Quadcopter Design and Build Log

M Dobosz

March 31, 2018

Revision Date	Description
01/09/18	Initial document
02/11/18	Update to use Mavic frame
03/31/18	Added electronics section

Contents

1 Introduction

The purpose of this document is to record and explain the design process of a quadcopter and why each decision was made. Since I have little experience with the design process, all steps performed for this project were made up as I went along and may or may not be representative of the real-world design process. This document was created to better organize my thoughts and each decision I made for future collaborators to get up to speed and to learn what is going on. All information that is obtained from outside sources is referenced with footnotes, however only the url or website is noted and no proper citation format is used. All information is presented in a way that someone with little to no technical experience can understand (hopefully).

A quadcopter is a four rotor manned or unmanned vehicle used mostly for aerial photography. Many sensors such as gyroscopes and accelerometers, which are located on the flight controller, are used to provide the aircraft with feedback on altitude, acceleration, orientation, etc. The "heart" of the quadcopter is the flight controller, which takes data from its sensors and the receiver and sends the information to the ESCs* More info can be found here.

All prices are presented in $CAD.

2 Objectives

The main objectives of the project are:

- a minimum of 10 minutes of flight time
- easily replaceable parts in the event of a failure or crash
- small enough to carry in a backpack
- easy to understand design so people with minimal technical experience can understand
- price under $250 USD (not including radio and tools)

*Electronic Speed Controller; used to convert the DC voltage from the flight controller to a three-phase AC signal for the motors

All decisions that must be made for which materials to use, physical design, etc. will follow these rules strictly.

Secondary objectives include:

- GPS support
- sonar for low-altitude hold
- space and bracket(s) for mounting of a GoPro camera in the future for aerial photography
- use of Hologram's Nova cellular modem for communication, GPS, or data logging

Two main design sections will be considered, the frame and the electronics. The frame will consist of the structural components of the quadcopter where all the electronic components will be mounted. The electronic components will include the flight controller, motors, ESCs, battery and receiver.

The main restriction imposed on this project is cost. Most, if not all, decisions are made with cost as one of the heaviest factors. Time and difficulty are not as important as this project does not have a deadline and new skills can be learned along the way.

For all custom components, either SolidWorks or Altium Designer will be used, if needed.

3 Frame Design

The frame design is the section that will cause the most trouble, as I have little to no mechanical experience and designing a frame that is both lightweight and durable is an entire project in itself. To simplify the designing of the frame, CdRsKuLL's Mavic F3 v4.1 frame from Thingiverse will be used. Full details can be found here.

3.1 Frame Material

According to Simplify3D, the estimated volume of the frame when 3D printed will be 250 cm^3. Depending on the material chosen, a weight can be calculated and suitable motors can be selected.

Five materials were considered for the frame design: PLA (Polylactic Acid), ABS (Acrylonitrile Butadiene Styrene), Carbon Fiber PLA and Nylon and PETG (Polyethylene Terephthalate Glycol). The advantages and disadvantages of each material were investigated and are presented below.

PLA:

+ easy to print with
+ biodegradable
- warps if exposed to sunlight for too long
- lower structural stability compared to other materials

Price: \$31 per kg

Density: 1.25g/cm^3

ABS:

+ high durability
+ flexible and lightweight
- unpleasant fumes released when printing
- prone to warping without heated enclosure

Price: \$30 per kg

Density: 1.05g/cm^3

CF PLA:

+ very high durability mimicking carbon fiber
+ prints like PLA

- required hardened nozzle
- expensive

Price: \$60 per kg + nozzle

Density: 1.30g/cm^3

Nylon:

+ strong. durable and flexible
+ less brittle than PLA and ABS
- high temperature required for printing
- emits toxic fumes when printing

Price: \$50 per kg

Density: 1.15g/cm^3

PETG:

+ high durability and flexibility
+ does not shrink
+ does not warp
- requires fine tuning of printer settings

Price: \$40 per kg

Density: 1.27g/cm^3

After extensive consideration it was decided that PETG would be used. PETG combines the simplicity of PLA printing with the strength of ABS. The relatively low price compared to carbon fiber also makes it the superior choice. The only downside that may arise is that PETG is the heaviest material out of the three (PLA, ABS, PETG), but shouldn't cause too much of an issue.

To calculate the total weight of the frame, the simple equation below was used:

$$density \cdot volume = 1.27\ g/cm^3 \cdot 250\ cm^3 = 317.5\ g \tag{1}$$

The battery and electronics weight will be considered in a later section.

3.2 Frame Finishing

3D printing produces a rough looking frame with a stepping effect due to the layer transitions. Although this does not affect the functionality of the aircraft, aesthetics should also be considered. A simple combination of body filler (i.e. Bondo car body filler), sanding and spray paint should be sufficient. (This video will be followed.) The effect of adding extra weight by use of body filler and paint are negligible.

4 Electronics

4.1 Motors and Propellers

The recommended motor that the author used is the Black Widow 2208 1200KV, however this motor is discontinued and no longer available off of HobbyKing. **To be added later.**

4.2 ESCs

ESC selected to match motor specs. **To be added later.**

4.3 Battery

The recommended battery is the MultiStar 3000mAh 3S Li-Po. This battery will be used as it is affordable and has a high capacity. The battery is 188g with dimensions 107 x 36 x 28mm.

Assuming ideal conditions, the flight time can be calculated using the following formula:

$$\frac{battery\ capacity}{load\ current} = \frac{3000\ mAh}{...\ mA} = ...\ hours = ...\ minutes \tag{2}$$

This time meets the required minimum 10 minute flight time.

4.4 Flight Controller and Receiver

The recommended flight controller is the Deluxe SP Racing F3. The one mentioned in the guide is the older version which uses a serial to USB adapter instead of straight USB. It also lacks some of the newer features such as i²c[†] which can be used for an OLED[‡] screen. For this project, the newer version will be used for its updated features and availability.

This flight controller features an accelerometer, gyroscope, barometer and magnetometer (compass). Optionally, a GPS and sonar can be added (which in the case of this quadcopter, will be added). An RGB LED and buzzer can also be added to show the status of the flight controller. There are many other advanced features that are beyond the scope of this project, and therefore will be ignored.

The receiver that will be used will be the FrSky X4RSB for its SBUS[§] capability and its high build quality.

4.5 Miscellaneous Electronics

The final electronics will be the sensors such as the GPS, sonar, LED, buzzer, etc. These all interface with the flight controller and provide the CPU with any environmental data it may need. For example, the GPS can be used for flight logging, return to home, and pre planned routes. The sonar is used to allow for low-altitude hold.

[†] Inter-Integrated Circuit; pronounced I-squared-C. A communication protocol that allows peripherals to be controlled by a master circuit, in this case an OLED screen will be driven by the flight controller

[‡] Organic Light Emitting Diode; a type of display that has a high contrast ratio, used often for small electronics for its low power consumption and price.

[§] Radio control communication protocol.

5 Software