# Flying Flashlight

# Design Document

May1738
Adviser: Dr. Gary Tuttle
Brady Koht - Team Leader
Joseph Wickner - Co-Team Leader & Co-Webmaster
Peter Bonnie - Group Communicator
Scott Melvin - Document Master
Sebastian Roe - Webmaster
Team Email – may1738@iastate.edu
http://may1738.sd.ece.iastate.edu
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# 1 Introduction

## 1.1 Project Statement

The Flying Flashlight team strives to design a portable, hands-free, drone based lighting system. Our target demographic will be varied as well as the implementation of our product. We view our product as a multi-purpose utility light.

## 1.2 Purpose

There are situations in our lives that require light. The purpose behind the Flying Flashlight is to provide a portable lighting system that allows a hands-free experience while providing uninterrupted lighting for an extended period of time.

One possible scenario includes night-time roadside emergencies. A person may need both hands free to change a tire which would leave no available hand for lighting necessities. The Flying Flashlight also serves to alert other drivers on the road to a person's whereabouts, creating a safer environment for the time the driver spends outside the vehicle.

Law enforcement could deploy our product instead of using road flares. Road flares pose fire and safety hazards, especially in dry climates. Road flares also burn for a finite period of time. Flying Flashlight is provided with a battery that far outlasts the burn time of a single flare.

Lighting for backyard activities. Parents can deploy the Flying Flashlight when their children are playing in the backyard where power for lighting may not be available. Light allows children to see and play safely during the twilight hours. Flying Flashlight can even be used for backyard barbecues or any yard activity requiring light where power is not readily available.

# 2 Design

## 2.1 System Specifications

The system specifications for our senior design project were initially fluid. Dr. Tuttle approached us with an idea that we found enticing. As such, we decided upon self-policing specifications, including light output, power consumption, and stable tethered stationary flight. Our metric for light output is the equivalent of a full size MAG-LITE, outputting approximately 168 lumens, while providing at least an hour of operation. MAG-LITE is a robust flashlight brand kept in homes and automobiles in case of emergencies.

### 2.1.1 Non-Functional

One of the final deliverables is a user manual, located in Appendix (II), which explains detailed operating procedures and safety protocols for user operation.

### 2.1.2 Functional

A stable drone was the primary deliverable. Secondary to this was lighting and power delivery via tether.

## 2.2 Design Method

Our primary objective is to keep the quadcopter stable. An accelerometer on the flight controller board is used to provide pitch, yaw, and roll data. That accelerometer data is then interpreted and applied to the motors to correct and level the quadcopter. The design of a flight controller is a senior design project in itself. As a group, we opted to purchase an off-the-shelf flight controller. The MultiWii Pro is an open source hardware project that started life as an Arduino-based project and has grown into a familiar hobbyist product. Unfortunately, cost was a major concern for this product and ultimately was one of the deciding factors for choosing the MultiWii over the DJI Naza-M. The MultiWii is $34 dollars and the Naza-M is $49. This cost is before any GPS attachments. With the GPS, Naza-M is $79 and the MultiWii is $52. The vast majority of applications with the Naza-M involves drones being controlled by hobbyists with remote controls.

Our application requires a hands-free device. This means we do not have a remote control (transmitter) and a receiver that is typical in a quadcopter system. As a result, we need to replicate the functionality of the transmitter and receiver. A microcontroller acting as a transmitter is located at the base station, sending height and lighting commands to another microcontroller, acting as the receiver, on the quadcopter. The microcontroller simulating the receiver controls the LED lighting system via PWM and communicates with the flight controller to power the motors and fly the quadcopter to the desired height. For the receiver and transmitter microcontrollers, the ATMega328 was chosen, due to its ease of access in both coding and PCB layout. Wireless communications were implemented using XBEE's on the transmitter and receiver.

We wanted a product that was small enough to be easily transportable, yet large enough to be able to handle some slightly windy conditions and potentially heavy lighting hardware. Factoring in these design characteristics, we settled on a medium-sized quadcopter with dimensions around 8 x 8 inches measuring from the center of a propeller to an adjacent propeller. This is similar in size to an industry standard "250-size" quadcopter. With those parameters in mind, selecting motors and speed controls was the next step. A typical 250-size quadcopter comes with an 1806 size motor. 1806 refers to a motor stator measuring 18mm in diameter and 6mm thick. Given that our quad would be a slightly larger and potentially heavier platform, we decided on a 2204 size motor. With slightly larger motors, we can produce more torque and lifting force to counteract the extra weight of an LED lighting system. A 20A electronic speed controller is used to control the motors, as it will provide a safe current range for our motors.

In order to provide power to the quadcopter during flight, a cable tether was developed with the help of Leland Harker. This tether features a servo-driven cable drum and a pair of slip-ring assemblies to provide power, yet allowing the drum to rotate.

The lighting system consists of four 3 watt RGB LEDs. The LEDs are controlled using three high power PMOS transistors, which are toggled using PWM.

### 2.2.1 Parts List

A list of purchased parts can be found in Appendix (III).

# 3 Testing & Development

## 3.1 Interface Specifications

A user must be able to operate the drone with ease. Thus, a simple interface for the user to operate the flight controller must be created. The final system operates using the following steps:

1. Microcontroller (MCU) that operates the user interface (in the control box) sends a signal to the transmitter.
2. Transmitter wirelessly sends data to the receiver on the drone.
3. Receiver sends signal to the MCU on the drone.
4. MCU processes new signal and sends new data to the flight controller and controls the LEDs.
5. Finally, the flight controller sends a signal to the ESCs to spin the motors

To reiterate, accomplishing the steps listed above requires several different hardware components to be interfaced. Since UART is a common mode of communication, the transmitter and receiver connection is done using XBEE communication.

The final hardware interfacing that has been accomplished is a joystick to control pitch and roll if desired. A linear potentiometer is used to control throttle input with a throttle disable switch. Three potentiometers were incorporated for our interface for red, green, and blue LED control.

## 3.2 Hardware/Software

Hardware testing instruments included multi-meters, oscilloscopes, and power supplies. Additionally, a Google Pixel’s light sensor and Sensors Multitool application was used for light output measurements. The light measurement data is listed below in section 4 Results.

Atmel Studio, Arduino, Multisim, and SolidWorks are programs implemented in programming, designing, and testing our Flying Flashlight. Additionally, the MultiWii

GUI has a built in monitoring system that was extensively used to calibrate and tune the flight controller via accelerometer and sensor data.

### 3.3 Process

A flowchart located in Appendix (I) shows the sequential order in which individual parts of the project were evaluated and tested.

Light output was measured with a light sensor on a smartphone. This output was compared to the reported output of a MAG-LITE 3 Cell LED Flashlight.

Flight stability was the primary concern for this project. Testing and tuning was done under controlled circumstances using a custom test fixture (Figure 3.1) and the CPRE 488 (Figure 3.2) test fixture. Our custom test fixture allows the quadcopter to move freely in the vertical direction while limiting horizontal movement. The CPRE 488 test fixture does not allow for vertical movement, but allows horizontal movement for stability testing.

Figure 3. 1

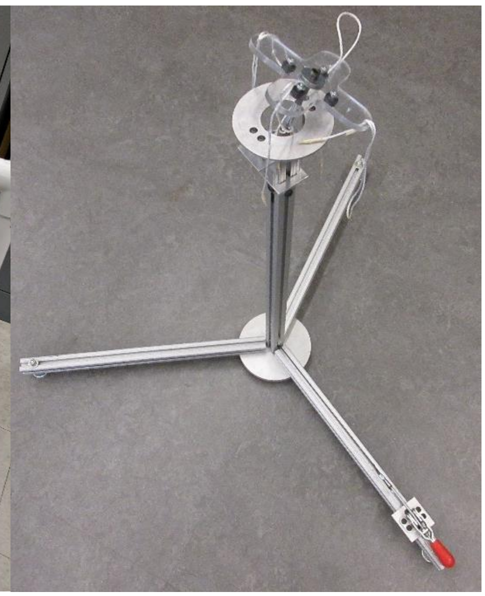


Figure 3. 2

## 4 Results

Initial qualitative tests reveal that a quantity of four 3 Watt RGB LEDs will provide sufficient light output. Once the lighting system was assembled, a max brightness level of 1958 lux was measured at full output brightness. This measurement was completed in a dark room and with only the quadcopter providing light. A Google Pixel smartphone with Sensors Multitool app was moved from a distance of about 2 feet away towards the quadcopter and stopping about 1 inch away from an LED. A plot of this measurement is included below in Figure 4.1.

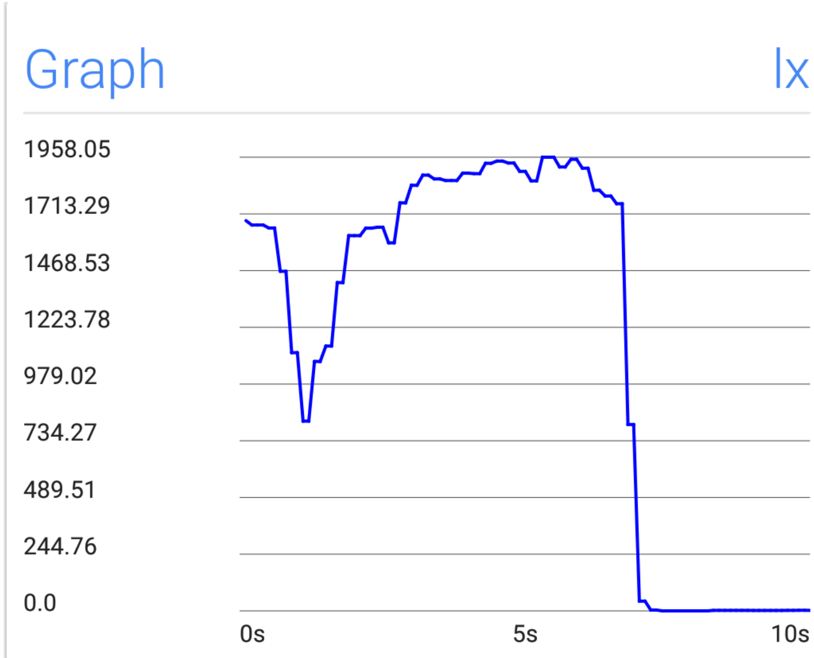



Figure 4. 1

Table 4.1 lists current measurements of each color individually and together at full and half brightness. These 3W RGB LEDS draw a large amount of current for a supply of 12V.

| | Red (A) | Green (A) | Blue (A) | All 3 LEDs (A) |
|---|---|---|---|---|
| 100% Brightness | 0.785 | 0.796 | 0.718 | 1.94 |
| 50% Brightness | 0.413 | 0.418 | 0.379 | 0.951 |

Table 4. 1

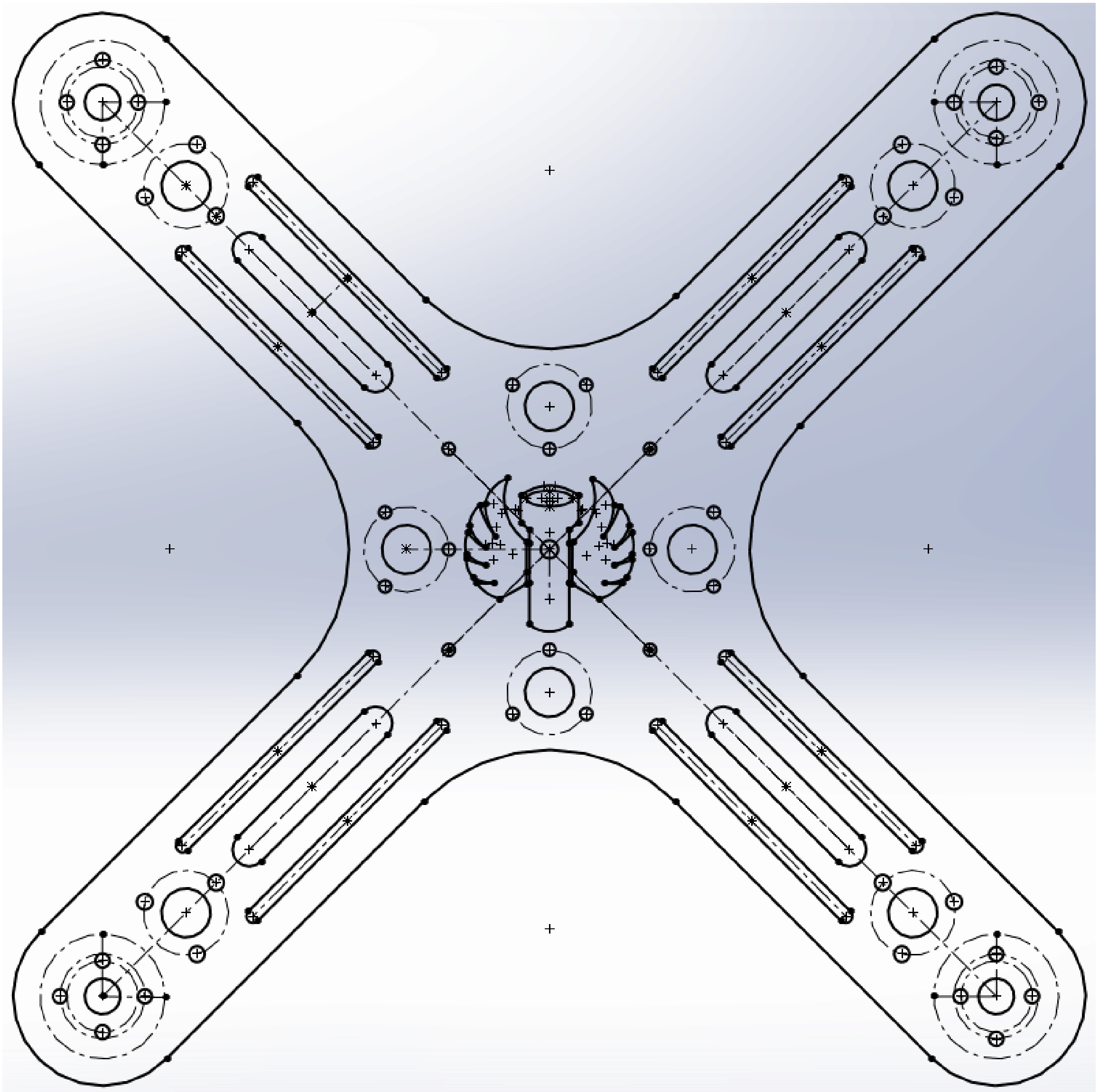
Tuning the quadcopter for stable flight proved to be a more difficult task than envisioned. Using a special tripod developed for quadcopter stability tuning, PID tuning was performed. During testing, no amount of PID tuning appeared to affect the stability of the quadcopter. This is believed to be a problem with the accelerometer on the flight controller.

During flight testing, large fluctuations were observed in the frame and sensor data displayed in the MultiWii GUI confirmed this. This led us to speculate our laser-cut acrylic frame had resonance issues. For this reason, two new frames were tested. The first new frame was a redesign of the original laser-cut acrylic frame and consisted of two thinner acrylic layers separated by nylon spacers. The second frame was a prefabricated store-bought 250-size hobby-grade frame. The vibrations persisted with the redesigned frame, thus, the prefabricated store-bought frame was chosen for further development.

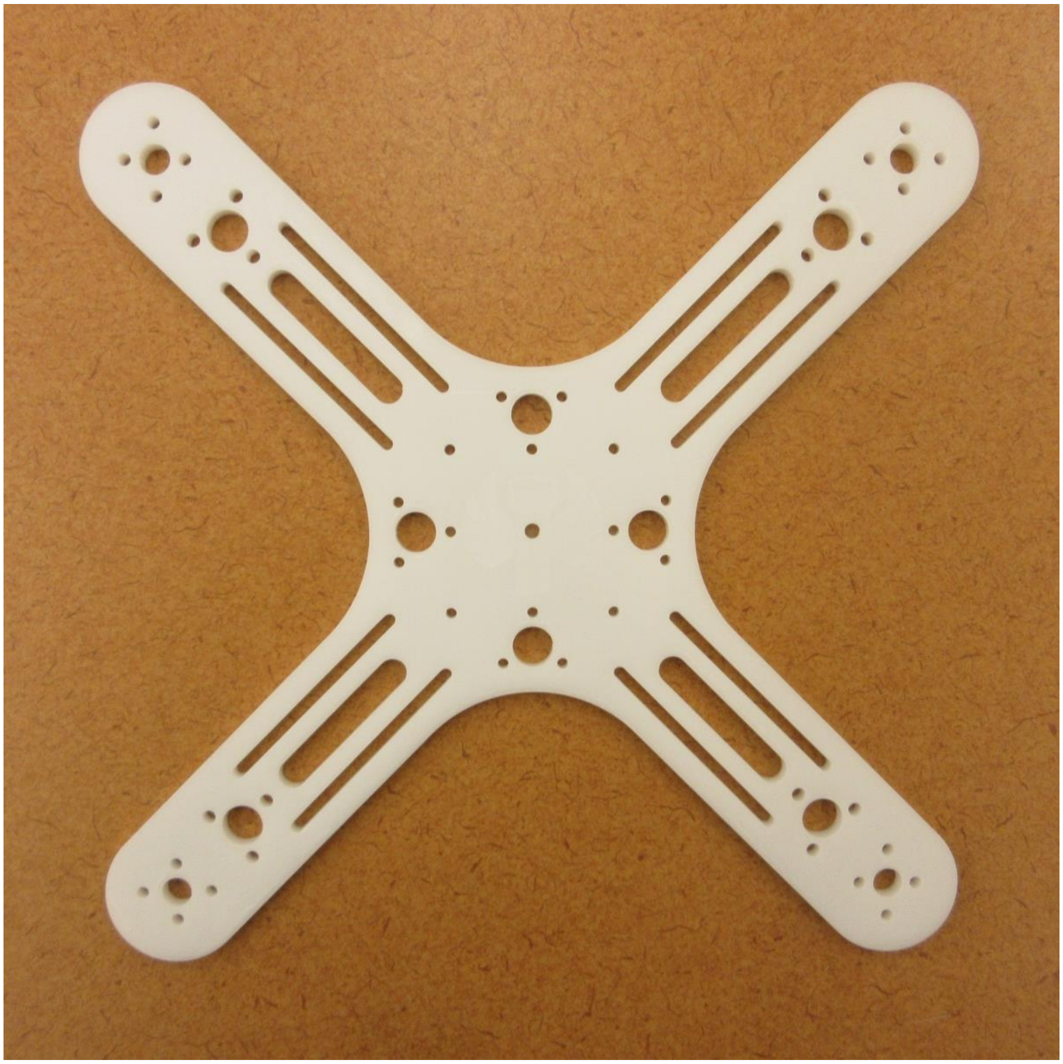
# 5 Conclusions

The driving specifications behind the Flying Flashlight was to design a portable, hands-free, drone based lighting system. Over the course of an academic year we were not able to 100% fulfill each of the design goals. A lighting system is in place and can be programmed for a variety of colors and flash patterns. We have a quadcopter that is tethered with motors that spool under its own power. Flight stability was a limiting factor in being able to finish this project. We were unsuccessful in developing a quadcopter to fly under its own control in a safe and stable manner. The reasoning behind this setback is discussed above in Section 4 Results. As this setback became more apparent throughout the semester, time and resources were drawn to flight control and limited for control box and winch design. If the quadcopter is not able to be flown; a user friendly interface and winch system did not warrant further development. That being said, a winch, tether, and control system exist in various stages and can be completed relatively quickly.

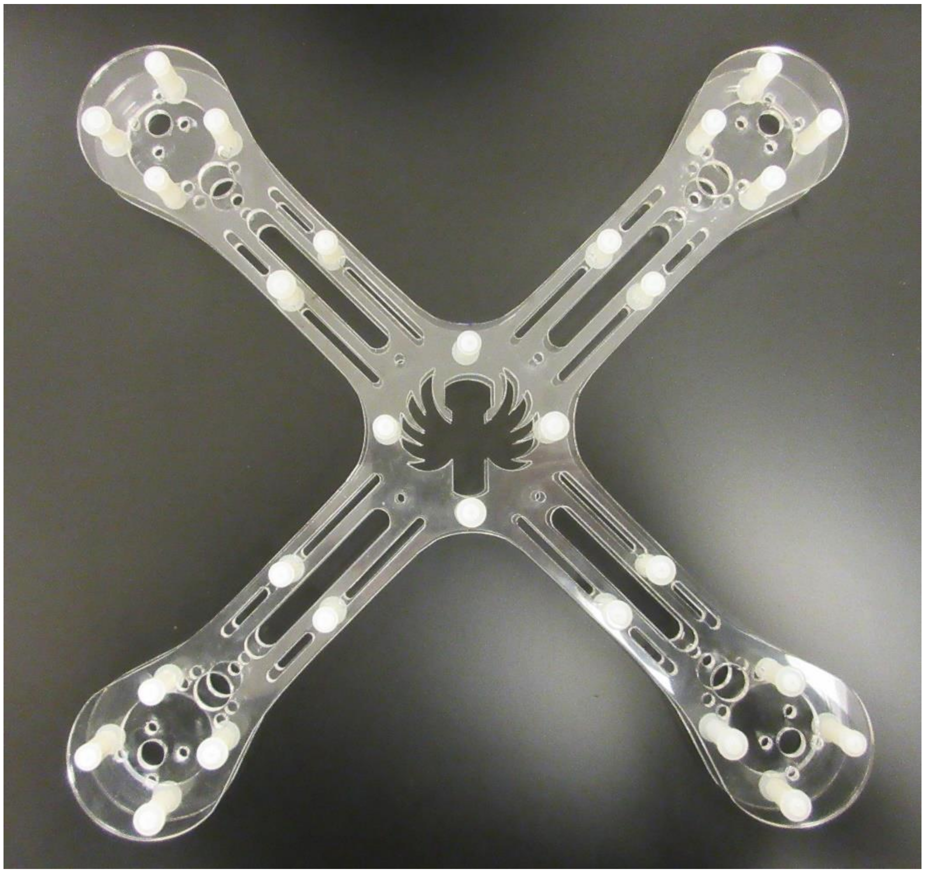
# 6.1 Appendix I: Images



Solid Works Drawing of Original Frame

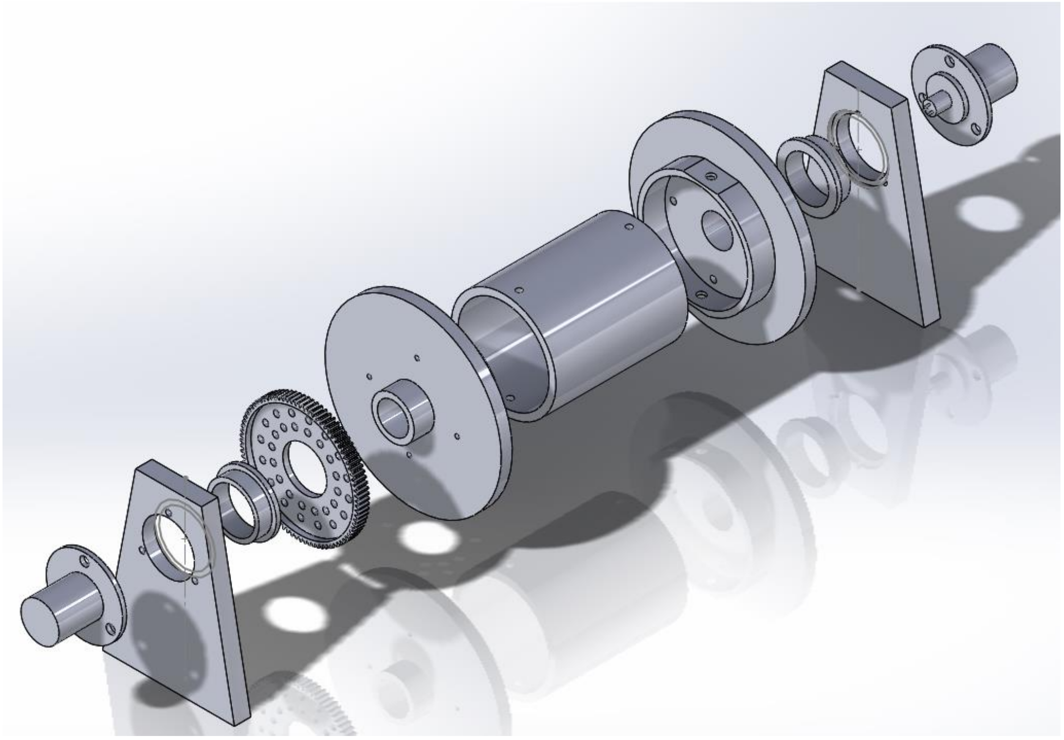


Quarter-Inch Acrylic Laser Cut Chassis.

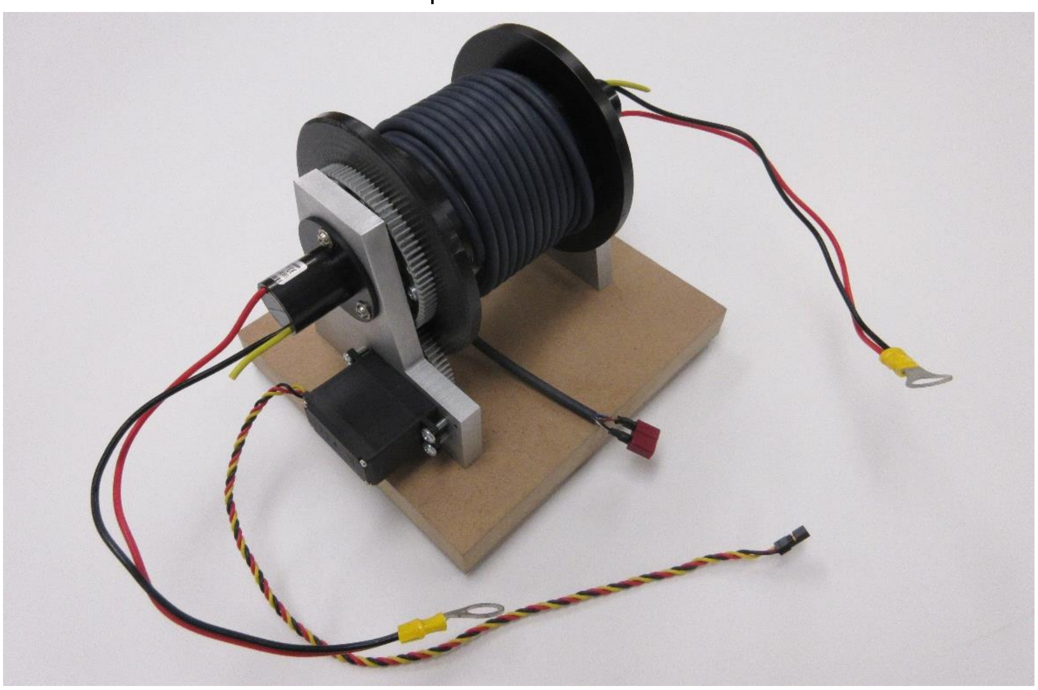


Double Layer Frame

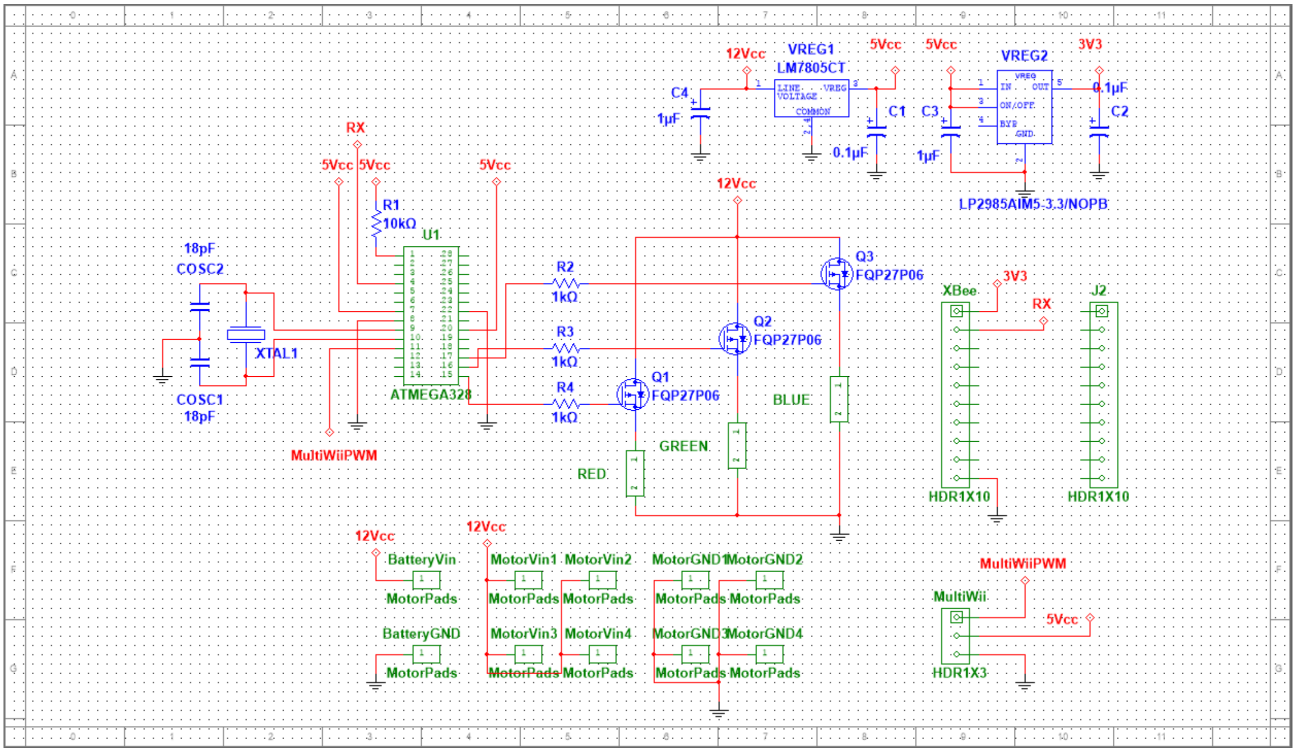
Final Assembled Quadcopter

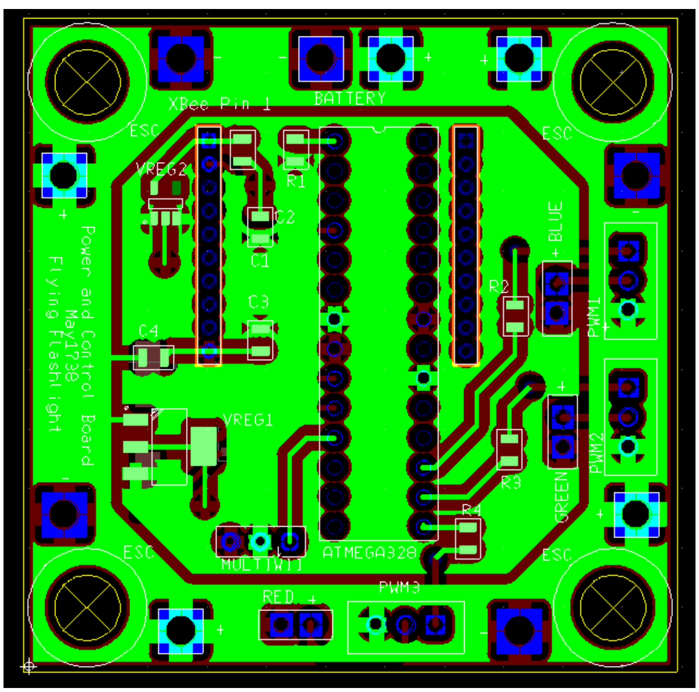


SolidWorks Exploded View of Winch Drum

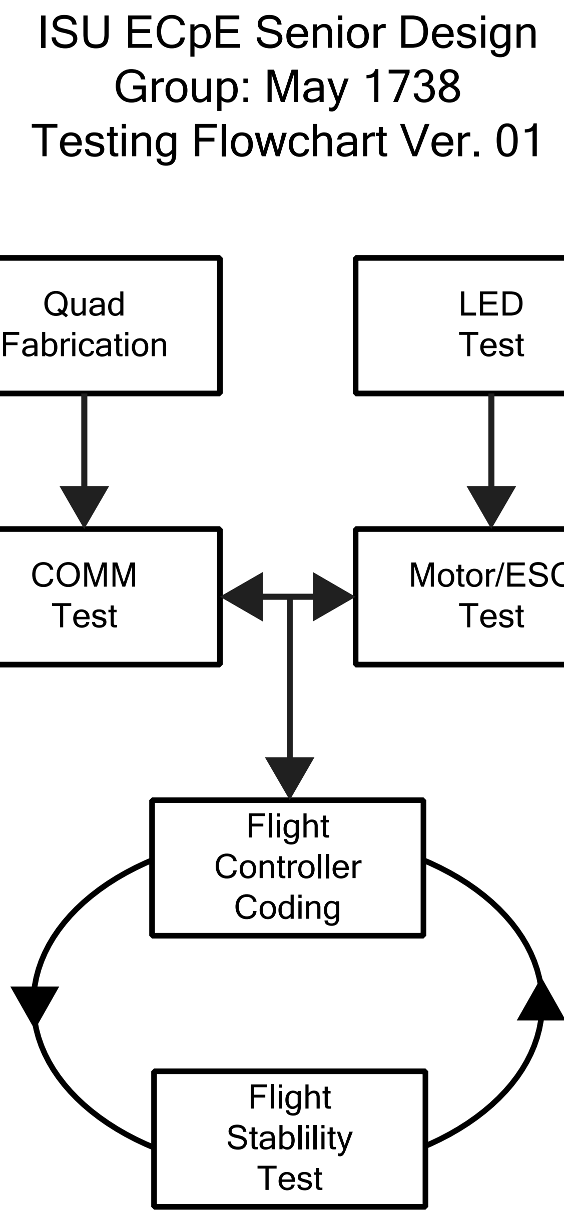


Winch Drum with Servo Motor Attached





Receiver Control Board and Schematic


ISU ECpE Senior Design
Group: May 1738
Testing Flowchart Ver. 01
Quad Fabrication
LED Test
COMM Test
Motor/ESC Test
Flight Controller Coding
Flight Stablility Test

# 6.2 Appendix II: User Manual & Safety Precautions

## Flying Flashlight User Manual

### Initialization Process

1. Place the Flying Flashlight on a level surface.
2. Connect the power cable from the tethering drum to the cable on the Flying Flashlight

    This cable only connects in one direction to prevent reversed polarity.
3. Turn on the power to the tethering drum

    Each of the ESC's on the Flying Flashlight will beep when ready.

    Verify that each of the ESC's is ON by locating the green ON indicator LED.

    Verify that the MultiWii is ON by checking for LED lights on the PCB.

    Verify communication to the Flying Flashlight receiver by turning on the LED lighting system on a DIM setting.

5. Arm the MultiWii using the controller.

    Arm the controller by flipping the enable switch to the ARM position.

    Once the MultiWii is ARMED, a red LED should light and stay lit.

### Flight Operation Process

1. SLOWLY increase the throttle on the controller. Set the servo on the cable drum to RELEASE.

    This allows the drum to spool out cable to the ascending Flying Flashlight.
2. Verify that the Flying Flashlight is ascending directly upward.

    If the Flying Flashlight is not, then decrease the throttle, and refer to the **Flight Tuning** section of this manual.
3. Once the Flying Flashlight has reached the desired height, decrease the throttle until the Flying Flashlight achieves a stable hovering position.

    Turn off the tether drum servo so the drum no longer feeds out more cable.
4. When end of flight is desired, slowly decrease the throttle until the Flying Flashlight begins to descend.

    Set the servo on the cable drum to REEL to reel in the cable as the Flying Flashlight descends.

5. Once the Flying Flashlight has landed, fully decrease the throttle.

Disarm the MultiWii.

Disarm the controller by flipping the enable switch to the DISARM position.

Turn Power off.

### LED Operation Process

Once the Flying Flashlight is in flight, SLOWLY dial in the desired light color using the three potentiometers located on the controller. Each potentiometer independently controls red, green, and blue color intensity.

### Flight Tuning Process

The Flying Flashlight should be tuned out of the box from the manufacturer. In case of undesired flight characteristics, the following process should be followed. Our tuning process is based on the Ziegler-Nichols tuning method.

1. All the below steps refer to the Roll, Pitch, and Yaw settings. Set the PID (Proportional, Integral, and Derivative) values to all zero.
2. Increase the Proportional gain value until the quadcopter has consistent oscillations. Measure the period of one oscillation.
3. Once the desired Proportional gain is found. Decrease it to 60% of its initial value. Ex. If oscillations begin at a value of 10. The final gain should be 6.
4. The value of the integral gain will be half of the period of one oscillations. If the Flying flashlight oscillated with a period of 0.5 seconds. The Integral gain would be 0.25.
5. The derivative gain will be $1/8^{th}$ the value of one oscillation. Ex. If the period of oscillation is 0.5 seconds. The derivative gain will be 0.0625.
6. If trouble persists with the tuning process. Please give us a call and a trained technician will be out to calibrate shortly.

## Safety Precautions

**Do not look directly into the LED lights on the Flying Flashlight. Doing so can cause temporary blindness or induce epileptic symptoms.**

**Keeps hands and face away from the Flying Flashlight during operation. Propeller blades operate at high rates of speed and can cause serious injury. Including but not limited to minor cuts, loss of fingers, or even death.**

# 6.3 Appendix III: Bill of Materials

| Bill of Materials | | | | | |
|---|---|---|---|---|---|
| **Part Description** | **Distributor** | **Distributor Product Number** | **Quantity Ordered** | **Price (per unit)** | **Extended Price** |
| Multistar Elite Motors | Hobby King | 9536000003-0 | 1 | 46.21 | 46.21 |
| Afro Race Spec Mini 20A ESC | Hobby King | 9192000258-0 | 4 | 9.85 | 39.4 |
| Gemfan Propeller (6x4.5) | Hobby King | 329000334-0 | 4 | 2.05 | 8.2 |
| Gemfan Propeller (5x3) | Hobby King | 329000304-0 | 4 | 1.47 | 5.88 |
| | | | | | |
| MultiWii Flight Controller | Ready to Fly Quads | | 1 | 52 | 52 |
| Vollong 3W RGB LEDs | SuperBrightLEDs | VL-H01RGB00302 | 4 | 4.95 | 19.8 |
| | | | | | |
| Arduino Uno Rev. 3 | Digikey | 1659-1000-ND | 2 | 25.38 | 50.76 |
| | | | | | |
| | | | | | **Order Total** |
| | | | | | 222.25 |
| | | | | | |
| | | | | | |
| **Part Description** | **Distributor** | **Distributor Product Number** | **Quantity Ordered** | **Price (per unit)** | **Extended Price** |
| APC 5x3 FPV Thin Electric Propeller (4) | Tower Hobbies | LXFYWL | 1 | 11.79 | 11.79 |
| | | | | | |
| | | | | | **Order Total** |
| | | | | | 11.79 |
| | | | | | |
| | | | | | |
| **Part Description** | **Distributor** | **Distributor Product Number** | **Quantity (ft)** | **Price (per unit)** | **Extended Price** |
| Continuous Flexing Control Cable (20 AWG) | Grainger | 24C082 | 15 | 2.66 | 39.9 |
| Continuous Flexing Control Cable (22 AWG) | Grainger | 24C077 | 15 | 2.36 | 35.4 |
| | | | | | |
| | | | | | **Order Total** |
| | | | | | 75.3 |
| | | | | | |
| | | | | | Summary Total |
| | | | | | 309.34 |

Semester 1 BOM

| Bill of Materials | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. Number** | **Part Description** | **Distributor** | **Distributor Product Number** | **Quantity (per board)** | **Quantity Ordered** | **Price (per unit)** | **Extended price** |
| COSC1,COSC | 18pF Ceramic Capacitor | Digikey | 1276-1107-1-ND | 2 | 10 | 0.044 | 0.44 |
| C3,C4 | 1uF Tantalum Capacitor | Digikey | 478-3050-1-ND | 2 | 6 | 0.46 | 2.76 |
| C1,C2 | 0.1uF Ceramic Capacitor | Digikey | 1276-2448-1-ND | 2 | 10 | 0.033 | 0.33 |
| R2,R3,R4 | 330R Resistor | Digikey | RMCF0805JT330RCT-ND | 3 | 10 | 0.015 | 0.15 |
| R1 | 10K Resistor | Digikey | RMCF0805JT10K0CT-ND | 1 | 5 | 0.015 | 0.075 |
| XTAL1 | 16MHz Crystal | Digikey | 535-9875-6-ND | 1 | 3 | 0.46 | 1.38 |
| U1 | Atmega328 Microcontroller | Digikey | ATMEGA328-PU-ND | 1 | 3 | 1.96 | 5.88 |
| J1,J2 | 2mm 1x10 male to female header pins | Digikey | 952-1354-5-ND | 2 | 6 | 1.49 | 8.94 |
| PWM1-3 | P-Channel MOSFET | Digikey | FQP27P06-ND | 3 | 10 | 1.2 | 12 |
| | | | | | | | Order Total |
| | | | | | | | 31.955 |
| | | | | | | | |
| | | | | | | | |
| **Ref. Number** | **Part Description** | **Distributor** | **Distributor Product Number** | **Quantity (per board)** | **Quantity** | **Price (per unit)** | **Extended Price** |
| | Slip Ring Assembly | Digikey | 1568-1183-ND | | 2 | 29.95 | 59.9 |
| | Sleeve Bearing | McMaster-Car | 6659K53 | | 2 | 5.91 | 11.82 |
| | 84T 32 Pitch Gear | ServoCity | 615226 | | 1 | 12.99 | 12.99 |
| | Servo Shaft Hub | ServoCity | 525122 | | 1 | 9.99 | 9.99 |
| | 48T, 32 Pitch Gear | ServoCity | 615190 | | 1 | 12.99 | 12.99 |
| | HSR-2645CRH Servo | ServoCity | 32645H | | 1 | 31.99 | 31.99 |
| | HS-755MG Servo | ServoCity | 32755S | | 1 | 39.99 | 39.99 |
| | | | | | | | Order Total |
| | | | | | | | 179.67 |
| | | | | | | | |
| | | | | | | | |
| **Ref. Number** | **Part Description** | **Distributor** | **Distributor Product Number** | **Quantity (per board)** | **Quantity** | **Price (per unit)** | **Extended Price** |
| | Xnova Racing Motors (4) | Hobby Haven | X-Nova XN2204-2300 | | 1 | 75.99 | 75.99 |
| | | | | | | | Order Total |
| | | | | | | | 75.99 |
| | | | | | | | |
| | | | | | | | |
| **Ref. Number** | **Part Description** | **Distributor** | **Distributor Product Number** | **Quantity (per board)** | **Quantity** | **Price (per unit)** | **Extended Price** |
| | Threaded Spacer | Digikey | 36-1902A-ND | | 40 | 0.595 | 23.8 |
| | Threaded Spacer | Digikey | 36-1902B-ND | | 40 | 0.609 | 24.36 |
| | Threaded Spacer | Digikey | 36-1902C-ND | | 40 | 0.634 | 25.36 |
| | Non-Threaded Spacer | Digikey | RPC1490-ND | | 40 | 0.2888 | 11.552 |
| | Washer | Digikey | 36-3157-ND | | 50 | 0.0656 | 3.28 |
| | Washer | Digikey | 36-3200-ND | | 50 | 0.0756 | 3.78 |
| | Nut | Digikey | H616-ND | | 100 | 0.105 | 10.5 |
| | Screw | Digikey | H544-ND | | 100 | 0.09 | 9 |
| | Resistor | Digikey | 696-1067-ND | | 10 | 0.805 | 8.05 |
| | Resistor | Digikey | PPC5D18.0CT-ND | | 10 | 1.251 | 12.51 |
| | | | | | | | Order Total |
| | | | | | | | 132.192 |
| | | | | | | | |
| | | | | | | | Summary Total |
| | | | | | | | 419.807 |

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