PROJECT REPORT

On QuadRotor-Aircraft

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Introduction

Our objective for this project was to design and build a quad-rotor aircraft (hereafter referred to as "quadcopter") that was capable of stable flight with manual radio control. More specifically, our goal was to implement an Arduino microcontroller as the quadcopter flight controller, and program this Arduino with our own custom code. While there are many open-source programs that enable Arduino boards to be used as flight controllers, we wanted to develop the code ourselves in order to learn more about what makes quadcopter flight possible.

1. Quadcopter Essentials

Every radio controlled (RC) quadcopter requires, at minimum, the following components: a frame, motors with propellers, motor speed controllers, a battery, a radio receiver, a flight controller, and an attitude sensor. This section will discuss the function of each component, why it is necessary, and what considerations to make when selecting that component.

1.1 Quadcopter Frame

The frame of the quadcopter provides the physical structure for the entire aircraft. It joins the motors to the rest of the aircraft and houses all of the other components. The frame must be large enough to allow all four propellers to spin without collision, but must not be too large and therefore too heavy for the motors. For our quadcopter we chose a DJI f450 Frame Kit as seen in Figure 1, which measures at width: 450mm height: 55mm across opposite motors.

Figure 1

1.2 Motors and Propellers

The motors spin the propellers to provide the quadcopter with lifting thrust. Quadcopters almost exclusively use brushless DC motors, as they provide thrust-to-weight ratios superior to brushed DC motors. However, they require more complex speed controllers.

Motors are typically given two ratings: Kv ratings and current ratings. The Kv rating indicates how fast the motor will spin (RPM) for 1 V of applied voltage. The current rating indicates the max current that the motor may safely draw. For our project, we selected 1000Kv, 12A max A2212 brushless motors (seen in Figure 2).

Figure 2

Figure 3

Propellers come in many sizes and materials. They are measured by their diameter and their pitch, in the format (diameter) x (pitch). Pitch is a measurement of how far a propeller will “travel” in one revolution. Prop selection is important to yield appropriate thrust while not overheating the motors. For our project, we selected 10x4.5 carbon fiber props (Figure 3) drawing 10.2A.

1.3 Speed Controllers

Every motor needs an individual electronic speed controller (ESC for short). These speed controllers accept commands in the form of PWM signals and output the appropriate motor speed accordingly. Every ESC has a current rating, which indicated the maximum current that it may provide the motor without overheating. Appropriate ESCs must be chosen to ensure that they can provide enough current for the motors. We selected 30A ESC for our project (Figure 4), as they are well reviewed for use with quadcopters and have a sufficient current rating.

Figure 4

Figure 5

1.4 Battery

The battery provides electrical power to the motors and all electronic components of the aircraft. Lithium Polymer (LiPo) batteries are used almost exclusively, because they have high specific energy. The capacity rating, in milliamp-hours (mAh) indicates how much current the battery may output for one hour. Discharge rating, indicated by the letter “C”, show how fast the battery may be safely discharged. For this project, we selected 2200mAh 20C battery, seen in Figure 5.

1.5 Radio Receiver

The radio receiver (Rx) receives radio signals from an RC transmitter and converts them into control signals for each control channel (throttle, yaw, roll & pitch). Modern RC receivers operate on a 2.4 GHz radio frequency, while older Rx units often used 72 MHz frequencies. Rx units may have as few as 4 channels, but many have more channels for additional control options. We selected a Flysky Rx Rs-6 Channel receiver for this project, seen in Figure 6.

Figure 6

Figure 7

1.6 Flight Controller

The flight controller is the “brain” of the quadcopter, and performs the necessary operations to keep the quadcopter stable and controllable. It accepts user control commands from the Rx, combines them with readings from the attitude sensor(s), and calculates the necessary motor output. For most hobby quadcopters, one would select a purpose-made flight controller board. These boards often have integrated attitude sensors, and provide well-tested flight control software. For our project however, we used an Arduino Uno (seen in Figure 7) as the flight controller, as we intended to program the flight control software ourselves.

1.7 Attitude Sensor

The attitude sensor provides the flight controller with readings of the quadcopter's orientation in space. At minimum this requires a gyroscope, but most quadcopters also incorporate an accelerometer. For a self-stabilizing quadcopter (such as ours), an accelerometer is required.We have used MPU6050 sensor module.It is a complete 6-axis Motion Tracking Device.It combines 3-axis Gyroscope,3-axis accelerometer and Digital Motion Processor all in a small package.(seen in Figure 8)

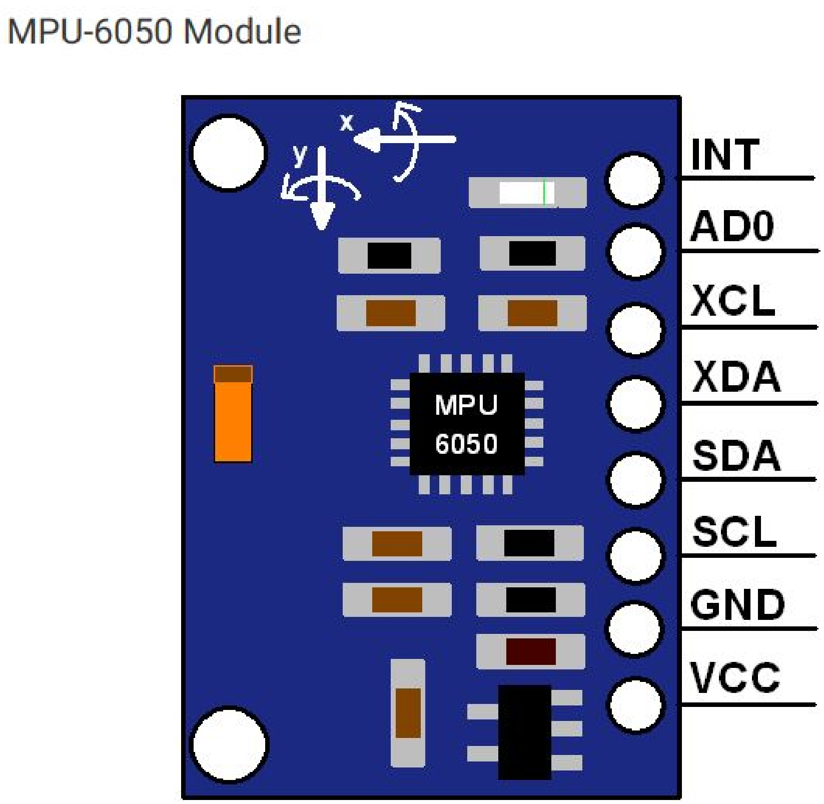


Figure 8

3-Axis Gyroscope

The MPU6050 consist of 3-axis Gyroscope with Micro Electro Mechanical System(MEMS) technology. It is used to detect rotational velocity along the X, Y, Z axes as shown in below figure 9

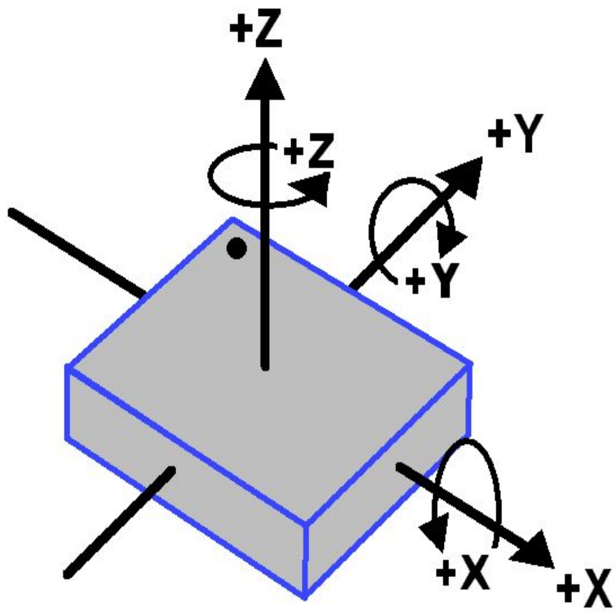


Figure 9

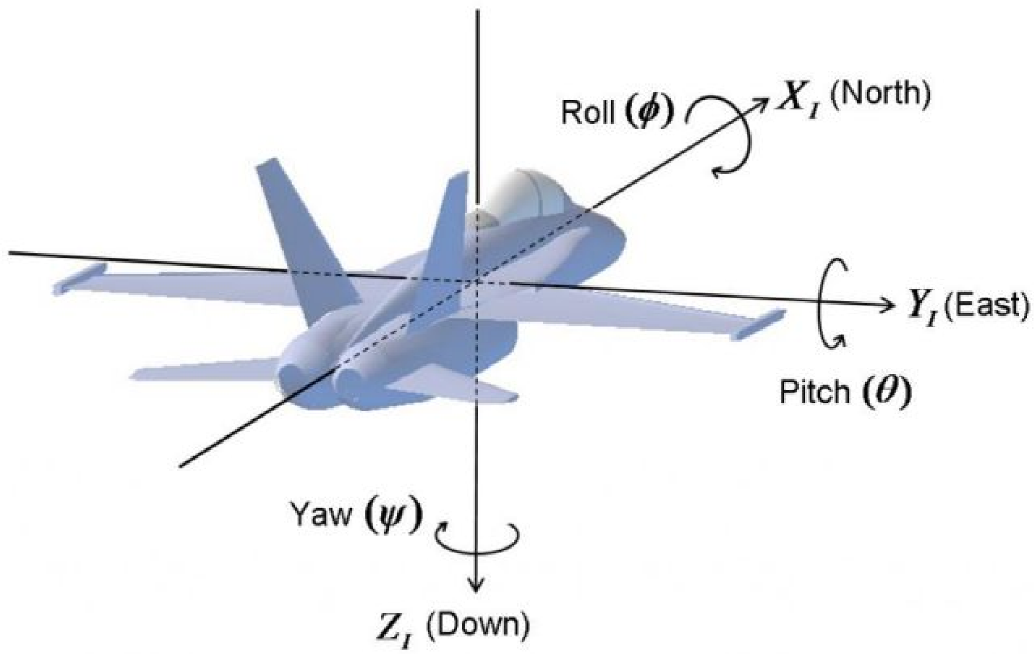
When the gyros are rotated about any of the sense axes, the Coriolis Effect causes a vibration that is detected by a MEM inside MPU6050.

- The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate.
- This voltage is digitized using 16-bit ADC to sample each axis.
- The full-scale range of output are +/- 250, +/- 500, +/- 1000, +/- 2000
- It measures the angular velocity along each axis in degree per second unit.

2. Dynamic System Control

A quadcopter is inherently a very unstable system. Anyone attempting to control a quadcopter with manual inputs only and no attitude sensor integration would quickly find that balancing the aircraft is very nearly impossible. So, to make the quadcopter a stable system, it is important to integrate an attitude sensor and a set of dynamic system controllers.

2.1 Determining Quadcopter Orientation



In order to stabilize the quadcopter, it is first crucial to determine the aircraft orientation (also called attitude) relative to the fixed inertial frame of the earth. This inertial frame is shown in figure, and consists of 3 orthogonal axes (North, East, & Down) and the rotations about these axes (Roll, Pitch, and Yaw).

In order to attain stable flight, the roll and pitch axes must first be stabilized. If these axes are not properly controlled, the quadcopter will immediately tip over and be unable to fly. In the case of our project, this was done using the gyroscope and accelerometer in conjunction .

The yaw axis must also be relatively stable for the quadcopter to be controllable, but is less critical. Slight drift in the yaw axis is easily counteracted using the radio controller, and usually will not result in a loss of control. Using only an accelerometer and gyroscope (as was done in this project), the absolute yaw orientation is in fact not measurable. Only the change in yaw orientation is measurable by using the gyroscope, but this proved to be sufficient to enable control of the quadcopter.

2.2 PID Control

After determining the attitude of the aircraft, it is necessary to implement a dynamic system controller to stabilize the quadcopter at the desired attitude (often simply level). One of the most effective methods of doing so is to implement a proportional, integral and derivative (PID) controller.

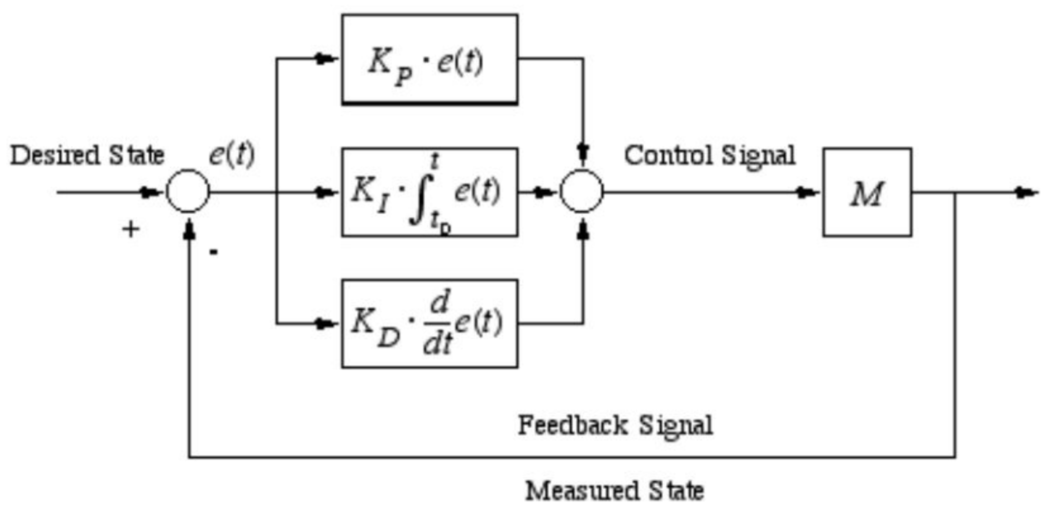


Figure 10

PID control is shown in block diagram form in Figure 10 and is performed in the following steps:

1. The error e(t) is calculated as Set point – Measured State

2. The proportional term P is calculated as Kp · e(t)

3. The integral term I is calculated as KI · (time integral of e(t))

4. The derivative term D is calculated as KD · (time derivative of e(t))

5. The 3 terms are summed to produce the controller output, u(t) = P + I + D

In order to stabilize the quadcopter, a separate PID controller was implemented for the roll, pitch, and yaw axes.

As mentioned in the previous section, an absolute measurement of the yaw axis is not available using only an accelerometer and gyroscope.

So to stabilize the quadcopter about the yaw axis, the PID controller was implemented to control the rate of rotation about the yaw axis.

PID control only produces desired performance when the three control gains, {Kp KI KD} are properly selected. The process of selecting these parameters is referred to as "tuning" the PID.

PID gain and limit settings

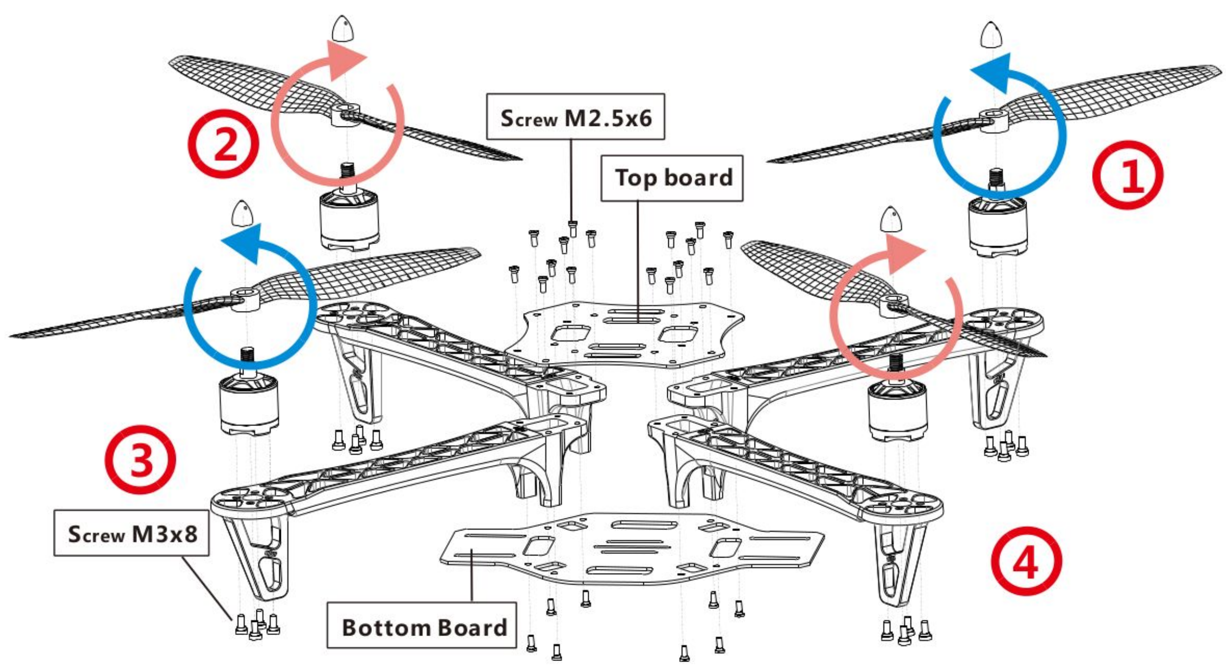
```
float pid_p_gain_roll = 1.3;         //Gain setting for the roll P-controller
float pid_i_gain_roll = 0.04;        //Gain setting for the roll I-controller
float pid_d_gain_roll = 18.0;        //Gain setting for the roll D-controller
int pid_max_roll = 400;              //Maximum output of the PID-controller
(+/-)

float pid_p_gain_pitch = pid_p_gain_roll;     //Gain setting for the pitch
                                              P-controller.
float pid_i_gain_pitch = pid_i_gain_roll;     //Gain setting for the pitch
                                              I-controller.
float pid_d_gain_pitch = pid_d_gain_roll;     //Gain setting for the pitch
                                              D-controller.
int pid_max_pitch = pid_max_roll;             //Maximum output of the
                                              PID-controller (+/-)
```

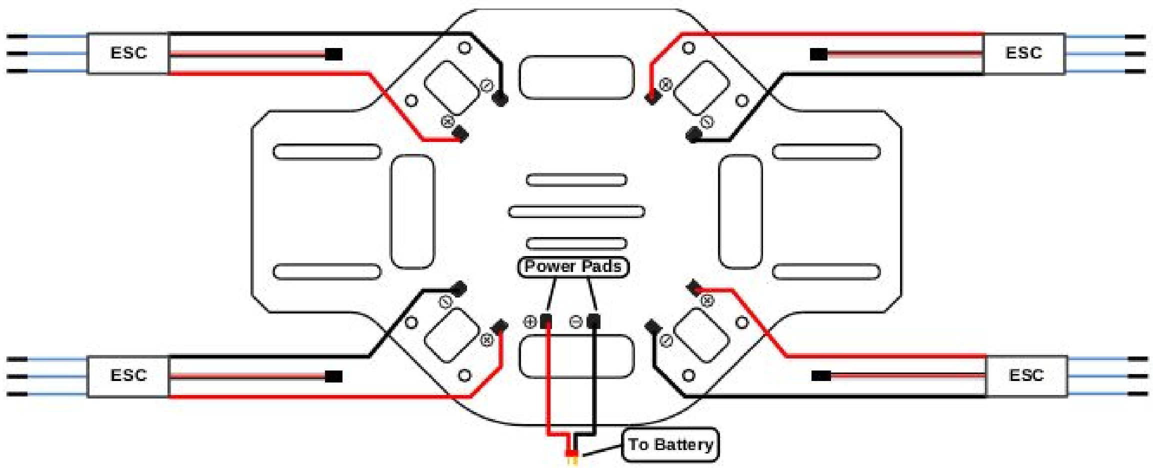
2.3 WORKING PRINCIPLE

Quadcopter generally use two pairs of identical fixed pitched propellers; two clockwise (CW) and two counter-clockwise (CCW). These use independent variation of the speed of each rotor to achieve control. By changing the speed of each rotor it is possible to specifically generate a desired total thrust.Each rotor produces both a thrust and torque about its center of rotation, as well as a drag force opposite to the vehicle's direction of flight. If all rotors are spinning at the same angular velocity, with rotors one and three rotating clockwise and rotors two and four counterclockwise, the net aerodynamic torque, and hence the angular acceleration about the yaw axis, is exactly zero, which mean there is no need for a tail rotor as on conventional helicopters. Yaw is induced by mismatching the balance in aerodynamic torques (i.e., by offsetting the cumulative thrust commands between the counter-rotating blade pairs).

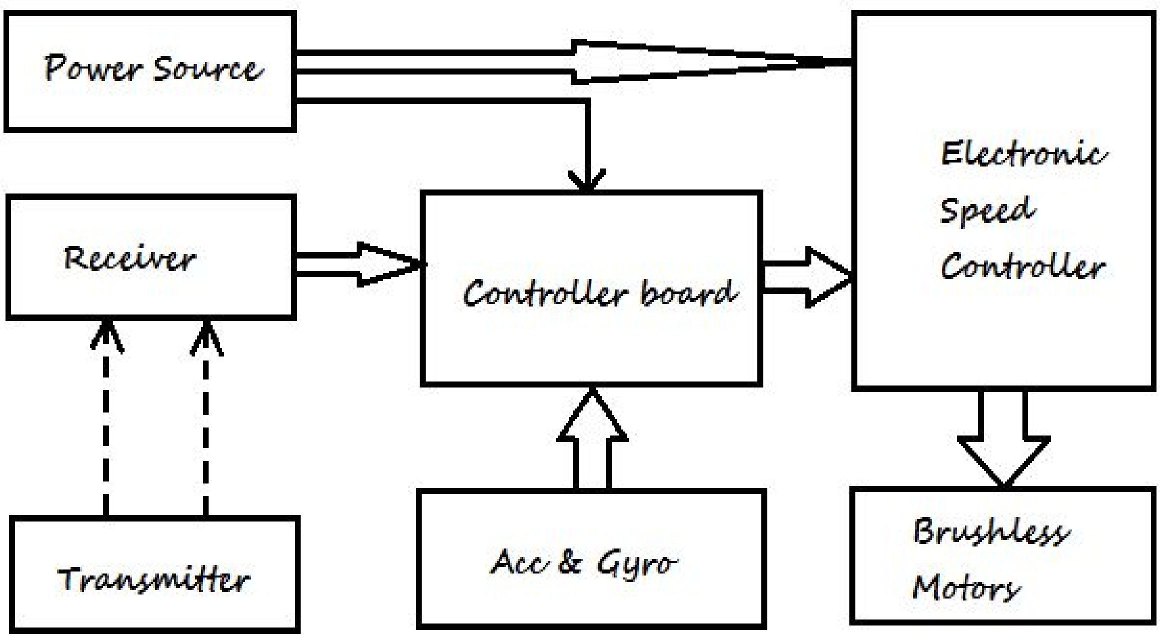
3.Basic Designing of Quadcopter



3.1 ESC Wiring



3.2 Basic Block Diagram:



3.3 Schematic Diagram

4.Bill of Materials

Purchased for Project			
Item	**Qty**	**Price(each)**	**Sum**
DJI F450 QUADCOPTER FRAME KIT	1	Rs.800	Rs.800
A2212 1000KV BRUSHLESS MOTORS	4	Rs.370	Rs.1480
30A BRUSHLESS MOTOR ESC	4	Rs.370	Rs.1480
1045 PROPELLER 10 inch 10X4.5	4	Rs.100	Rs.400
MPU-6050 6DOF 3-AXIS GYRO WITH ACCELEROMETER SENSOR MODULE	1	Rs.180	Rs.180
FLYSKY FS-CT6B 2.4G 6CH RADIO SET SYSTEM WITH RX FS-RS6B RECEIVER	1	Rs.2950	Rs.2950
ARDUINO UNO	1	Rs.450	Rs.450
LITHIUM POWER BATTERY 12V 2200mah WITH CHARGER	1	Rs.2300	Rs.2300
TOTAL	17	-	Rs.10,040

5.References

- FlameWheel 450 User Manual
- How To Read an RC Receiver With A Microcontroller http://rcarduino.blogspot.co.uk/2012/01/how-to-read-rc-receiver-with.html
- A Guide To Using IMU (Accelerometer and Gyroscope Devices) in Embedded Applications. .http://www.starlino.com/imu_guide.html

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