PEP25

Navigation

Cube ArduPilot Installation Instructions

Telemetry Radio Manual

PEP 2025 Information

Rule book Link

Major Rules

Requirements

- Distance: 2 miles
- Maximum Voltage: 55 V
- Maximum Amp-Hours: 500 Ah
- Emergency Shut Off
- Secured Batteries
- Maximum 5 minutes at the ramp
- ½ in. rope connection for towing

Optional

- Carry a 30 lb OR 60 lb payload
- Best Propeller design
- Using OPTIMA Battery

Deadlines

Scores	Completion Date	Possible Points
Bonus: Mid-Year Review	Feb. 10, 2025	3
White Paper	Mar. 25, 2025	20
Video Presentation	Mar. 25, 2025	20
Demo Video (200m/2 min. Operation)	Apr. 1, 2025	N/A
Race Performance	Apr. 15-17, 2025	60
Bonus (Unmanned): 60 lb payload	Apr. 15-17, 2025	5
	Total Possible Points	108

Code

Temperature sensors

CAN ports : https://discuss.ardupilot.org/t/how-to-send-data-from-arduino-to-pixhawk-using-i2c/99814

Temp sensor datasheet : https://www.analog.com/en/products/ds18b20.html

Applets : https://github.com/ArduPilot/ardupilot/tree/master/libraries/AP_Scripting/applets

Ardupilot forum: https://ardupilot.org/copter/docs/common-optional-hardware.html

Temp sensor ardupilot: https://ardupilot.org/copter/docs/common-temperature-sensor.html

Pihawks with Raspberry

https://ardupilot.org/dev/docs/raspberry-pi-via-mavlink.html

Hull Design

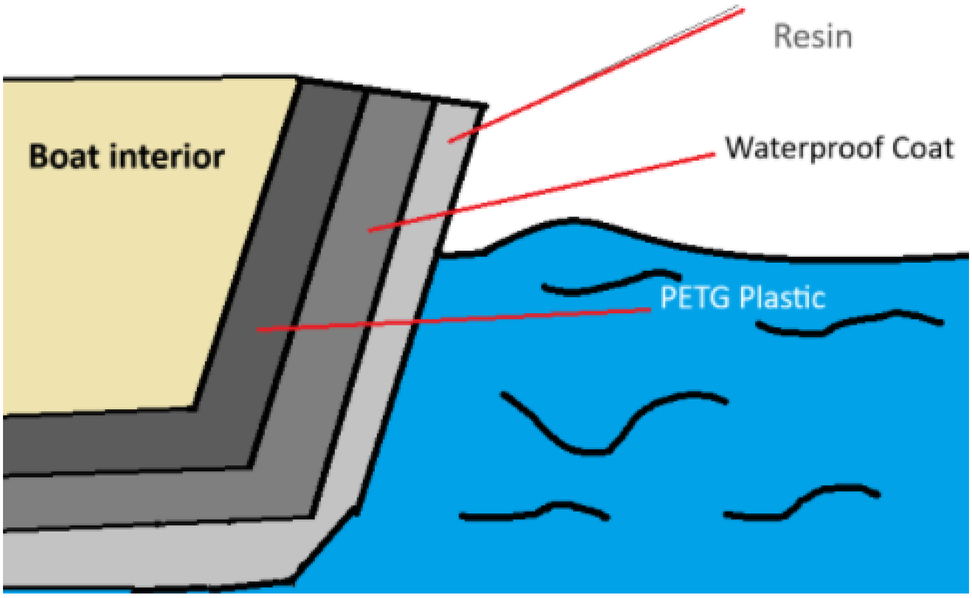
Hull Design - General Notes

Hull Composition:

The hull of our vessel has to accomplish multiple things in order to be successful.

1. **Don't sink**
2. **Go fast**
3. **Fit everything nicely**
4. **Don't put us in debt**

The first thing it has to do is **not sink**, as we are designing a surface vessel, not a submarine. The way a ship doesn't sink depends entirely on its hull's ability to resist taking on water during normal use. The way we have chosen to do this with our hull is by creating a composite hull, comprised of the following layers:



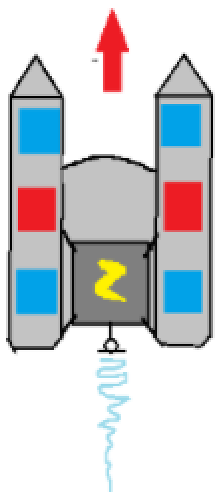
- The first (or inner) layer of PETG plastic will be 3D-printed, in panels, which provide the outer skin of the boat. **PETG was chosen for its temperature resistance, general rigidity** (which aids the "skeleton" in maintaining structural integrity), **and water resistance after printing.** It is a flexible middle-ground between PLA and TPU, having more flexibility than PLA (being less brittle) and being more rigid than TPU.
- The second (or middle) layer of the hull's skin is a roofing-grade waterproofing paste. Though plastic is not usually thought of as susceptible to water absorption, if water is absorbed into PETG plastic over time, the structural integrity of the plastic may be compromised. It may become more brittle and therefore less resistant to impacts from waves or the wakes of other boats, which is bad. So, this paste layer will prevent water

from damaging the plastic underneath.

- (OPTIONAL) A second middle layer may be added if decals / art is to be added to the hull. Whatever paints / dyes are used will be sealed by the following layer, but **must be placed on the outside of the opaque waterproofing layer** so that it A) does not prevent the waterproofing layer from waterproofing, and B) is not obscured by the opaque paste.
- The last (outer) layer will be a translucent resin, which will act as a sealant. This final layer prevents the elements from interacting with the paints, waterproofing layer, and plastic. It will also make the boat shiny :D, and may negligibly albeit positively impact the structural integrity of the boat.

The second thing the boat hull has to do is **go fast.** This component is dependent on the electrical and motor teams' abilities to collaborate effectively to deliver an optimal motor for our boat. It is also, however, dependent on the hull team's ability to deliver a hydrodynamic hull.

The hull team has chosen a catamaran design for our boat. This essentially implies that the hull will have two "pontoons" which are structurally integral to the central, primary cabin (interior, below-deck room of a ship) that houses our electronics box. The basic layout for the boat is below:



The two "pontoons" of the boat are on either side of the electrical box, annotated by the yellow lightning bolt. They are spaced as such to prevent the boat from rolling over. The pontoons will also house the 4 batteries (blue boxes) and the payloads (red boxes).

The third thing a hull has to do is **fit everything nicely.** Our hull will accomplish this by default; we will dimension it around the necessary components, which are listed below:

Component	Full dimensions	Scaled dimensions	Weight
Battery **(x4)**	**12 x 9 x 7** inches	**3 x 2.25 x 1.75** in	*undefined*
Payload **(x2)**	*undefined*	*undefined*	30 lbs

Electrical box **(x1)**	**12 x 16 x 8** inches	**3 x 4 x 2** in	*undefined*

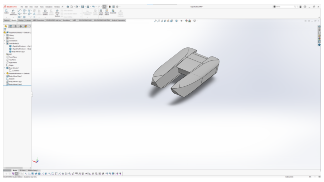
scale: 1/4

The fourth thing the hull has to do is prevent us from going into debt. The way we accomplish this is by using affordable materials, planning our production of the hull, and through testing scale models to avoid wasting excessive material. The production procedure, as it currently stands, is below:

Step	**Procedure**	**Purpose**	**Status**
1	decide on a hull type	to decide on the best course of action for the mission.	*complete*
2	prototype the first rudimentary iteration of the hull	to allow the team members to make decisions on the hull while they are able to comprehend it as a 3d concept	*complete*
3	prototype the next iterations of the hull in CAD	to allow each member to implement their own ideas on hull design; to allow each member to gain 3D CAD experience; to begin the process of figuring out the best general shape for the scale design	*in progress*
4	Decide on the best CAD scale prototype for testing purposes	to decide which CAD model is the most optimal; to give each member the chance to have their ideas heard and weighed	--
5	Print the scale model / panel test	to test the effectiveness of 3D-printed hulls; to test the printers and optimize their settings for printing panels out of PETG later on; to provide data for optimizing the thickness and infill of the panels which will be printed later on	--
6	Design the skeleton of the real boat in CAD	the skeleton is necessary for the structural integrity of the boat, and for anchoring the panels along bulkheads.	--

7	Design the real hull in CAD	this step is necessary for simulations (OPTIONAL); the general shape of the hull will be required before we can break it up into individual panels.	--
8	Break up the CAD design into panels	Each panel gets printed individually. We also need to figure out how they will be attached to the skeleton.	--
9	Print the panels and 3D geometry	This is necessary for assembly of the final boat.	--
10	Assembly	The final boat needs to be assembled.	--
11	Finishing	The assembly needs to be finished (plastic welds around electrical box, apply coatings, etc...)	--
12	Dry testing	The Dry test is necessary for making sure the electronics won't explode. During dry testing, a single panel should be submerged in water for a few hours to determine the effectiveness of the finishing process on waterproofing the hull panels.	--
13	Wet testing	The Wet test is necessary for determining the performance of the boat in actual water. Leaks should be addressed in this phase, and they should be thoroughly patched. This phase is also necessary for determining if the hydrofoils are go/no-go, and if they need to be adjusted.	--
14	Competition	:D	--

Current hull iterations:

Author	**Iteration**	Image	Description
Cai, Dylan, et. al	0	(cardboard model)	• general catamaran shape • included hydrofoil geometry • 1/4 scale
Cai	1		• pontoons were generated via subtractive manufacturing techniques (he cut the pontoons out of solid rectangular prisms with the extrude-cut tool) • Includes an "air-ram" geometry in the front/center which theoretically increases the lift force, aiding the hydrofoils • accurate dimensions
Li	1		• (add your description here, Li)
Dylan	0		• (add your description here, dingus)
Brooke	0		• (add your description here, Brooke)
Anyone Else			

Materials used for final hull:

Material	**Quantity**	**Purpose**	**Cost $$**
PETG Plastic filament	undefined	All models will be made of PETG. The final boat will use PETG panels for its skin.	undefined
Waterproof Material	--> Edits required		
Translucent Resin (brand? type?)	undefined	Final layer of boat will be translucent resin. It will act as a sealant.	undefined
Hydrofoils (type, brand, material, etc...)	--> Edits required		
--			
--			

Notes

11/08/2024

Meeting goals

Get ArduPilot up and running on Cube

Meeting Notes

What was completed?

- Installed latest ArduPilot firmware to Cube
  - Issue with flashing firmware on QGC (Ubuntu), worked with APM Mission Planner (Windows)
  - Once firmware updated, the FC was able to communicate with QGC
  - Experimented with calibrating accelerometer and compass
- Telemetry Radio [Manual]

What is in progress?

- Looking in to telemetry radio - Matthew
- Goal is to have software fully integrated by the end of semester
  - Working control (Thrust & Steering)
    Working w/ RC Controller
  - Working GPS
    Working Telemetry Radio

What is the goal for the next meeting?

11/12/2024

Meeting goals

Meeting Notes

What was completed?

- Issue w/ QGC finding firmware seems to be fixed, able to flash autopilot firmware from QGC
- Got RC Receiver working by connecting receiber to RCIN pins on controller and forcing SBUS protocol in ArduPilot parameters
- Configured motor parameters, servo functions
  - Servo 1 - Steering
  - Servo 3 - Throttle

What is in progress?

-

What is the goal for the next meeting?

- Get PWM Control working

11/15/2024

Meeting goals

- Get PWM Control working with flight controller to control motor

Meeting Notes

What was completed?

- Researched GPS modules, trying to find one with the right connector and protocol to be recognized by AutoPilot
- Configured PWM output and got it working. Receiver is now controlling motor

What is in progress?

- Finalizing GPS modules pick
- Getting telemetry radio working

What is the goal for the next meeting?

- Get telemetry radio connection between ground station and flight controller

1/14/2025

Meeting goals

- Work on getting M8N GPS Module Connected

Meeting Notes

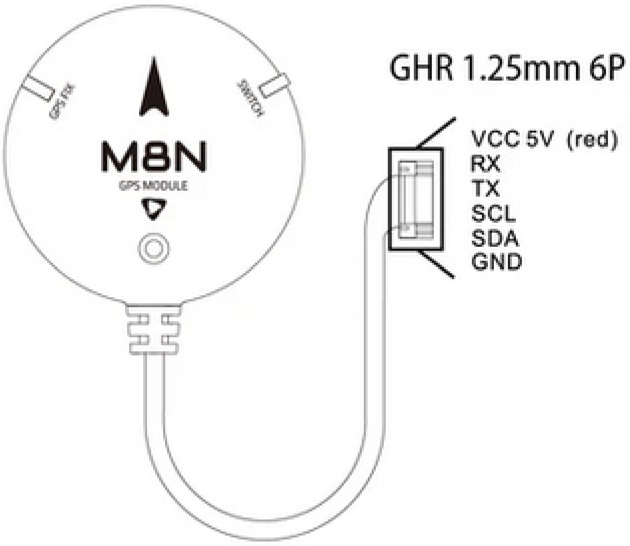
What was completed?

- Resoldered the wires on the GPS using these colors to connect it to I2C:
    - I2C

Pin #	Name	Dir	Wire Color	Description
1	VCC_5V	out	red / gray	Supply to peripheral from AP
2	SCL	in/out	blue / black	SCL, 5V level, pull-up on AP
3	SDA	in/out	green / black	SDA, 5V level, pull-up on AP
4	GND	-	black	GND connection

      POWER 2
    - Did not work
- I believe it should be this to connect it to the GPS 2 Module but unsure of how the colors line up:
    - GPS 2

Pin #	Name	Dir	Wire Color	Description
1	VCC_5V	out	red / gray	Supply to GPS from AP
2	MCU_TX	out	yellow / black	3.3V-5.0V TTL level, TX of AP
3	MCU_RX	in	green / black	3.3V-5.0V TTL level, RX of AP
4	SCL	out	gray / black	3.3V-5.0V I2C2
5	SDA	in	gray / black	3.3V-5.0V I2C2
6	GND	-	black	GND connection

- 

What is in progress?

What is the goal for the next meeting?

- Resolder the 6 wires onto an 8 pin connector and test the GPS on the GPS2 Port
  - If this does not work, pick out another GPS and order

Images

Propeller Design Research and Specifications

Date: 9/6/24

Meeting goals

- Research into manufacturing options
  - Metal
  - Resin
  - ASA
- Research into propeller design
- Research into counter-rotating propellers

Meeting Notes

LINKS:

https://bblades.com/props-101/#:~:text=Rake%20is%20the%20amount%20of,outboard%20propellers%20is%2015%20degrees. -Propeller 101

https://fliteboard.com/products/flite-air-pro-acai?variant=43220266189000 - eFoil with diff. propellers

https://bit.ly/4e8DVso - Tentative motor

CAESES Video Tutorials › CAESES - Design software

https://web.mit.edu/2.016/www/handouts/2005Reading10.pdf - MIT paper on propellers

Manufacturing

3D-printing for prototype and later have the propeller milled

Propeller design

We were brainstorming about the use of 2 or 3 blades due to the size of the boat. Depending on the actual power needed to lift the hydrofoil out of the water we could reduce the amount of blades used on a counter rotating prop. Since the efficiency of the counter rotating prop design is more efficient, maybe it is possible to reduce the amount of blades from 6 to 4 on the shaft.

Counter-rotating propellers

What was completed?

What is in progress?

What is the goal for the next meeting?

Images

Propeller Design Research Part 2

Date: 09/17/24

Meeting goals

- Calculator for approximate propeller thrust given motor specifications
- Learn how to use a simulator to simulate propeller performance
- Compare calculator results to simulator results

Meeting Notes

- Propeller thrust can be calculated using:
  - Thrust = (Motor power * Propeller efficiency) / Flow velocity
  - Source: Propeller Performance: An introduction, by EPI Inc. (epi-eng.com)
- Flow velocity can be calculated using:
  - Speed (inches/minute) = Pitch * RPM * (1 - Slip)
  - Source: http://dunnritepropellers.co.nz/images/prop_tips_03.pdf
  - **Factors contributing to propeller slip and how to reduce propeller slip**:
    - Boat weight and design: The weight and design of your boat can affect how much resistance the propeller encounters in the water, which can impact prop slip.
    - Engine power: If your engine is producing more power than your boat can handle, it can cause the propeller to slip in the water.
    - Propeller size and design: The size and design of your boat’s propeller can impact how efficiently it moves through the water and how much resistance it encounters.
    - Water conditions: Rough water or strong currents can increase the resistance your propeller encounters, which can lead to higher prop slip.
    - Source: How To Reduce Prop Slip: Tips and Techniques For Better Boat Performance - Waves Weekender
    - A slip of 1 or 100% means that the propeller will not advance in water.
    - "Calculated propeller slip within the
    - range of 5% to 25% is typical and acceptable. If slip is greater than 25%, there is likely an issue with the propeller." Prop Bite: Understanding Propeller Slip |

[Mercury Marine]

- **Propeller efficiency is related to propeller diameter.** The greater the diameter, the more efficient the propeller (The propeller will be able to move more water/ produce more thrust per revolution). But the greater the propeller diameter, the more drag. So for low-speed craft, a higher diameter propeller is preferred whereas for a higher-speed propeller, a smaller diameter propeller is preferred. How Propeller Pitch and Diameter Affect Boat Performance (citimarinestore.com)
  - "The main opportunities for propulsion efficiency improvements are in hull efficiency (typically 0.95–1.3), propeller open water efficiency (typically 0.55–0.70) and relative rotative efficiency (typically 0.98–1.07)" Propeller Efficiency - an overview | ScienceDirect Topics
- Selected motor: APISQUEEN 70167 7.5KW internal rotor brushless waterproof motor for hy – Underwater Thruster

What was completed?

- The calculator: https://docs.google.com/spreadsheets/d/1fZU8p28u3xLca4Ge9oelJ2ioDH1f_wty5EOEaINy_YU/edit?usp=sharing

What is in progress?

- Learn how to use a simulator to simulate propeller performance
- Compare calculator results to simulator results

What is the goal for the next meeting?

- Simulate a propeller and compare results with the calculator

Images

V

Abstract

Whether one is prototyping, recreating, or even creating a new unique item there is no question that 3D printing is a positively helpful tool in the process of an item going from a fantastical idea to reality. The Robotics Club of Central Florida (RCCF) has found 3D printing an essential part of bringing forth an idea to the real world; however, this process is not without its challenges. With this paper, RCCF’s Rapid 3D team presents the challenges of designing, developing, and testing a fully custom 3D printed hull designed around a central direct drive electric propulsion system. This system is based upon RCCF’s direct expertise in robotics, specifically the need to keep component interactions simple, functional, and reliable. With that in mind, the drive assembly of the boat (Rapid 3D) features an optimized propeller, selected based on diameter and pitch to maximize thrust efficiency, a submersible pod electric motor for direct drive propulsion, and a custom-geared rudder system for both enhance maneuverability and control. The power system integrates 4 $LiFePO_4$ and a LiPo battery, ensuring a balance of power efficiency, safety, and redundancy. \

Software Report

How, what, why?

Software Goals:

Primary

- Reliable RC Controls for long distance
- Telemetry data feed back: Primarily battery voltage, current draw

Secondary:

- Autonomous navigation through way points via GPS
- Data logging to allow for us to gather data on battery usage, speed, etc.

Control Software:

We moved away from our completely custom software setup on ESP32 last year. The ESP32 was simple and great for allowing plain RC controls, however was limited for further development. We also had no way to receive data back from the boat in real time.

- ArduPilot:
    - Why: Already built library for autonomous and semi-autonomous vehicles
        - Ability to tune PID controls w/ integration w/ IMU
        - Ability to switch from remote to autonomous controls
        - Ability to communicate with ground control station allowing for us to view position of boat, send waypoints, view real time telemetry.
        - ArduPilot would also allow for control of active hydrofoils if we develop those in the future

Hardware Choices:

- OrangeCube Pilot: Connects directly w/ RC controller, integrated IMU,
- RPi 4: Interface with ArduPilot via WiFi for data streaming
- ESP32 controls the stepper motor by translating the PWM signal for the rudder from the Flight controller into the apropiate signals for the stepper

Rudder

9/20/2024

Balanced Barn door rudder which can either be attached from just the top or form a top and bottom, which is a rudder with a shaft through the middle which will spin the rudder.

Benefits:

- Less force needed so steer the rudder
- relatively simple to use a stepper motor with
- can be made modular

Cons:

- Fails to support big boats
- more likely to break if hits an object
- If we attach only from the top is less stable

OpenProp Design Parameters

OpenProp Design Parameters

- B-series propeller design parameters: [Untitled]
- B-series propeller design procedure: [OptimumdesignofB-seriesmarinepropellers.pdf]

1. c/D (Chord Length / Diameter Ratio)

- **Description**: The ratio of the chord length of the blade to the propeller diameter.
- **Effects of Changing c/D**:
  - **Higher c/D**:
    - **Increased Lift**: A larger chord length can generate more lift, which may be beneficial for high-thrust applications.
    - **Higher Drag**: It may also increase drag, reducing overall efficiency.
  - **Lower c/D**:
    - **Reduced Lift**: A smaller chord length can decrease lift generation.
    - **Lower Drag**: It typically results in less drag, improving efficiency at higher speeds but may limit thrust.

2. Cd (Drag Coefficient)

- **Description**: A dimensionless number representing the drag force acting on the blades relative to the dynamic pressure and reference area.
- **Effects of Changing Cd**:
  - **Lower Cd**:
    - **Improved Efficiency**: A lower drag coefficient generally leads to better aerodynamic efficiency, allowing the propeller to produce more thrust with less energy.
    - **Potential for Higher Speeds**: Reduced drag can enhance performance in high-speed applications.
  - **Higher Cd**:
    - **Increased Resistance**: A higher drag coefficient can lead to more energy loss and reduced overall performance.
    - **Lower Efficiency**: May result in lower efficiency and increased fuel consumption or power usage.

3. t0/D (Thickness at Hub / Diameter Ratio)

- **Description**: The ratio of the blade thickness at the hub to the propeller diameter.
- **Effects of Changing t0/D**:

- **Higher t0/D**:
  - **Increased Strength**: Thicker blades can withstand greater stresses, enhancing structural integrity and cavitation resistance.
  - **Potential for Higher Drag**: Thicker blades can increase drag, potentially reducing efficiency.
- **Lower t0/D**:
  - **Weight Savings**: Thinner blades can reduce weight, which may be advantageous in lightweight applications.
  - **Reduced Strength**: May lead to increased risk of structural failure under heavy loads or high-speed conditions.

4. **Skew**

- **Description**: The angle at which the blade is twisted or skewed along its length.
- **Effects of Changing Skew**:
  - **Increased Skew**:
    - **Improved Thrust Distribution**: More skew can help distribute thrust more evenly along the blade, reducing the likelihood of cavitation and improving overall performance.
    - **Changes in Flow Dynamics**: It can alter the flow around the blade, potentially enhancing lift at specific angles of attack.
  - **Decreased Skew**:
    - **More Traditional Blade Shape**: Less skew may lead to a more conventional blade profile, which might not optimize performance in certain applications.
    - **Increased Risk of Cavitation**: Less skew can concentrate forces and pressure, potentially increasing the risk of cavitation at certain operating points.

5. **Xs/D (Distance from Leading Edge to Maximum Thickness / Diameter Ratio)**

- **Description**: The ratio of the distance from the leading edge to the point of maximum thickness to the propeller diameter.
- **Effects of Changing Xs/D**:
  - **Higher Xs/D**:
    - **Thickness Distribution**: Shifting the maximum thickness further back can alter the lift and drag characteristics, potentially improving performance at higher speeds.
    - **Stability**: Can enhance stability and control characteristics, especially in high-performance applications.
  - **Lower Xs/D**:
    - **Early Thickening**: Moving the maximum thickness closer to the leading edge can increase initial lift but may lead to higher drag at certain angles of attack.
    - **Increased Sensitivity**: Can make the blade more sensitive to changes in flow conditions, potentially affecting performance during maneuvering.

Motor

9/10/2024

By looking at the possible motors that we have chosen and comparing them with power and price we have decided to go with:

[APISQUEEN 70167]

Also worked on calculation in the spread sheet, Current spread sheet to calculate values(PDF):

Motor

Info	Description	Formula	Value
Time to last	The time the motor can run at **rated power** and such given current battery (min)	Ah/(W/V)	27.65
Relative W to Time	A relative factor that equalizes the relationship between the time to last and motor power (Higher is better)		

Propellor

Info	Description	Formula	Value
Velocity	Idk calculator online needs it	Pitch * RPM * (1/1056)	0.60036364
Thrust	Above (N)	Thrust = (2 * Efficiency * Power * 746) / (Velocity * Propeller Diameter * 0.0254)	1824634654

Boat

Info	Description	Formula	Value
Boat Drag	Multiplier in which boat's hull causes force to require more (<1)		
Required force	The required force needed to be created by the propellor to move the boat at desired speed (Mph)		

Power

Info	Description	Formula	Value
Batter	Multiplier in which boat's hull causes force to require more (<1)		

Selected Motor Option

Option	1	
Power		7500
Voltage		48
Price	$	285.50
KV		130
Horsepower		10.0575

6240

Coming up
will need to pick out a ESC before friday.

Motor Controllers

Main motor controller (link)

We made the decision to go with the Flipsky 75350. We made this decision because of prior years experience with Flipsky controllers and they give some of the best functionality and configuration.

Pros

- High power output
- Built in water cooling
- Multiple forms of communication
- Highly configurable motor control

Cons

- Size and weight
- Overpowered for current motor selection

Specs

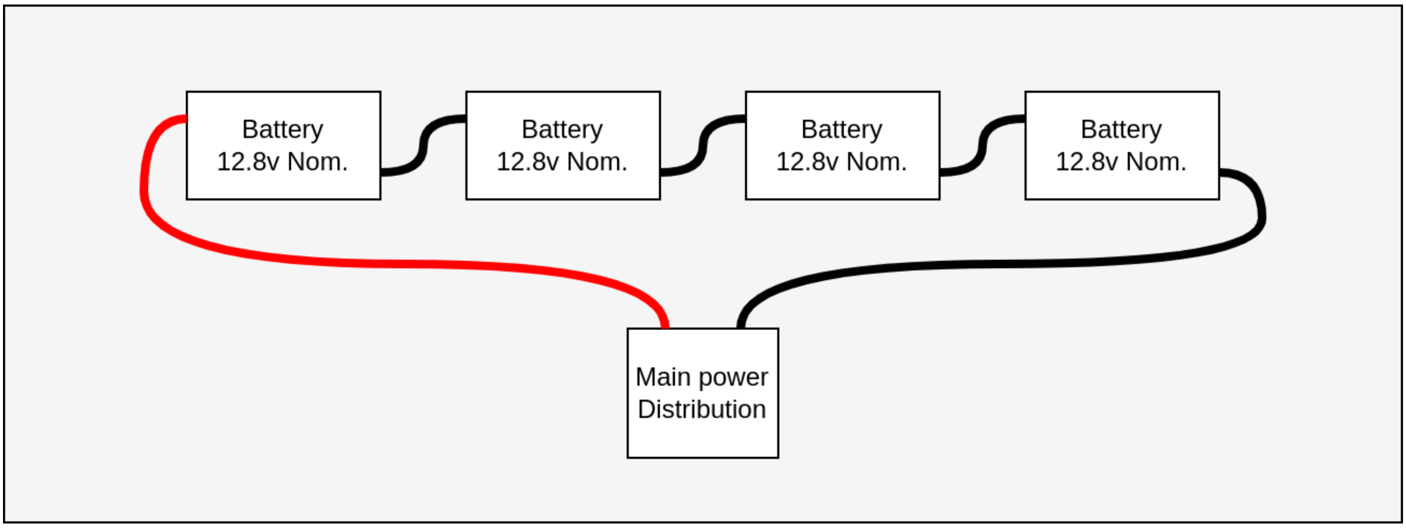
- Voltage: 14-84V (safe for 3-20S)
- Continuous Current : 50V/350A,75V/250A (Duration depends on external heat dissipation)
- Instantaneous Peak Current : 800A
- Supported sensors: ABI, HALL, AS5047, AS5048A
- EPRM: 150000
- Phase filter: Yes

Batteries

High Power System Batteries (link)

We will continue to use out 4 100ah Lithium Iron Phosphate (LiFe) batteries that we choose last year for our competition. These batteries were very oversized for our purposes last year but will much better suited this year with our higher power requirements. Lithium iron phosphate was chosen for it's safety to density ratio. Compared to Lithium Ion(Li-Io) or Lithium Polymer(Li-Po) LiFe is less energy dense but also comes with a more safe chemistry.

Battery Configuration



The batteries will be configured in a 4s configuration of the battery packs we use. If you consider the internal configuration of each pack we will be using a 16s battery configuration.

PCB

Old Boat PCB.zip

Notes

Notes

09/06/24

Meeting goals

Meeting Notes

List of sensors/control connections for the boat

- temp sensors
- actuator communication
- imu / GPS
- main motor
- Controller
- data collection
- e-stop control

What was completed?

What is in progress?

- motor selection
- controller selection
- PCB improvements
- battery requirements (based off motor selection)
- boat computer decision
  - esp32

    - rasberry pi
    - flight controller
- Software
    - ardupilot

What is the goal for the next meeting?

Images

09/10/24

Meeting goals

- Basic EasyEDA design
    - Example project

Meeting Notes

What was completed?

What is in progress?

What is the goal for the next meeting?

Images

Enter section select mode

No Comments

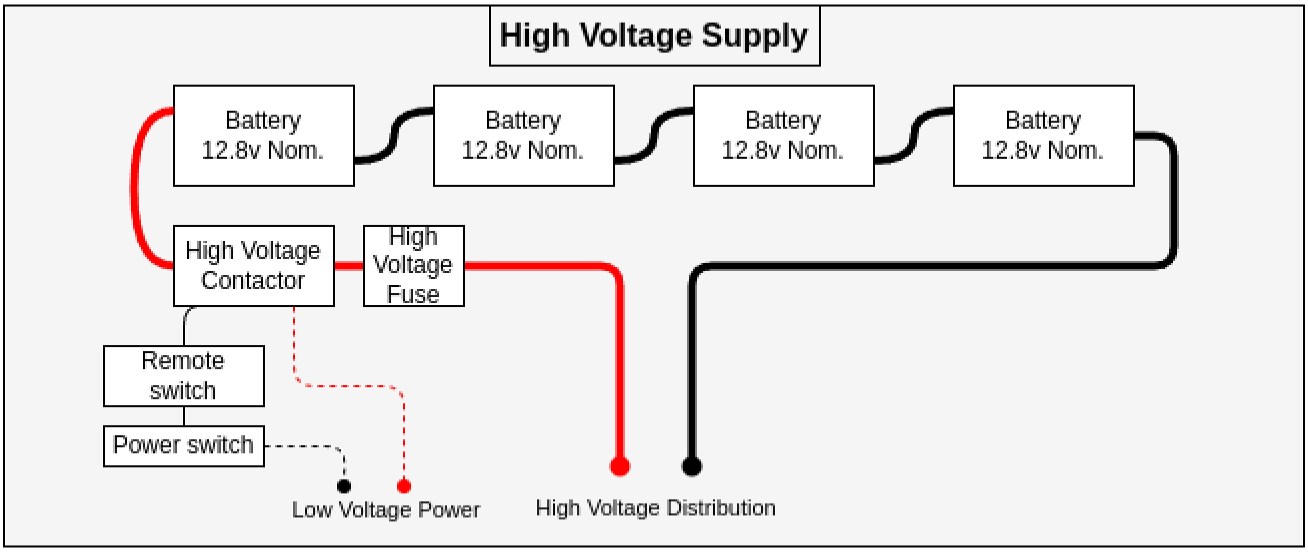
Add Comment

Full System Layout

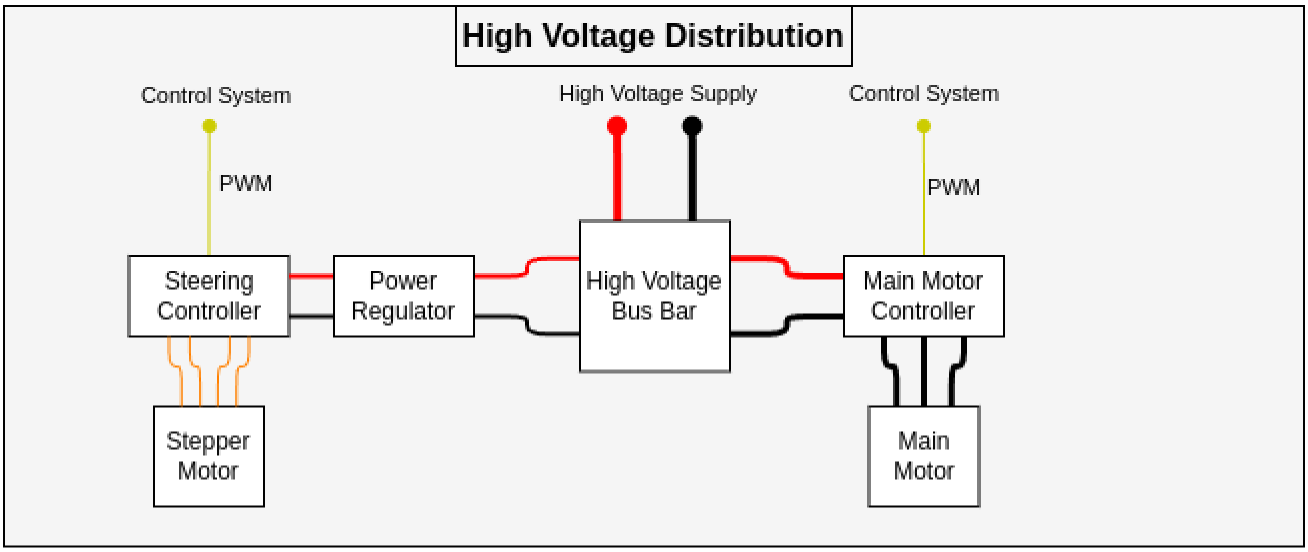
Full System

High Voltage System

High Voltage Supply



High Voltage Distribution



Low Voltage System