Project Phase Report 1

Open Advanced Course in Embedded Systems

Jonas Gartner
Sigge Axelsson

November 8, 2024

Summary

Over the past two weeks, we have focused on researching and selecting key components for the drone project. We finalized the choice of brushless DC (BLDC) motors and electronic speed controllers (ESCs) suitable for the motor's current and voltage requirements. Additionally, we selected Li-Ion batteries capable of supporting the motors' power needs. Two different propeller models were also purchased for testing to determine the optimal thrust and efficiency for the drone.

1 Theory

1.1 Brushless DC Motors

Brushless DC (BLDC) motors operate by using electronic commutation to generate rotational motion. These motors consist of a permanent magnet rotor and stator windings, as shown in Figure 1. Unlike traditional brushed motors, BLDC motors use electrical signals to switch the current in the stator windings, creating a rotating magnetic field that interacts with the rotor magnets, causing the rotor to spin [1].

Rotor position sensors (e.g., Hall effect sensors) or sensorless methods are used to determine when to switch the current to the correct windings, optimizing torque. BLDC motors are known for being efficient, reliable, and low-maintenance due to the absence of brushes and commutators.

1.1.1 Rotor Speed - Kv

Kv is a term that describes the motor's speed per volt applied, as represented by Equation 1:

$$RPM = Kv \cdot V \tag{1}$$

Where:

- RPM is the rotational speed of the motor (revolutions per minute)
- V is the applied voltage

1.2 Electronic Speed Controllers

Electronic Speed Controllers (ESCs) regulate the speed, direction, and braking of electric motors, commonly in applications such as drones, RC vehicles, and BLDC motor systems. ESCs convert DC power from a battery into controlled pulses using Pulse Width Modulation (PWM) to adjust the motor's speed. They receive input signals from a controller (e.g., throttle) and control the current and voltage supplied to the motor by switching transistors at high speeds [2].

In BLDC motors, ESCs monitor the rotor's position, typically using sensors, to ensure the correct timing for energizing the motor's coils, which results in smooth operation and efficient performance.

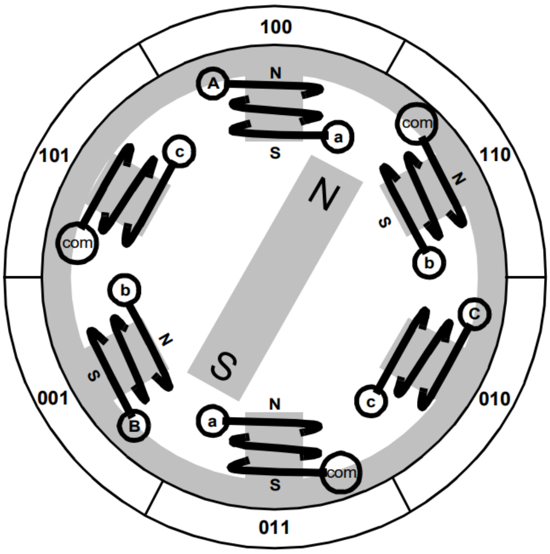


Figure 1: Diagram of BLDC motor operation [1]

2 Components

Recent work has primarily focused on researching and testing components for the drone. In the following sections, the selected components are described, along with the theory and motivation behind each choice.

2.1 Batteries

We selected Samsung Li-Ion 21700 cells for the batteries. These cells offer a lightweight energy storage solution with a capacity of 4000mAh and a maximum discharge current of 35A, which can reach up to 45A if the temperature is monitored. The high current discharge capability allows the motors to run at full throttle without damaging the batteries.

The rated current of 35A is sufficient to power the four motors during normal operation, where we expect the motors to draw between 24A and 32A. However, further research and a power limit implementation will be necessary, as the motors' maximum current exceeds the batteries' rated current.

To power the four motors, we plan to use 2-3 cells in series, providing a voltage of 7.4V to 11.1V.

Figure 2: Samsung Li-Ion 21700 battery

2.2 BLDC Motor

For the drone motor, we selected the Emax ECO Micro 1404 due to its appropriate dimensions, propeller RPM, maximum current, and lift capacity.

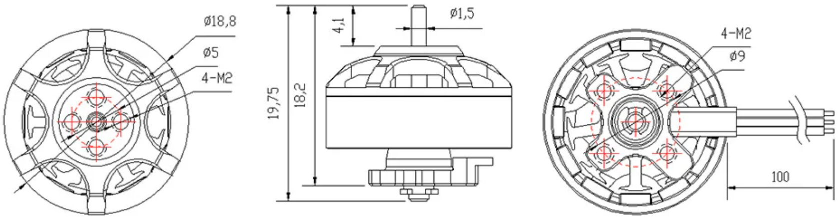
Based on the data in Figure 3, we expect one motor to generate approximately 300 grams of lift. With four motors, this results in a total lift of 1200 grams. A general guideline [3] suggests that motors should generate lift equivalent to twice the weight of the drone, allowing a maximum drone weight of 600 grams.

The motors have a maximum rated current of 12-14A, depending on the propeller size, as shown in Figure 4. This results in a total peak current of 48-56A, though we expect a total current of 24-32A during normal operation.

The motors are rated for 2-4 cells. We plan to use 2-3 cells in series. Since we will be operating at the lower end of the voltage range, we selected a motor with a Kv rating of 4800. This, using equation 1, results in motor speeds between $7.4 \cdot 4800 = 35,520\,\text{RPM}$ and $11.1 \cdot 4800 = 53,280\,\text{RPM}$, depending on the number of cells we decide to use.

Prop (inch)	Voltages (V)	Throttle (%)	Load Currency	Pull(g)	Power(W)	Efficiency(g/W)	Temperature (in full throttle load 5's)
GF2.5*4*3	11.1	25%	1.5	49	16.7	2.943	61℃
		50%	7.3	144	81.0	1.777	
	14.8	75%	1.7	98	25.2	3.895	65℃
		100%	7.9	288	116.9	2.463	
HQ 3*2.5*3	11.1	50%	2.9	70	32.2	2.175	77℃
		100%	11.4	216	126.5	1.707	
	14.8	50%	2.7	140	40.0	3.504	80℃
		100%	14.1	432	208.7	2.070	

Figure 3: Test data for the ECO1404 BLDC motor with 2.5-inch propeller (top - GF2.5*4*3) and 3-inch propeller (bottom - HQ3*2.5*3)



ECO 1404 EMAX

	KV3700	KV6000
Idle Current(7V/10V)	0.5A(10V)	1.0A(7V)
Internal Resistance	265mΩ	120mΩ
Peak Current(3S/4S)	12A(3S)	14A(4S)
Max.Power(3S/4S)	170W(3S)	120W(4S)
No.of cells	2-4S	2S
Propeller	2"-3"	
Lead	28#AWG 100mm	

Figure 4: Dimensions and maximum ratings for the ECO1404 BLDC motor

2.3 Electronic Speed Controller

Initially, we used an overdimensioned RUIZHI 40A ESC (2-4S) for testing. After testing the current drawn by the motors, we found that 40A was excessive.

We then switched to a smaller ESC that fit within the expected current range of the motors. We selected the Turnigy Plush-32 12A (2 4S) Brushless Speed Controller, shown in Figure 5, as it meets the required current and voltage ratings.

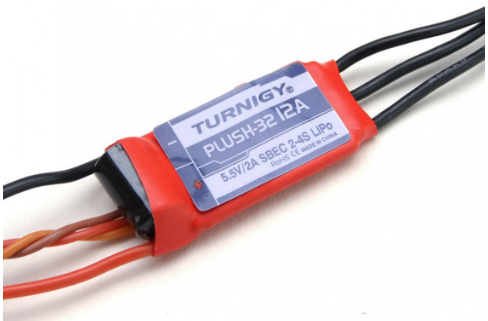


Figure 5: Turnigy Plush-32 12A (2 4S) Brushless Speed Controller

2.4 Propellers

We purchased two different propeller designs: the 2.5-inch GEMFAN 2540-3 Flash Propeller and the 3-inch Gemfan 75mm Ducted Durable 3-Blade Propeller, shown in Figure 6. Both propeller dimensions are recommended for use with the Emax ECO Micro 1404. Testing will determine the required current and thrust generated with each propeller. A general rule is that higher motor speeds require smaller propellers.

(a) GEMFAN 2540-3 Flash

(b) Gemfan 75mm Ducted Durable 3-Blade

Figure 6: Propeller models tested for the drone

References

[1] W. Brown, *Brushless DC Motor Control Made Easy*, Microchip Technology Inc., 2002, aN857, DS00857A. [Online]. Available: https://ww1.microchip.com/downloads/en/appnotes/00857a.pdf

[2] Wikipedia contributors, "Electronic speed control — Wikipedia, the free encyclopedia," 2024, [Online; accessed 20-September-2024]. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Electronic_speed_control&oldid=1239136727

[3] L. Raes, *Carbon Aeronautics Quadcopter Build and Programming Manual*, Carbon Aeronautics, August 2022, first edition. Licensed under Creative Commons Attribution-Noncommercial-ShareAlike 4.0 International Public Licence. [Online]. Available: https://github.com/CarbonAeronautics/Manual-Quadcopter-Drone