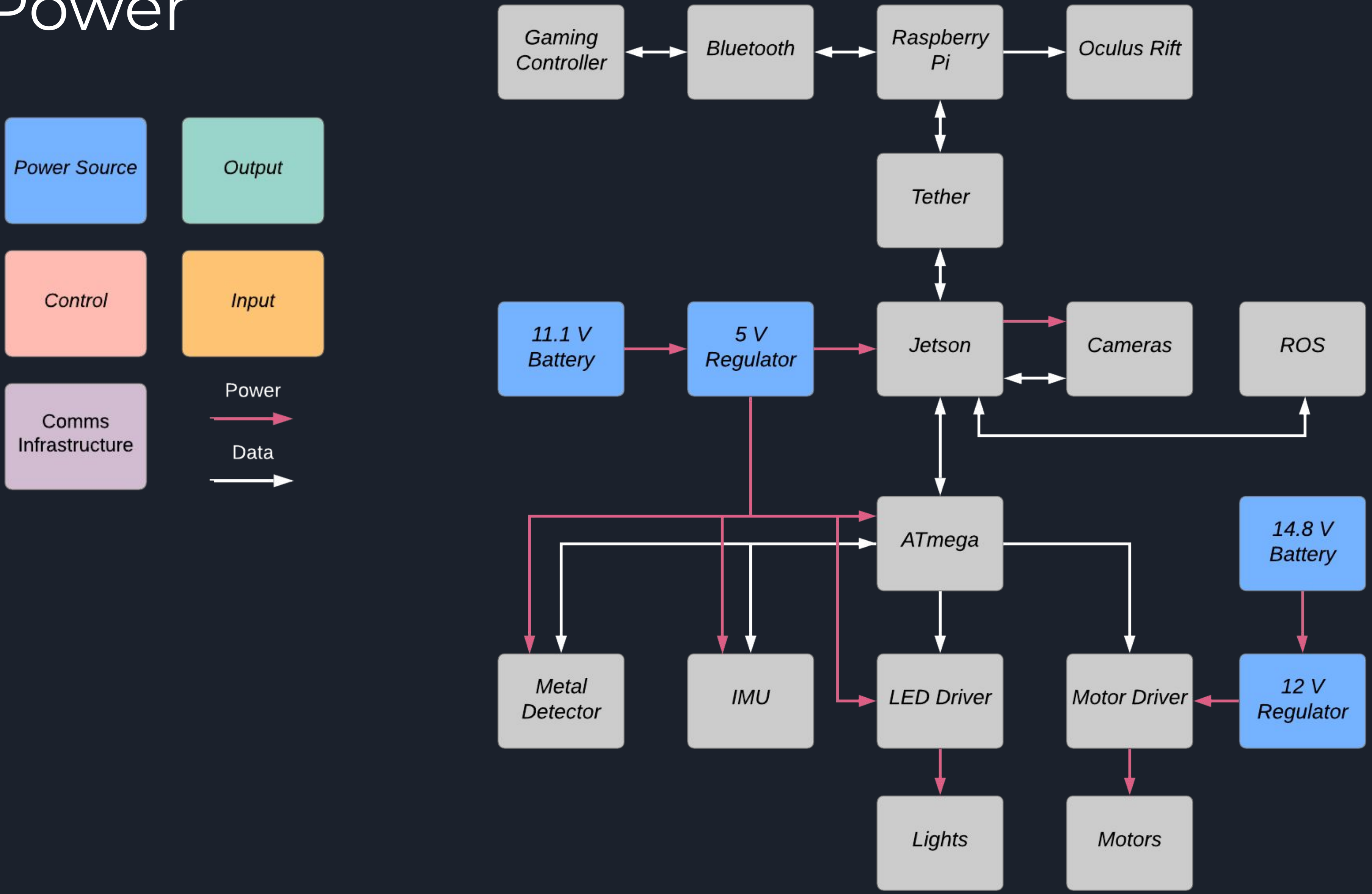
Enclosure

- Main body of enclosure is 6” diameter PVC
- ½” think acrylic end caps with 3” diameter acrylic domes for cameras
- Threaded rods hold end caps onto the body of the ROV
- 3D printed motor mounts and skid mounts
- Laser cut acrylic skids
- Lead weights added to make neutrally buoyant

Power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Batteries

- We are using 2 different batteries on the submerged system
- Top battery: Used for lower power devices ($23)
- Bottom battery: Used for higher power devices ($38)
- A single comparable battery would cost ~$100

Top powers: Lights, IMU, Jetson

Bottom powers: Motors, Metal Detector

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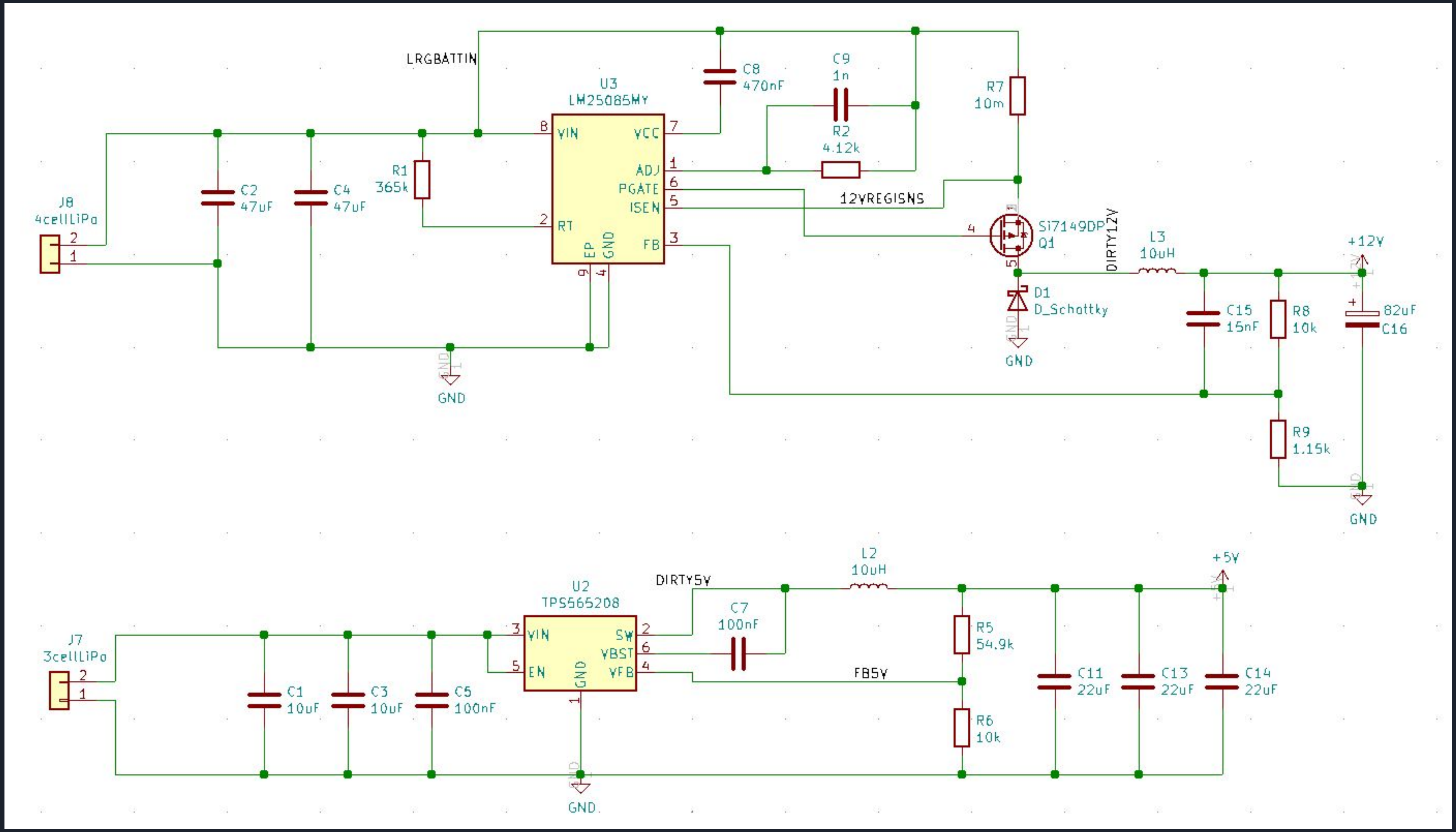
Regulators

- TI WEBENCH Power Designer was used for Supply Design
- 12V supply capable of delivering 10A
- 5V supply capable of delivering 3A
- 5V supply was not able to withstand being back-driven, and was ultimately bypassed due to fiscal restrictions



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Financing

Part	Cost	Total Cost
Jetson Nano and related parts	$151.03	$151.03
Cameras	$103.39	$254.42
RJ45 components	$23.23	$277.65
Pressure Sensor	$23.80	$301.45
Bilge pumps and components	$93.50	$394.95
LEDs and Reflectors	$35.24	$430.19
Batteries	$65.50	$495.69
PCB Version 1	$53.25	$548.94
PCB Version 2	$48.10	$597.04
Mouser Components	$229.94	$826.98
Enclosure	$89.40	$916.38
Miscellaneous	$74.86	$991.94
Grand Total	$991.94	

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Constraints

Economic

- COVID-19 pandemic stunted potential sponsorships.
- Completely self-funded and a need for budget components while still meeting expected criteria.

Environmental

- Important to push production and the recycling of electronics towards a sustainable endpoint.
- Modular systems help.

Legal

- Metal detecting is prohibited in national parks and other federal lands.
- There are several laws pertaining to metal detecting and our team must ensure that we have permission to use our ROV in any desired location.

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Constraints Continued

Health and Safety

- Lithium Polymer in batteries. Special care is needed to make sure they don't become submerged in water or pierced.
- The head mounted display can create feelings of vertigo or nausea. Special care must be taken.
- Electrical components must never be exposed to the water, otherwise electrocution may occur.

Manufacturability

- Our housing must be able to handle the force being exerted on it underwater.
- Electrical components must stay dry.
- Buoyancy needs to be considered for stability. Neutral buoyancy desired.
- Motor placement must also be considered for structural stability.

Ethical

- It's important that when we're exploring waterways that the natural ecosystem remains undisturbed.

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Table of Related Standards

Standard Type	Description
Battery	IEEE 485-2010 recommended practice for sizing lead-acid batteries
PCB	IPC-a-610 and IPC-A-630
Bluetooth	Bluetooth 5.0, data transfer speed of 2Mbps
H.264 AVC	H.264 supports up to 4k and 8k video playback
360 Video Formats	The photosphere is warped into an equirectangular projection
RoHS	RoHS 3 contains substance limitations of hazardous materials such as lead < 1000 ppm
CAT-6	Sixth generation of twisted pair Ethernet cabling and proceeds its predecessors in cross talk and system noise
I^2C	I^2C supports up to 1008 slave devices and communicates at a rate of 100kHz or 400kHz.
UDP/IP	Used for video playback. Headers have four two byte fields
STL	Gives the geometry of the surface of an object’s surface

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Questions?

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