CHAPTER ONE

Introduction

1.1 General Concepts

The world is looking for the most helpful things and tools in humans' life. One of these things is vehicles. During different years the human tried to develop vehicles. Among these, recently human developed unmanned or remotely controlled vehicles for various applications to meet different needs.

The main reasons for using and developing remote control vehicles is first : To replace the humans place when doing a hard work to do . or doing tasks may pose a risk for human. Second : If any bad thing or dangerous happened while doing that work (fire , wind, …ect) , the only part that will affected is the robot (remote control vehicle). True there will be a cost and loss , but it do not compare with human safety and his life .Third : with the evolution of technology and science , it will be easy to develop these vehicles to improve its performance to meet more requirement that humans may need in the future.

1.2 problem statement

Commonly Most scientists, researchers , journalist or photographers face a lot of problems and difficulties in collecting data and taking pictures or recording videos in dangerous places and crowded areas that considered risky for the human (like battle fields, volcanoes , caves, toxic gases .Wires cannot reach these places so another way must be considered for direct broadcasting. Planes cannot be used in narrow places and unreachable ones .

1.3 Objectives

The goal of this project is to design a multi rotor vehicles that has the ability to take of and landing safety, beside doing other tasks like broadcasting video.

- ✓ General objective: The general objective is to make a conceptual and practical design of a multi-role vehicle called Quad copter .
- ✓ Specific objectives:
- ❖ Conducting a conceptual design of the quad copter .
  - ➢ Calculating length of the frame .
  - ➢ Chose the right material .
  - ➢ Choosing the right components .
  - ➢ Testing the component specifications (voltages , amps , watts, …)
  - ➢ Math weight of frame and total component to meet specifications and need .
- ❖ Conducting a practical design of the quad copter .
  - ➢ Design the frame , weighting it .
  - ➢ Weighting each component .
  - ➢ Match the total real weight with the conceptual weight.
  - ➢ Testing the component specifications (multi meter) .
  - ➢ choosing PID gains .
  - ➢ match the conceptual design and the practical design

1.4 Methodology

The project can be made by designing a Calculated dimensional structure or frame . And a Multi-Rotor controller , it is a flight control board for multi-rotor aircraft (Tri copters, Quad copters, Hex copters etc). Its purpose is to stabilize the aircraft during flight. To do this it takes the signal from the gyroscope/accelerometer (roll, pitch and yaw) then passes the signal to the processor. The processing unit processes these signals according the users selected firmware and passes control signals to the installed Electronic Speed Controllers (ESCs). These signals instruct the ESCs to make fine adjustments to the motors rotational speed which in turn stabilizes your multi-rotor craft. The camera that been implanted in the craft record video and been sent wirelessly to TV connected with receiver.

1.5 Project Lay out

The project consists of five chapters , Chapter one demonstrate the problems statement and the objectives of the project beside methodology . Chapter two talks about the main concepts of the project such as flight controller and brush less motors. Chapter three shows the components of the project and its use. Chapter four demonstrates the functions and operation of the drone. Chapter five contains the conclusion and recommendations in addition to the references and appendences.

CHAPTER TWO

General Information

2.1 Introduction

A remote control machine is needed to collect in difficult environments. Air planes can be controlled remotely but cannot be used in some places .Hovering crafts are the best choice commonly .The Most popular craft is quad copter . in this chapter quad copter will be described in general and its components.

2.2 Quad Copter

A quad-copter called a quad-rotor helicopter or quad rotor is a multi-rotor helicopter that is lifted and propelled by four rotors. Quad-copters are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors (vertically oriented propellers). Unlike most helicopters, quad-copters use two sets of identical fixed pitched propellers; two Clock Wise (CW) and two Counter-Clock Wise (CCW). These use variation of RPM to control lift and torque. Control of vehicle motion is achieved by altering the rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics, And The quad-copter is one of the most complex flying machines due to its versatility and maneuverability to perform many types of tasks. Classical quad-copters are usually equipped with a four rotors. Our specific project is concerned with the design and control of a miniature rotorcraft, known as a quad-copter.

Quad-copters are symmetrical vehicles with four equally sized rotors at the end of four equal length rods , Each of the rotors on the quad-rotor helicopter produces both thrust and torque. Given that the front and rear motors both rotate counter-clockwise and the other two rotate clockwise,there for the aerodynamic torque will be zero, as seen in Figure(2.1).

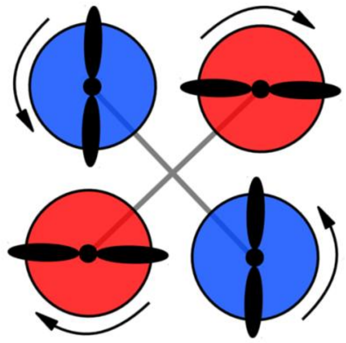


Figure2.1: Quad-copter propellers direction and aerodynamic torque

2.2.1 Comparison between the helicopter and the quad copter

A quad-copters is a multi-copter that is lifted and propelled by four rotors. Quad-copters are classified as rotorcraft. Quad-copter is a vertical takeoff and landing vehicle as the helicopter but it has several advantages over helicopter: First, quad-copters do not require mechanical linkages to vary the rotor blade pitch angle as they spin. This simplifies the design and maintenance of the vehicle. Second, the use of four rotors allows each individual rotor to have a smaller diameter than the equivalent helicopter rotor, allowing them to possess less kinetic energy during flight .This reduces the damage caused should the rotors hit anything. Some small-scale quad-copters have frames that enclose the rotors, permitting flights through more challenging environments, with lower risk of damaging the vehicle or its surroundings.

2.2.2 Quad-rotors Literature Review

Quad-copter is a vertical takeoff and landing vehicle. Quad-copter is used for military and civilian purposes. A number of manned designs appeared in the 1920s and 1930s. These vehicles were among the first successful heavier-than-air Vertical Take Off and Landing (VTOL) vehicles.

However, early prototypes suffered from poor performance, and latter prototypes required too much pilot work-load, due to poor stability augmentation and limited control authority. More recently Quad-copter designs have become popular in unmanned aerial vehicle (UAV) research.

2.3 Quad-Copter Systems and Parts

Quad-copter systems has many parts and explained as flow

2.3.1 Battery

battery is an electrochemical cell (or enclosed and protected material) that can be charged electrically to provide a static potential for power or released electrical charge when needed . A battery generally consists of an anode, a cathode, and an electrolyte.

Common types of commercial batteries and some of their characteristics and advantages are summarized in the following table(2.1). Battery types not shown include the Zinc-Air, Flooded Lead Acid, and Alkaline batteries.

Table 2.1 : Type of battery

Battery Type	Characteristics	Typical Uses	Advantages
Sealed Lead Acid (SLA) battery	Can hold a charge for up to 3 years	Backup emergency power source	Inexpensive
Nickel-Cadmium (Ni-Cd) battery	Fast, even energy discharge	Appliances, audio and video equipment, toys; most popular batter	Relatively inexpensive; widely available
Nickel-Metal Hydride (Ni-MH) battery	Typical power capacity i1.2 V - 1200 to 1500 mAh; extended life 2300 mAh; 2.5 to 4 hours battery life	Portable computers;cellular phones; same as for Ni-Cd batteries	No memory effect; unused capacity remains usable
Lithium Ion (Li-Ion) battery	Stable and safe; highest energy capacity	Portable computers; cellular phones; same as for Ni-Cd batteries	Twice the charge capacity of Ni-Cd; slow self-discharge

And battery Electricity , as you probably already know, is the flow of electrons through a conductive path like a wire. This path is called a *circuit*.

Batteries have three parts, an anode (-), a cathode (+), and the electrolyte. The cathode and anode (the positive and negative sides at either end of a traditional battery) are hooked up to an electrical circuit as shown in figure(2.2).

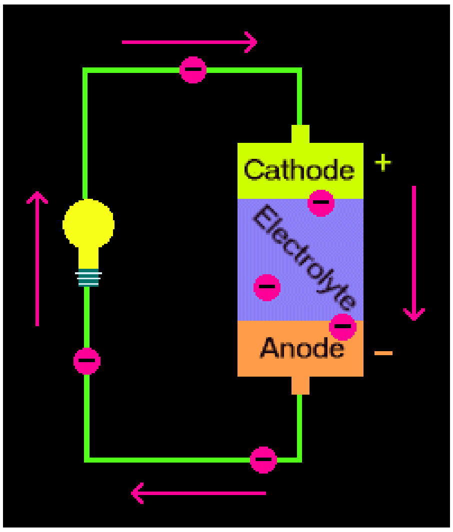


Figure2.2: Battery circuit

The chemical reactions in the battery causes a build up of electrons at the anode. This results in an electrical difference between the anode and the cathode. You can think of this difference as an unstable build-up of the electrons. The electrons wants to rearrange themselves to get rid of this difference. But they do this in a certain way. Electrons repel each other and try to go to a place with fewer electrons. In a battery, the only place to go is to the cathode. But, the electrolyte keeps the electrons from going straight from the anode to the cathode within the battery. When the circuit is closed (a wire connects the cathode and the anode) the electrons will be able to get to the cathode. In the picture above, the electrons go through the wire, lighting the light bulb along the way. This is one way of describing how electrical potential causes electrons to flow through the circuit.

However, these electrochemical processes change the chemicals in anode and cathode to make them stop supplying electrons. So there is a limited amount of power available in a battery. When you recharge a battery, you change the direction of the flow of electrons using another power source, such as solar panels. The electrochemical processes happen in reverse, and the anode and cathode are restored to their original state and can again provide full power .

2.3.2 Motors

An electric motor is an electrical machine that converts electrical energy into mechanical energy. The reverse of this would be the conversion of mechanical energy into electrical energy and is done by an electric generator , the main constructions of any motor can listed as shown .

- ✓ **Rotor**

In an electric motor the moving part is the rotor which turns the shaft to deliver the mechanical power. The rotor usually has conductors laid into it which carry currents that interact with the magnetic field of the stator to generate the forces that turn the shaft. However, some rotors carry permanent magnets, and the stator holds the conductors.

- ✓ **Stator**

The stator is the stationary part of the motor's electromagnetic circuit and usually consists of either windings or permanent magnets. The stator core is made up of many thin metal sheets, called laminations. Laminations are used to reduce energy losses that would result if a solid core were used.

Figure 2.3 : Electric motor rotor (left) and stator (right)

- ✓ **Airgap**

In between the rotor and stator is the air gap. The air gap has important effects, and is generally as small as possible, as a large gap has a strong negative effect on the performance of an electric motor.

- ✓ **Windings**

Windings are wires that are laid in coils, usually wrapped around a laminated soft iron magnetic core so as to form magnetic poles when energized with current.

- ✓ **Commutator**

A commutator is a mechanism used to switch the input of most DC machines and certain AC machines consisting of slip ring segments insulated from each other and from the electric motor's shaft. The motor's armature current is supplied through the stationary brushes in contact with the revolving commutator, which causes required current reversal and applies power to the machine in an optimal manner as the rotor rotates from pole to pole ,In absence of such current reversal, the motor would brake to a stop. In light of significant advances in the past few decades due to improved technologies in electronic controller, sensorless control electromechanically commutated motors are increasingly being displaced by externally commutated induction and permanent-magnet motors.

- ✓ **Motorsupply**

A DC motor is usually supplied through slip ring commutator as described above. AC motors' commutation can be either slip ring commutator or externally commutated type, can be fixed-speed or variable-speed control type, and can be synchronous or asynchronous type. Universal motors can run on either AC or DC .

General classification of motors :

There are two main kind of magnets :

- ❖ Permanent magnets.
- ❖ Electro magnets.

Table (2.2) shows motor classifications

Rotor	**Stator**	**Applications**
Electromagnet	Electromagnet	• Induction motors • Universal motors
Electromagnet	Permanent magnet	Brushed DC motors
Permanent magnet	Electromagnet	• BLDC motors • Stepper motors
Permanent magnet	Permanent magnet	Not possible to build a motor .

Motors are the starting point when calculating flight stability and control. The motors chosen should meet the following objectives:

- ➢ Lightweight.
- ➢ High speed and torque.
- ➢ Cost effective.
- ➢ PWM speed controlled.
- ➢ Synchronized.

After a deep search to find the motor that achieves specifications mentioned earlier. Brushless motor is the best options available.

2.3.3 Control system

Include the following parts

✓ RC system

Radio system include Sending and receiving parts (radio transmitter and receiver TX & RX) : which send and receive signals via radio waves.

Everyone has seen waves on the surface of water. You made them in the bathtub when you were small, All of you have listened to radio waves from your favorite radio stations. All waves have certain things in common. Let's look at Figure (2.4)below to learn more about the parts of wave .

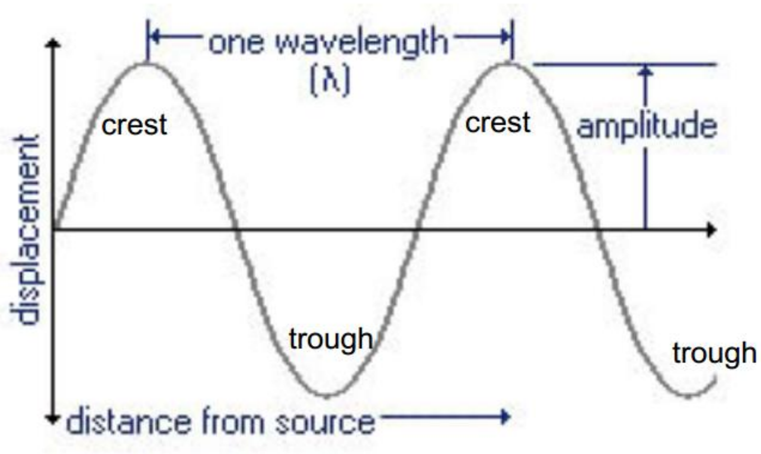


Figure 2.4 :The parts of wave

All waves have crest(high points), troughs(low points), a wave length(the distance from one crest to another or one trough to another), amplitude(the height of a crest or trough), and a frequency (the number of complete wave lengths that pass a given point in a second.) When we talk about frequency Waves that we see and make in water are mechanical waves, as are sound waves. Both require stuff or a medium to travel through. The sound waves that you hear when someone speaks push air that hits your eardrum. The compressions of the wave cause a vibration on your eardrum, which you translate into sound This sound can be speech, music, or simply noise. The media that water waves travel in is not surprisingly, water. Mechanical waves can switch media that they are traveling in. For, when a wave crashes on the beach we can hear it or if music is played really, really loud it can vibrate walls. However mechanical waves always need something to travel in. There is another group of waves called electromagnetic waves that can travel in certain media and in a vacuum .

✓ Electromagnetic waves

Electromagnetic waves have the same characteristic parts as mechanical waves (e.g., wavelength, amplitude, frequency ،etc), but they behave very differently. Sound waves travel in air at a speed of approximately 344 meters/second, while electromagnetic waves travel at the speed of light 300000000meters/second). While mechanical waves (something to move in e.g., air or water, electromagnetic waves can travel in a vacuum Another important characteristic of electromagnetic waves is that they will travel in a straight line unless something changes their course (e.g., think of a laser beam).

Electromagnetic waves have many uses and enormous range of frequencies , and they are very effective in sending and receiving informations. The radio waves are one part of many parts of Electromagnetic waves the sending part is called a transmitter and the receiving part called the receiver.

✓ Flight control board

A flight controller is a circuit board that reads sensors data and user commands, and makes adjustment to the motor speed, in order to keep the multirotor balanced and in control . All multicopter flight controllers have Gyro (Gyroscopes) and Acc (Accelerometer) these days, some more advanced FC even have Barometer (barometric pressure sensors), magnetometer (compass) and GPS. For example the gyroscopes is for orientation, the barometers is for holding altitudes, while the GPS can also be used for auto-pilot or fail-safe purposes.

While many flight controllers have similar hardware or sensors, they have very different software and calculation algorithms, which results in different flight characteristics, and user interface. That's why the same multicopter flies and feels differently with different flight controller insalled.

There are so many flight controllers available at the moment on the market. Some of them are more expensive, while some are richer in functionality. Some have been around a long time, while some are just cheaper clone of others .

✓ PID

PID (proportional-integral-derivative) is a closed-loop control system that try to get the actual result closer to the desired result by adjusting the input. Quadcopters or multicopters use PID controller to achieve stability.

The error is the amount at which your device is not doing something right. For example, if your robot is going 3 mph but you want it to go 2 mph, the error is 3 mph-2 mph = 1 mph. Or suppose your robot is located at x=5 but you want it at x=7, then the error is 2. A control system cannot do anything if there is no error – think about it, if your robot is doing what you want, it would not need control!

➢ The effect of each parameter

The variation of each of these parameters alters the effectiveness of the stabilization. Generally there are 3 PID loops with their own PID coefficients, one per axis, so you will have to set P, I and D values for each axis (pitch, roll and yaw). To a quad-copter, these parameters can cause these behavior.

❖ Proportional Gain coefficient

your quad-copter can fly relatively stable without other parameters but this one. This coefficient determines which is more important, human control or the values measured by the gyroscopes. The higher the coefficient, the higher the quadcopter seems more sensitive and reactive to angular change. If it is too low, the quadcopter will appear sluggish and will be harder to keep steady. You might find the multicopter starts to oscillate with a high frequency when P gain is too high.

- **Integral Gain coefficient**

this coefficient can increase the precision of the angular position. For example when the quadcopter is disturbed and its angle changes 20 degrees , in theory it remembers how much the angle has changed and will return 20 degrees. In practice if you make your quadcopter go forward and the force it to stop, the quadcopter will continue for some time to counteract the action. Without this term, the opposition does not last as long. This term is especially useful with irregular wind, and ground effect (turbulence from motors). However, when the I value gets too high your quadcopter might begin to have slow reaction and a decrease effect of the Proportional gain as consequence, it will also start to oscillate like having high P gain, but with a lower frequency.

- **Derivative Gain coefficient**

this coefficient allows the quadcopter to reach more quickly the desired attitude. Some people call it the accelerator parameter because it amplifies the user input. It also decrease control action fast when the error is decreasing fast. In practice it will increase the reaction speed and in certain cases an increase the effect of the P gain.

❖ Simplification

Rarely will you need the integral term so you can just delete and ignore it. The only time you will need this term is when acceleration plays a big factor with your robot. If your robot is really heavy, or gravity is not on it’s side (such as steep hills), then you will need the integral term. Control without the integral term is commonly referred to as simply PD control.

- ❖ There are also times when you do not require a derivative term, but usually only when the device mechanical stabilizes itself, works at very low speeds so that overshoot just does not happen, or you simply do not require good precision.

2.3.4 Electronic speed controllers (ESCs)

An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor. Most modern ESCs incorporate a battery eliminator circuit (or BEC) to regulate voltage for the receiver, removing the need for separate receiver batteries. BECs are usually either linear or switched mode voltage regulators. DC ESCs in the broader sense are PWM controllers for electric motors. The ESC generally accepts a nominal 50 Hz PWM servo input signal whose pulse width varies from 1 ms to 2 ms. When supplied with a 1 ms width pulse at 50 Hz, the ESC responds by turning off the DC motor attached to its output. A 1.5 ms pulse-width input signal drives the motor at approximately half-speed. When presented with 2.0 ms input signal, the motor runs at full speed.

The correct phase varies with the motor rotation, which is to be taken into account by the ESC: Usually, back EMF from the motor is used to detect this rotation, but variations exist that use magnetic (Hall Effect) or optical detectors. Computer-programmable speed controls generally have user-specified options which allow setting low voltage cut-off limits, timing, acceleration, braking and direction of rotation. Reversing the motor's direction may also be accomplished by switching any two of the three leads from the ESC to the motor. We note that there are three wires that go between the motor and the ESC. These motors are three phase motors, meaning there are three coils inside. The coils are energized in sequence to make the motors spin. So the ESC's job is to energize the coils in sequence, but it needs to time each energization correctly so the motor can actually accelerate to the right speed. The ESC has a microcontroller inside that turns on or off the coils using FETs and also determines timing by measuring the feedback in the coils caused by the movement of the magnets.

2.3.5 Frame

In considering the frame, the first consideration is the material to be used. It must be lightweight, sturdy, and affordable. The forces which act on the aircraft primarily will be gravity and air pressure. Gravity allows for construction under the guidance of a limited mass to allow for structural stability on the ground, as well as control of the copter in the air. Air pressure, which is used to determine the airspeed, will affect the quad-copter’s stress on the screws at higher altitudes. The higher the altitude, the lighter the air, the smaller the forces against the frame, which implies the copter’s frame, is being stretched. This is what is kept in mind when considering for the base material for our aircraft. For the project, three materials are possibilities due to their popularity in the RC World: wood, aluminum and plastic.

2.3.6 Propellers

Quad copters uses two clockwise(CW) and two counter-clockwise(CCW) propellers. Propellers are classified by length and pitch. For example 9×4.7 propellers are 9 inch long and has a pitch of 4.7.

Generally, increased propeller pitch and length will draw more current. Also the pitch can be defined as the travel distance of one single prop rotation. In a nutshell, higher pitch means slower rotation, but will increase your vehicle speed which also use more power.

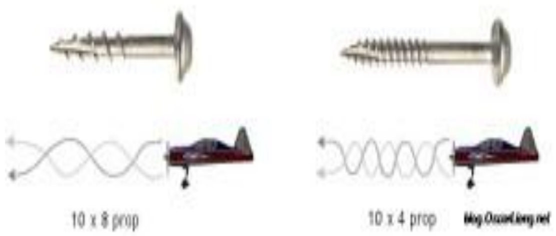


Figure 2.5 : propellers length and pitch

✓ comparison between high pitch and low pitch props

Generally a prop with low pitch numbers can generate more torque. The motors don’t need to work as hard so it pulls less current with this type of prop. If you want to do acrobatics, you will need torque propellers which provide more acceleration and it puts less pressure on the power system. Lower pitch propellers will also improve stability. A higher pitch propeller moves greater amount of air, which could create turbulence and cause the aircraft to wobble during hovering. If you notice this with your quadcopter, try to choosing a lower pitched propeller .

✓ comparison between small length and large length props

When it comes to the length, propeller efficiency is closely related to the contact area of a prop with air, so a small increase in prop length will increase the propeller efficiency. (pretty much like swimmers with larger hands and feet can swim faster, but also more tiring for them) . A smaller prop is easier to stop or speed up while a larger prop takes longer to change speeds (inertia of movement). Smaller prop also means it draws less current, that is why hexa-coptors and octa-copters tend to use smaller props than quad-copter of similar size.

Increased propeller pitch and length will draw more current and the high current effect on the motors and increase their heat quickly, High KV motors need small props to work efficiently, Low KV motors need a large props to work efficiently. If you put a large propeller on a high KV motor ,it will draw a lot of current and become so hot quickly , If you put a small propeller on a low KV motor , it will pull a small weight and decrease stability.

With a well balanced motor and propeller combination, your quadcopter should achieve great efficiency, not only improve battery life time, but also allows great user control experience.

2.4 Quad-Copter Movements

Before we take a look on the physics, it is important to understand how a quad-copter moves and how we can control it.

We first have to define :

2.4.1 Quad-copter flight dynamics

Flight dynamics is the science of air vehicle orientation and control in three dimensions. The three critical flight dynamics parameters are the angles of rotation in three dimensions about the vehicle's center of mass, known as roll, pitch and yaw . Each one of the three parameters is oriented around one of the three axes x, y and z . as shown in figure(2.6)

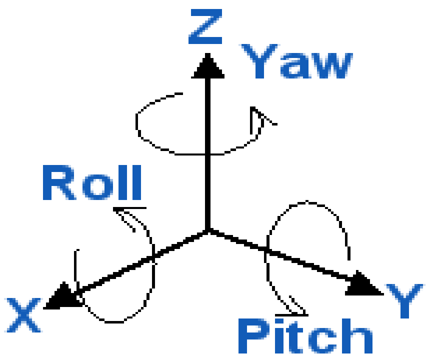


Figure 2.6 : Yaw, pitch and roll around x, y and z axes

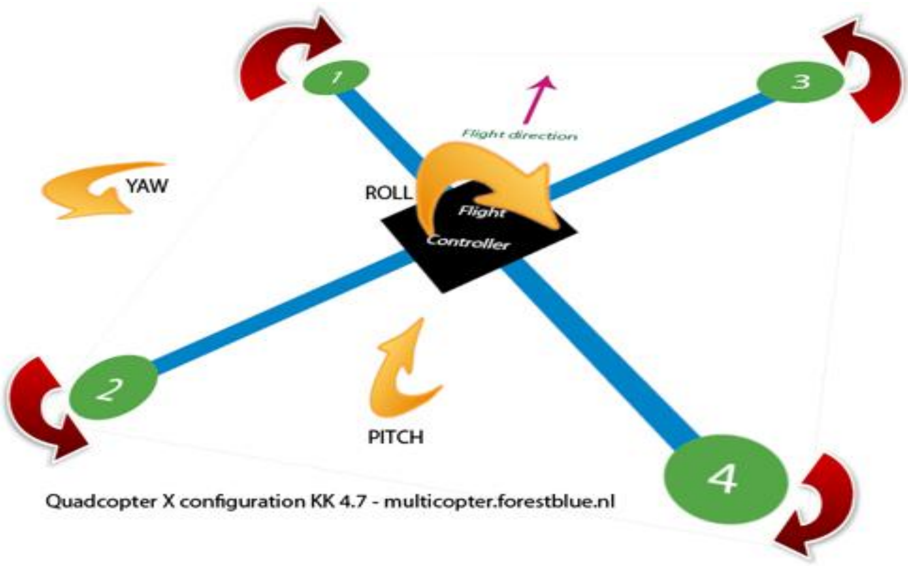


Figure 2.7 : Yaw, pitch and roll on the quad-copter

The main movements of the quadcopter can be summarized as follows:

2.4.2 Roll , Pitch ,Yaw and Throttle

Pitch and roll angles are generated with different speed of opposed rotors. To move the quad-copter upward (throttle), the speed of every motor is increased. The tricky part is the yaw angle. If every rotor would turn in the same direction, the quad-copter would start turning around the z axis (like a helicopter without a rear rotor). Therefore rotation directions are configured as seen in figure (2.8).

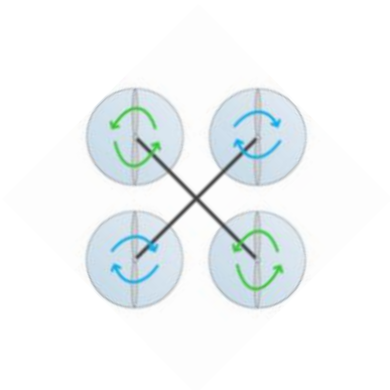


figure (2.8) : Rotor Direction.

2.4.3 Hovering

For hovering a balance of forces is needed. The picture below shows such a situation. If we want the quad-copter to hover, **SUM(F_i)** must be equal **m•g** (where **m** is the mass of the quad-copter, **g** the gravity acceleration and **F_1 - F_4** the forces of the motors). For this simple example we assume all motors are equal and have the same force. So if **SUM(F_i)** is smaller then **m•g** than the quad-copter is declining, if it is greater, it is climbing.

SUM(F_i) >m•g<=> climb

SUM(F_i) = m•g<=> hover

SUM(F_i) <m•g<=> decline

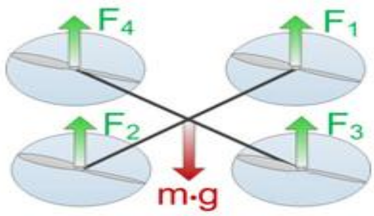


Figure 2.9 : Balance of Power while hovering.

2.4.4 Tilting

Now let us take a look on what is happening when we tilt the quad-copter. Figure 2.10 shows such a situation. For simplification only two of the four rotors are shown. We see that the force is divided in two different parts. **F_{L1}** and **F_{L2}** are the part of the force used to lift the quad-copter. **F_{T1}**and **FT_2** represents the part used for the translation. It is obvious that the lift part becomes smaller with increasing **φ**.

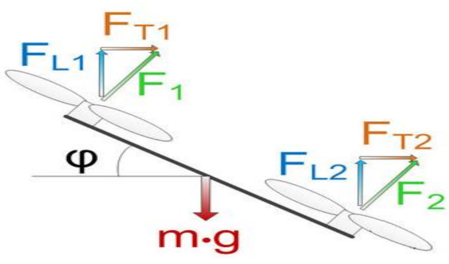


Figure 2.10 : Force Distribution for Tilting.

2.4.5 Configurations

There are two configurations for quad-copter motors positioning (X) configuration and (+) configuration .

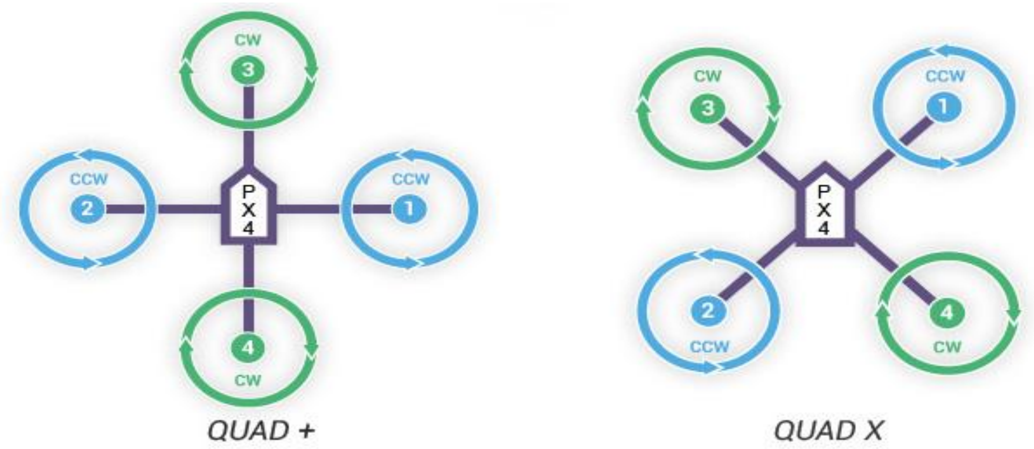


Figure (2.11): Quad-copter x & + configuration [22]

The main motions that the vehicle should perform are front, back, left and right.

✓ **For the (x) configuration**

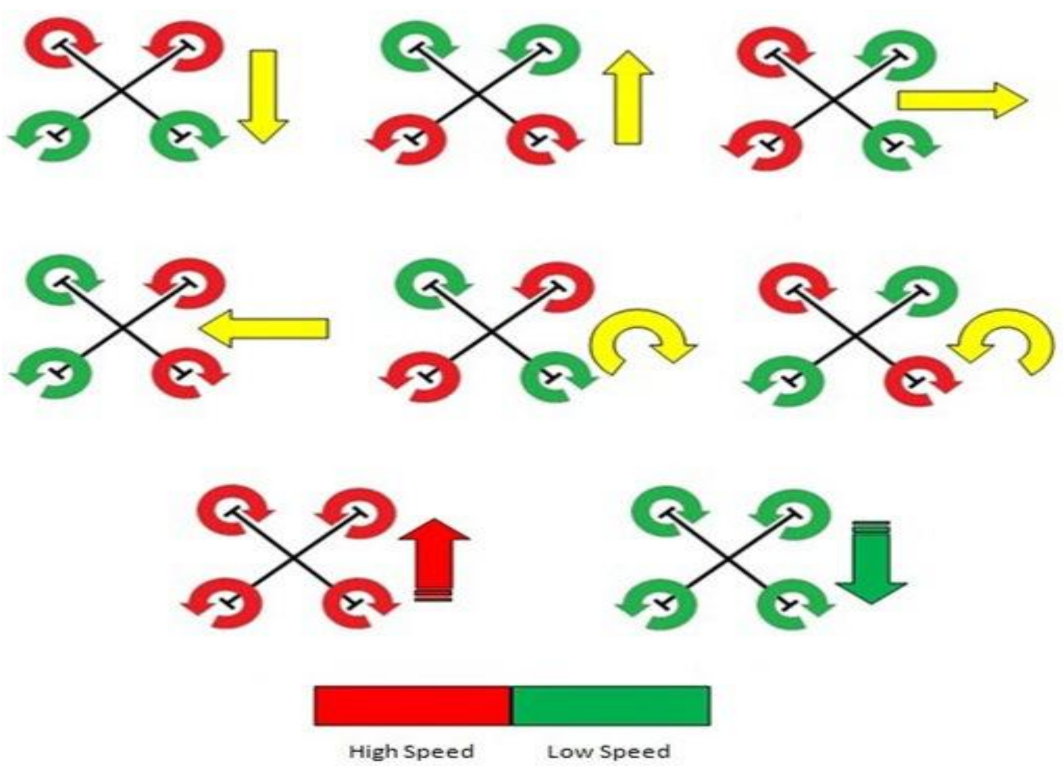


Figure 2.12 : X configuration motions

✓ **For the (+) configuration**

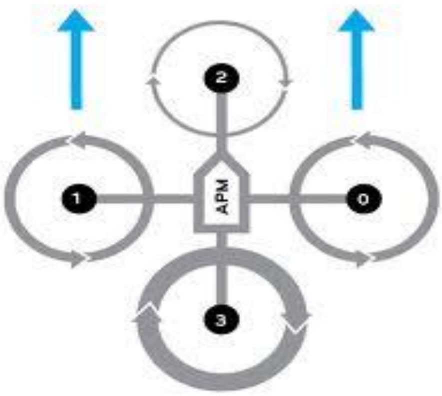


Figure 2.13: (+) Configuration

go forword

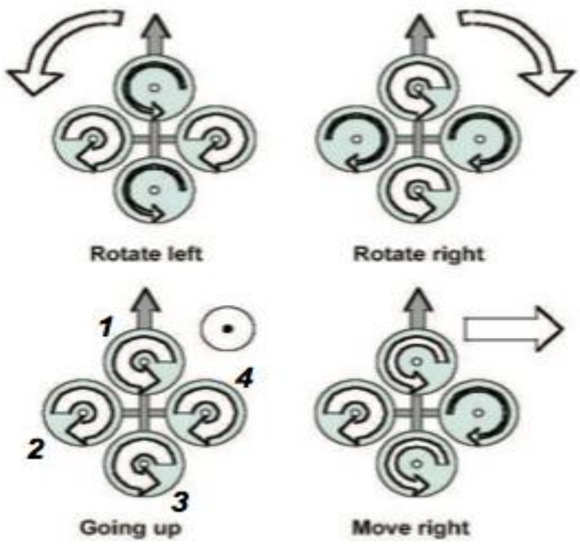


Figure 2.14 : (+) Configuration

Rotate left, right, going up and move right

CHAPTER THREE

Components and Connection

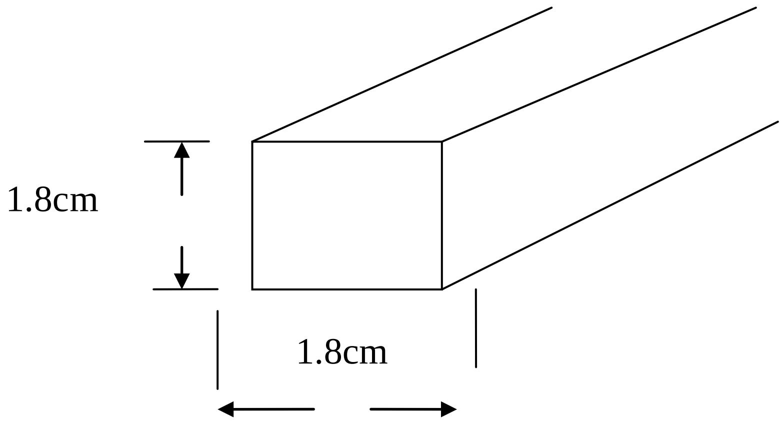
3.1 Introduction

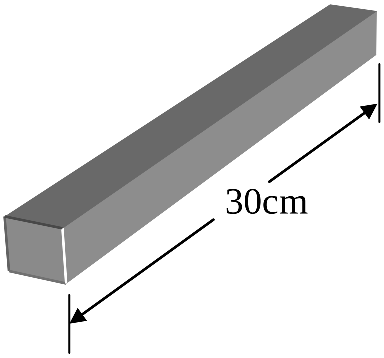
In this chapter we discuss the component of the quad copter specifically with its design, its way of work and mechanism. Also the connection and the assembly of all component will be described.

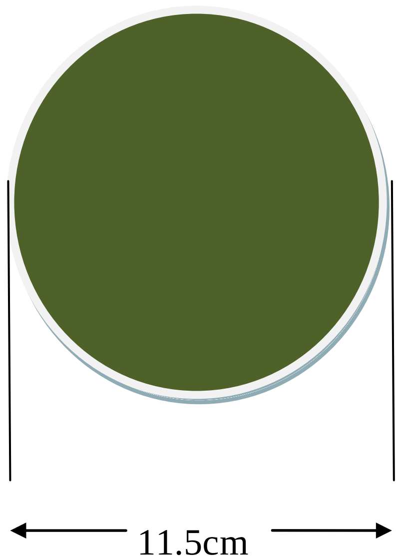
3.2 Frame

wood was the best choice. With wood, test flights can be performed repeatedly , And modifications can be easily made on it . Furthermore, due to its increased strength to stress, wood is less likely to bend due to take-off or stable flight; also, it carries a stronger stability to the frame. wood is less weight from the other material to meet the minimum quad-copter requirements. The lightweight frame must be designed to support all the quad-copter subsystems. So a prototype frame was designed with a 11.5 circle square wood central plate with four 30cm wood struts which are shown next .

- **Frame dimensions**







3.3 The controller(KK2.1.5)

The next evolution of the rotor revolution is here!! The KK2.1.5 is packing new found power with updated sensors, memory and header pins. The KK2.1.5 is next big evolution of the first generation KK flight control boards. The KK2.1.5 was engineered from the ground up to bring multi-rotor flight to everyone, not just the experts. The LCD screen and built in software makes install and setup easier than ever. A host of multi-rotor craft types are pre-installed, simply select your craft type, check motor layout/propeller direction, calibrate your ESCs and radio and you're ready to go! All of which is done with easy to follow on screen prompts!

The original KK gyro system has been updated to an incredibly sensitive 6050 MPU system making this the most stable KK board ever and allowing for the addition of an auto-level function. At the heart of the KK2.1.5 is an Atmel Mega644PA 8-bit AVR RISC-based microcontroller with 64k of memory. An additional polarity protected header has been added for voltage detection, so no need for on-board soldering. A handy piezo buzzer is also included for audio warning when activating and deactivating the board. The KK2.1.5 added polarity protection to the voltage sense header and a fuse protected buzzer outputs, in case something is accidentally plugged in incorrectly. The voltage sense line has been updated for better accuracy. The board is clearly labeled and the voltage sense line color has been changed to red for easy identification, making installation and connections a snap. The 6 Pin USBasp AVR programming interface ensures future software updates will be quick and easy.

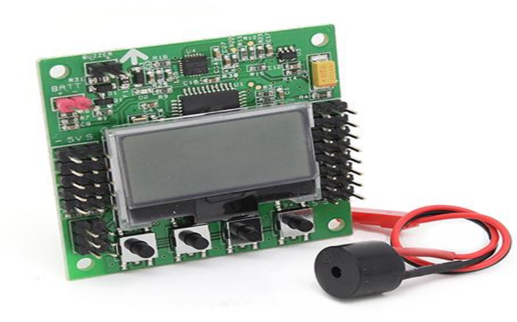


Figure 3.1: KK2.1.5

Specifications

The Specifications of KK2.1.5 is

- **Size:** 50.5mm x 50.5mm x 12mm
- **Weight:** 21 gram (Inc Piezo buzzer)
- **IC:** Atmega644 PA
- **Gyro/Acc:** 6050MPU InvenSense Inc.

- **Auto-level:** Yes
- **Input Voltage:** 4.8-6.0V.
- **AVR interface:** standard 6 pin
- **Signal from Receiver:** 1520us (5 channels)
- **Signal to ESC:** 1520us

The pins identification as shown below:

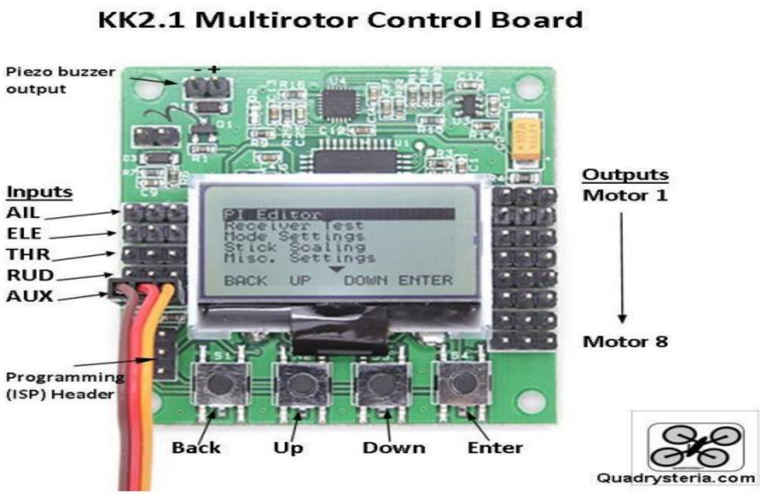


Figure3.2: pins identification

3.4 Lithium-Polymer Battery Series

Lithium-polymer batteries offer a variety of significant advantages over NiCd, NiMH and Li-Ion batteries for use in R/C electric devices. It is very important to have a good understanding of the operating characteristics of LiPo batteries - especially how to charge and care for them safely. Always read the specifications printed on the battery's label and this instruction sheet in their entirety prior to use. Failure to follow these instructions can quickly result in severe, permanent damage to the batteries and its surroundings and even start a FIRE!Before and after every use of your LiPo battery, inspect all cells in the pack as much as possible to ensure no physical damage or swelling is evident. Such signs can often indicate a dangerous problem exists with the battery that could lead to failure.

➢ Turnigy batteries

Turnigy batteries are known the world over for performance, reliability and price. It’s no surprise to us that Turnigy Lipoly packs are the go-to pack for those in the know. Turnigy batteries deliver the full rated capacity at a price everyone can afford.

Turnigy batteries are equipped with heavy duty discharge leads to minimise resistance and sustain high current loads. Turnigy batteries stand up to the punishing extremes of aerobatic flight and RC vehicles. Each pack is equipped with gold plated connectors and JST-XH style balance connectors. All Turnigy Lipoly batteries packs are assembled using IR matched cells.

You won’t find a better deal in Lipoly batteries anywhere!

We choose :

4000mah-3S-30C lipo back

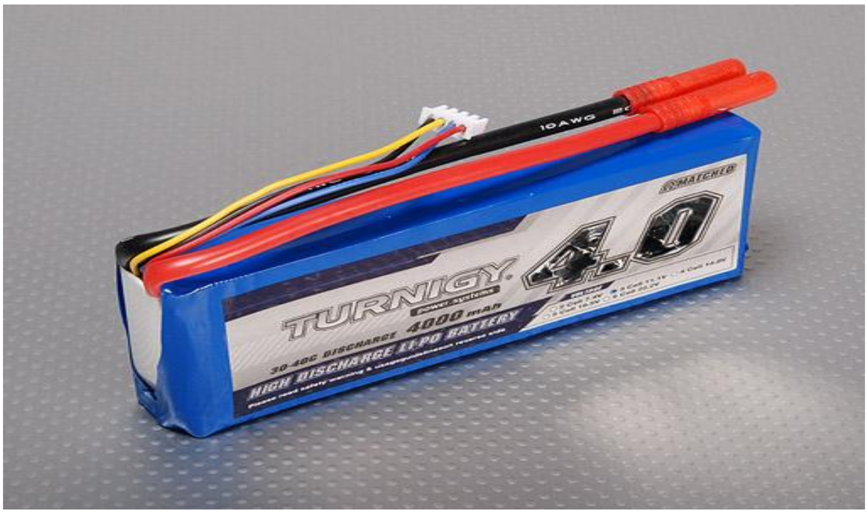


Figure 3.3 :Electric motor rotor (left) and stator (right)

Specifications

The Specifications of the battery is

- Minimum Capacity: **4000mAh**
- Configuration: **3S1P / 11.1v / 3Cell**
- Constant Discharge: **30C**
- Peak Discharge (10sec): **40C**
- Pack Weight: **347g**
- Pack Size: **144 x 50 x 22mm**
- Charge Plug: **JST-XH**
- Discharge plug: **4mm Bullet-conn**

- **Voltage Cells**

The first thing to talk about is the battery's voltage. While the batteries exact voltage may not be printed on the battery itself but it will tell how many cells the battery has. LiPo batteries are made up of cells. Each cell is 3.7 volts. for example the battery shown above is a 3s battery. This means that is has 3cells, which would give it a total voltage of

3.7x 3 = 11.1 v .

3.5 Electronic speed controller(Brushless ESC 40A)

This is a solid Electronic Speed Controller (ESC),shows in Figure (3.4), ideal for use with our quad-copter. It can support a max of 40 Amp continuous output to handle both large and small motors. We use this ESC with our Configuration to perform a throttle calibration with all motors at once with our quad-copter.

Figure 3.4 :Brushless ESC 40A.

Specifications

The Specifications of Esc is

- Cont Current: 40A
- Burst Current: 55A
- BEC Mode: Linear
- BEC : 5v / 3A
- Lipo Cells: 2-6
- NiMH : 5-18
- Weight: 33g
- Size: 55x28x13mm

3.6 Brushless Motor

After we discuss the motor at general . here we choose a specific type which is called brushless DC motor .

The brushless motor, unlike the DC brushed motor, has the permanent magnets glued on the rotor. It has usually 4 magnets around the perimeter. The stator of the motor is composed by the electromagnets, usually 4 of them, placed in a cross pattern with 90 degrees angle between them. The major advantage of the brushless motors is that, due to the fact that the rotor carries only the permanent magnets, it needs of NO power at all. No connection needs to be done with the rotor, thus, no brush-commutator pair needs to be made! This is how the brushless motors took their name from. This feature gives the brushless motor great increasment in reliability, as the brushes wear off very fast. Moreover, brushless motors are more silent and more efficient in terms of power consumption.

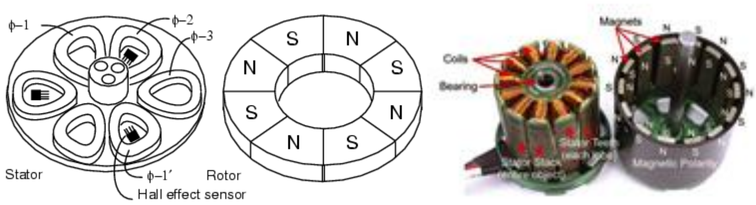


Figure 3.5 : Brushless DC motor main part

✓ Advantages

- ❖ Brushless motors offer several advantages over brushed DC motors, including high torque to weight ratio, more torque per watt (increased efficiency), increased reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator .
- ❖ High Speed Operation – A BLDC motor can operate at speeds above 10,000 rpm under loaded and unloaded conditions.
- ❖ Responsiveness & Quick Acceleration – Inner rotor Brushless DC motors have low rotor inertia, allowing them to accelerate, decelerate, and reverse direction quickly.
- ❖ High Power Density – BLDC motors have the highest running torque per cubic inch of any DC motor.

Any BLDC motor has two primary parts; the rotor, the rotating part, and the stator, the stationary part. Other important parts of the motor are the stator windings and the rotor magnets .There are two basic BLDC motor designs: **inner rotor and outer rotor design** .as shown in figure(3.6).

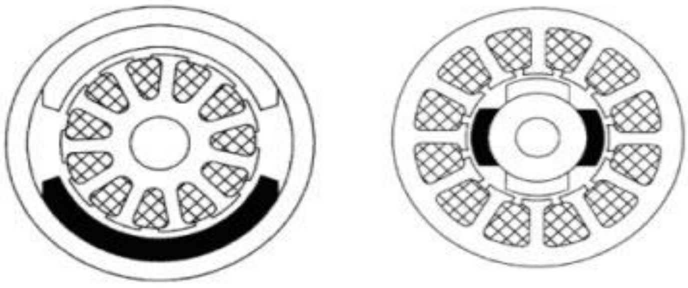


Figure 3.6 : BLDC motor designs

In an outer rotor design, the windings are located in the core of the motor. The rotor magnets surround the stator windings as shown here. The rotor magnets act as an insulator, thereby reducing the rate of heat dissipation from the motor. Due to the location of the stator windings, outer rotor designs typically operate at lower duty cycles or at a lower rated current. The primary advantage of an outer rotor BLDC motor is relatively low cogging torque. In an inner rotor design, the stator windings surround the rotor and are affixed to the motor's housing as shown here. The primary advantage of an inner rotor construction is its ability to dissipate heat. A motor's ability to dissipate heat directly impacts its ability to produce torque. For this reason, the overwhelming majority of BLDC motors use an inner rotor design. Another advantage of an inner rotor design is lower rotor inertia .

3.6.1 Instructure and the method of work

The stator comprises steel laminations, slotted axially to accommodate an even number of windings along the inner periphery. The rotor is constructed from permanent magnets with from two-to-eight N-S pole pairs. The BLDC motor's electronic commutator sequentially energizes the stator coils generating a rotating electric field that 'drags' the rotor around with it. Efficient operation is achieved by ensuring that the coils are energized at precisely the right time. brushless motors have no commutator nor brushes. Thus, there is actually no way of knowing where each time the rotor is. BLDC motors use one of two methods to achieve this, either employing Hall sensors or measuring back EMF.

❖ Hall effect sensor method

BLDCs use pairs of Hall sensors while most of them use just one Hall sensor. . The Hall sensor is placed in an appropriate position. It can sense if in front of it is the North or the South pole. The Hall sensor will then transmit this signal to the controller of the motor. The controller will then switch on or off the appropriate coils needed in order to provide the torque. And that's the way it goes...

The **Hall sensor** that is attached to the stator. It faces the magnets perpendicularly and can distinguish if the North or South pole is in front of it. The following image Figure(3.7) shows this Hall senor. The photo is taken from a PC fan.

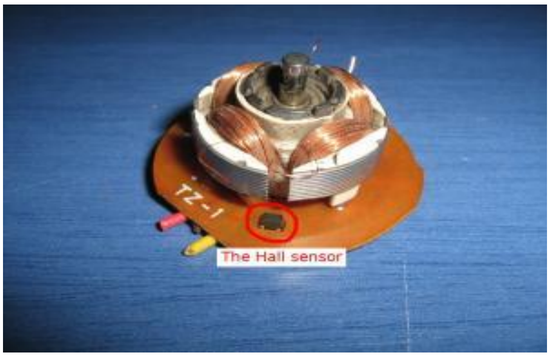


Figure 3.7: Hall effect sensor

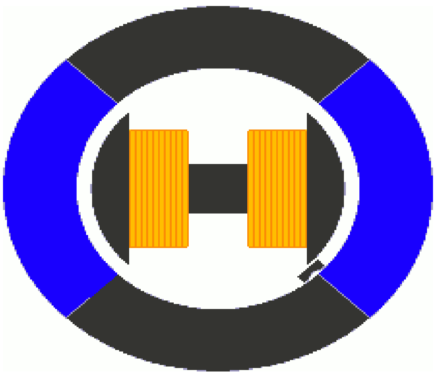


Figure 3.8 : Hall effect sensor position

❖ Sensorless BLDCs , BEMF method

Using a Hall sensor will result in an increase of the overall price of the motor. Moreover, there are situations that a sensor cannot be used, as for example in submersible pumps, or in applications where the wiring must be kept to minimum. In such applications, the sensorless BLDC can be used instead. The operation of such motor is based on the BEMF effect. The BEMF (**B**ack **E**lectro-**M**agnetic **F**orce) is inducted by the movement of a permanent magnet in front of a stator coil .There are two problems that must be solved for the proper operation of the motor. First of all, the rotation direction. As no sensor is used, the controller cannot know where the rotor is stopped at any time. Thus, the rotation direction that the motor will start is -at least for the first degrees of rotation- coin toss. The other problem is the zero detection. The controller does not know when to change the polarity of the coils, as there is no sensor to sense when the permanent magnet pole crosses a specific point.

There are special designed controller chips to solve these problems. The chips will use the characteristics of the BEMF and the voltage generated on the coils from the BEMF effect. For example, the current produced on a coil due to BEMF will change its polarity, if the rotation of the permanent magnet is changed. Also, the amplitude of the produced waveform is proportional to the speed of the rotors, and the phase of the waveform depends on the position of the permanent magnet in respect to the coil.

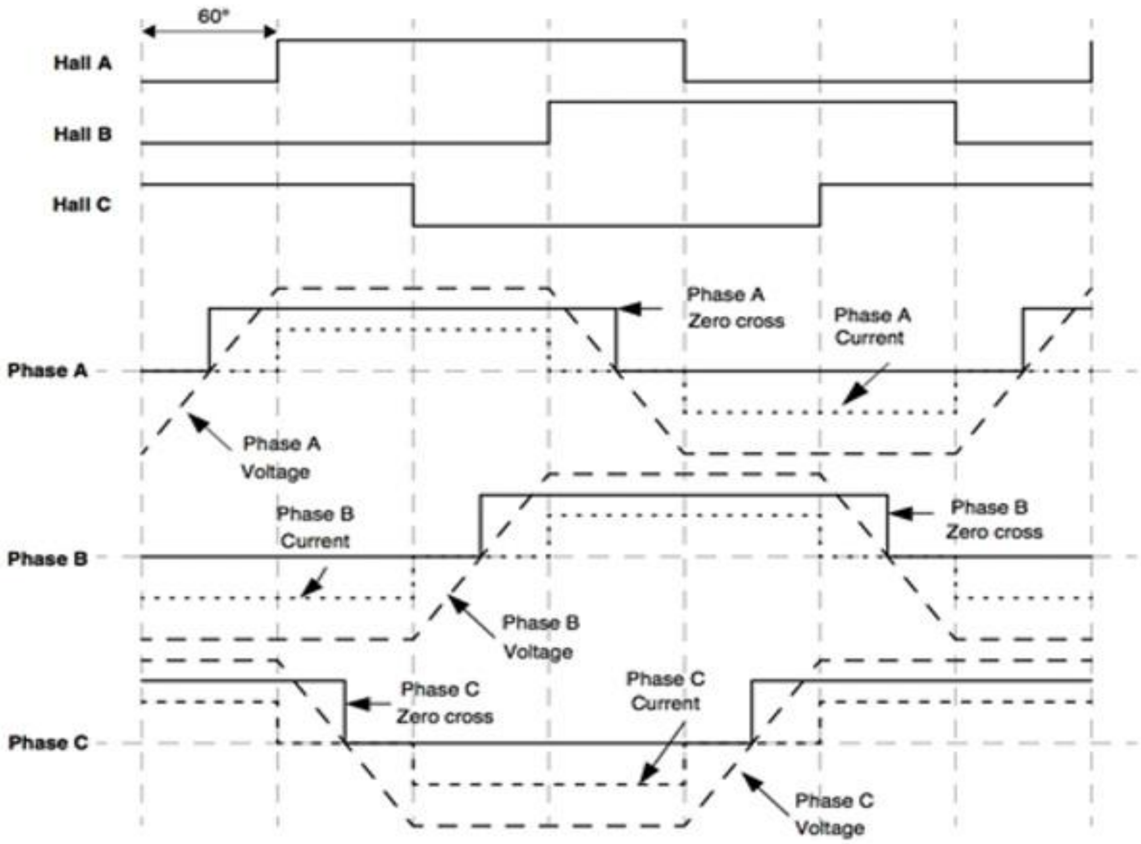


Figure 3.9: Hall sensor output compared with back EMF for three-phase BLDC motor. Note how switching of Hall sensor output coincides with the respective coil's back EMF crossing the zero point in a sensorless motor .

3.6.2 Choosing Motors

To choose a motor we first need to how much weight you are planning to take, and then to work out the thrust required to lift the quadcopter. A general rule is that you should be able to provide twice as much thrust than the weight of the quad. If the thrust provided by the motors are too little, the quad will not respond well to your control, even has difficulties to take off. But if the thrust is too much, the quadcopter might become too agile and hard to control.The general rule for Required Thrust per motor is towise the weight of the vehicles over 4 . we planning to design a vehicles have almost a weight of 2 KG , so : **Required Thrust per motor = (2 x 2) / 4 = 1 KG** So we have to choose a motor can pull almost 1000 gm ,

From this calculation we chose **D2826-6 out runner brushless motor ,** which can pull that weight .

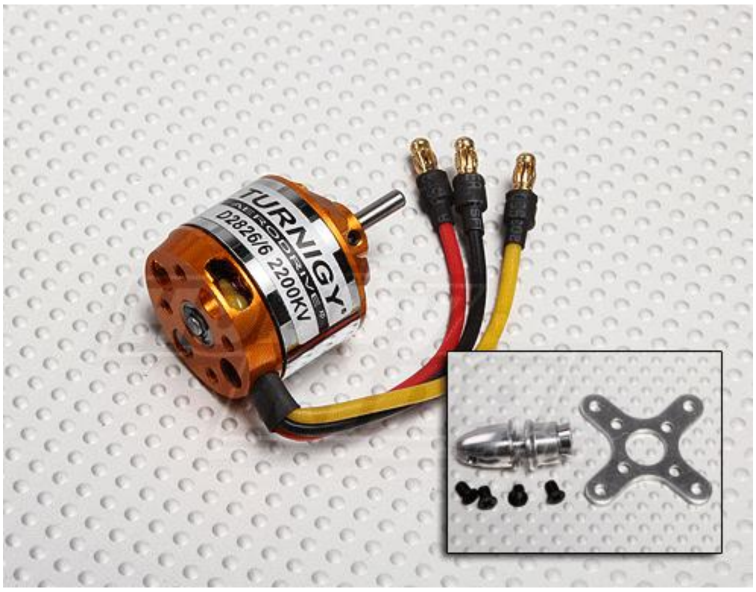


Figure 3.10 :D2826-6 out runner brushless motor

3.7 Camera

This high resolution camera comes with a 3.6mm lens pre-installed. 3.6mm is the optimal angle of view for FPV purposes. also includes an extra 2.8mm wide angle lens should you prefer a wider viewing angle. The lens is interchangable. It also included an extra plastic lens mount so you do not have to use the metal case to save weight. Without the metal case, it only weights 12grams / 0.4oz. With the metal case, it weighs at 52grams / 1.8oz. The metal case is 1.4 by 1.4 inch.

This is an excellent camera for FPV with great low ligh performance. We still be able to see everything clearly through the camera even at very dark environment (0.002lux moonlight condition).

It also adapts to lighting changes very fast, which is essential for FPV flying that typically encounter constant changes in various lighting conditions.

✓ Features

Supports 960H/760H CCD image sensor .

Horizontal resolution of over 700 TV-Line (MAX).

Wide dynamic range function (WDR).

ATR-EX (Adaptive Tone Reproduction).

2D and 3D noise reduction.

Star light function, the illumination up to 0.002Lux

Power input : DC 12V

Figure 3.11: SONY CCD camera

3.8 Transmitter

perfect for smaller hands or for packing in your travel case, this 5X TX is a full range, entry level 2.4GHz transmitter that includes switchable mode functions between mode-1 and mode-2 (although this TX is configured to mode 1), fixed wing and delta mix function, servo reverse, dual rates and adjustable stick length. It comes with a 5ch receiver .

Figure 3.12: Transmitter

Specifications

The Specifications of the transmitter

- Weight: **265g**
- Dimensions: **156 x 152 x 50mm**
- Frequency: **2.4GHz FHSS**
- Channels: **5**
- Voltage: **6V (4 AA Size Battery)**

3.9 Receiver

The receiver is what goes into your aircraft and controls the servos and motor(s). You can see from this receiver that it is a 5 channel receiver(Aileron, Elevator, Throttle, Rudder , and Aux). The BAT slot is not considered a channel. The receiver above connects wirelessly to the transmitter using a 2.4Ghz frequency. 2.4Ghz frequency is the standard frequency for RC planes. The receiver runs by 5v, and sends signals to the servos to turn them. It also sends a signal to the ESC to tell it how fast the run the motor. Now you may be wondering were the receiver gets it's

5 volts from. It gets that from the ESC's BEC, or battery elimination circuit.

Figure 3.13 Receiver

Specifications

The Specifications of riceiver

- Weight: **6.5g**
- Dimensions: **33.5 x 20.5 x 13mm**
- Voltage: **4.8-6v**

3.10 Connection

In this part e talk about how to assemble and connect each part of the craft attaching that with pictures .

3.10.1 Assembling the Frame

Connecting the four wood parts with the central square part . as shown in figure(3.14).

3.10.2 Attaching the Flight Control Board

Connecting the flight control board to the central wood part **.** as shown in figure(3.15).

Figure 3.14 Assembling the Frame

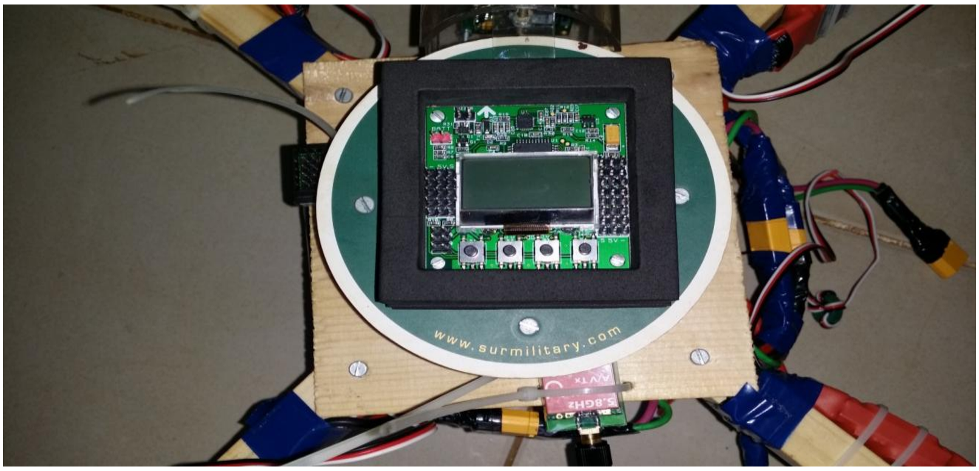


Figure 3.15 Attaching the Flight Control Board

3.10.3 Connecting the ESCs

we connect the ESCs in three different places :

- **Power Wires**

Connect the red and black power wires from each ESC to red and black power wire from my power harness. Connect red to red and black to black to avoid shorting and ruining the ESC . as shown in figure (3.16) .

- **Motor Phase Wires**

The order these wires are connected determines the rotation direction of the motor and prop. Depending on the ESC being used the colors may vary. You initially connect the three motor wires from each ESC to the 3 motor wires in any order. Later, you can switch any two of the three motor wires to reverse the direction of a motor and prop if necessary. as shown in figure (3.17) .

✓ Battery Elimination Circuit(BEC) & Signal Connector

Finally, Connect the BEC power and signal wires to the flight control board. Most flight control board manuals suggest only connecting the BEC power wires from one ESC to the flight control board.

A board only needs one power source and multiple power and ground wires can cause problems. The easy fix for this is to just remove and place heat shrink around all but one ESC power and ground wires.

For each motor, connect the ESC BEC/Signal connector to its matching flight control board connector.

You can see from the picture above that the ESC BEC/Signal wires are brown, red and orange. Brown is the ground, red is power, and orange is the signal wire. Many other ESC BEC/Signal wires are black, red, and white where black is the ground, red is power and white is the signal wire. as shown in figure (3.18) .

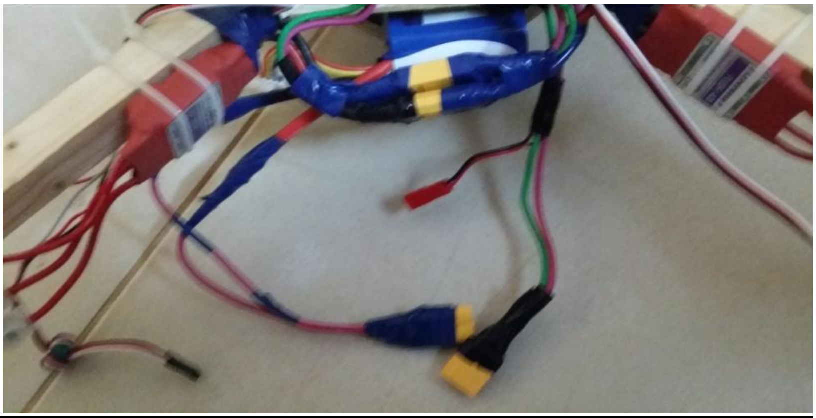


Figure 3.16 : ESCs Power Wires connection

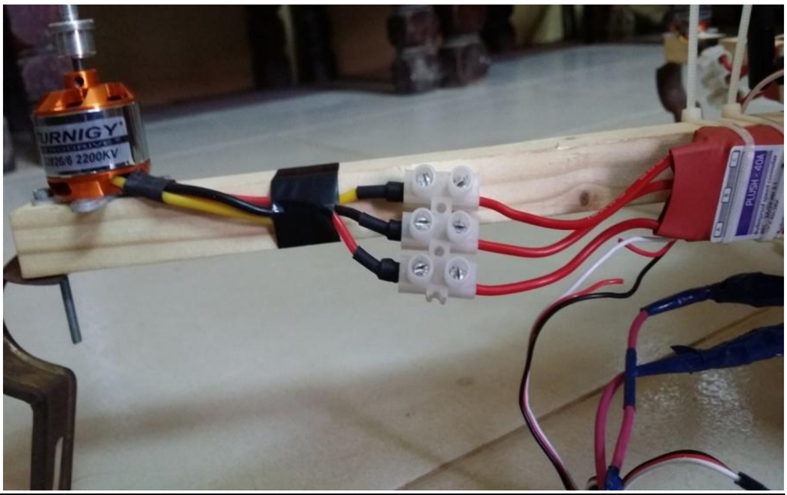


Figure 3.17: ESCs Motor Phase Wires connection

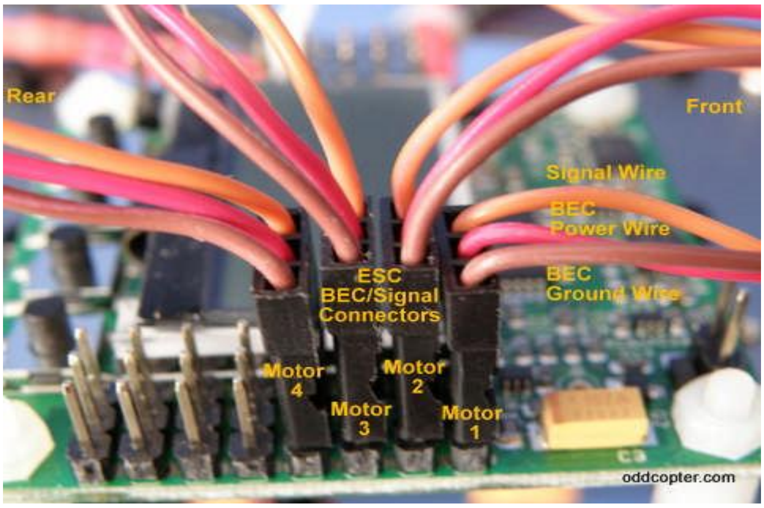


Figure 3.18 : Battery Elimination Circuit(BEC) & Signal Connector connection

3.10.4 Attaching & Connecting the Receiver

The connector labels mean the following:

CH1 = Aileron

CH2 = Elevator

CH3 = Throttle

CH4 = Rudder

CH5 = Auto Level (Aux)

The pins on the inside are the signals, the middle pins are for power and the outer pins are the grounds. The receiver gets its power from the flight control board and only needs one power and ground wire connected.
You can see we connected all three pins on the aileron channel with one servo lead to provide power to the receiver. Since the other channels only need to carry a signal, I used another servo connector to connect the signal pins of the elevator, throttle, rudder , and Aux . as shown in figure (3.19) .

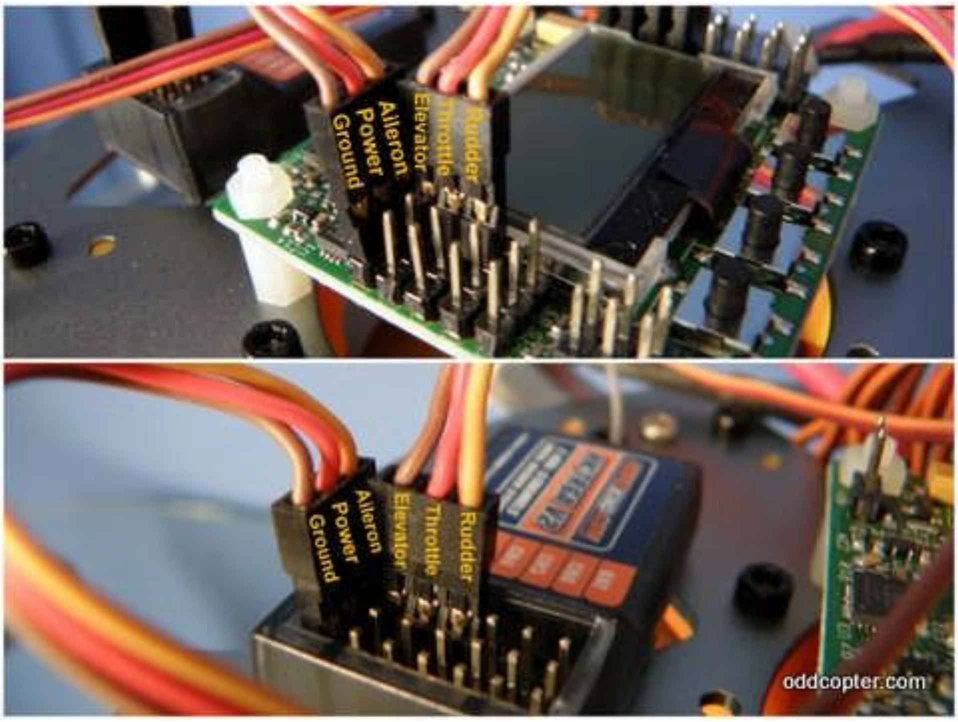


Figure 3.19 :Esc Receiver Connecting

CHAPTER FOUR

Functions and Operation

4.1 INTRODUCTION

This chapter consist of the idea of operation and how its working with the remote controller. The kk flight controller board arming and disarming. Math calculation with the motor throttle and its total flight time according to it . Software implementation express how the over flight stability acts according on it.

4.2 Operation

To start the operation of the vehicle , we must have to follow the steps below :

4.2.1 bind the radio transmitter (TX) and receiver (RX)

And to do that we have to switch on the transmitter first and then feed the receiver with power (5 volt) .

4.2.2 Connecting the battery to the vehicle's main cable

From this step , the power distribute for the all four ESCs, every ESC have a voltage regulator in its BEC cable , so first these BECs feed the flight control board (KK2), and the flight controller then feed the receiver with its needed power (5v) .

4.2.3 The KK2.1.5 board Operation

It do a multi missions , it takes signals from on-board gyroscopes (roll, pitch and yaw) and passes these signals to the Atmega324PA processor, which in-turn processes signals according the users selected firmware (Quadcopter) and passes the control signals to the installed Electronic Speed Controllers (ESCs) and the combination of these signals instructs the ESCs to make fine adjustments to the motors rotational speeds which in-turn stabilizes the craft.

It also uses signals from your radio system via a

receiver (Rx) and passes these signals together with stabilisation signals to the Atmega324PA IC via the aileron; elevator; throttle and rudder user demand inputs. Once processed, this information is sent to the ESCs which in turn adjust the rotational speed of each motor to control flight orientation (up, down, backwards, forwards, left, right, yaw).

4.2.3.1 Arming the KK2 board

For arming operation we have to move the throttle stick on the TX to the max right YAW and minimum THROTTLE , the KK2 now in arming mode and ready to get orders and feed the motors . as shown in figure (4.1) and figure(4.2) .

4.2.3.2 disarming the KK2 board

To disarm the KK2 board we have to move the throttle stick on the TX to the max left YAW and minimum THROTTLE , now the KK2 board return to the safe mode , as shown in figure(4.3) .

Figure 4.1 : Arming the transmitter

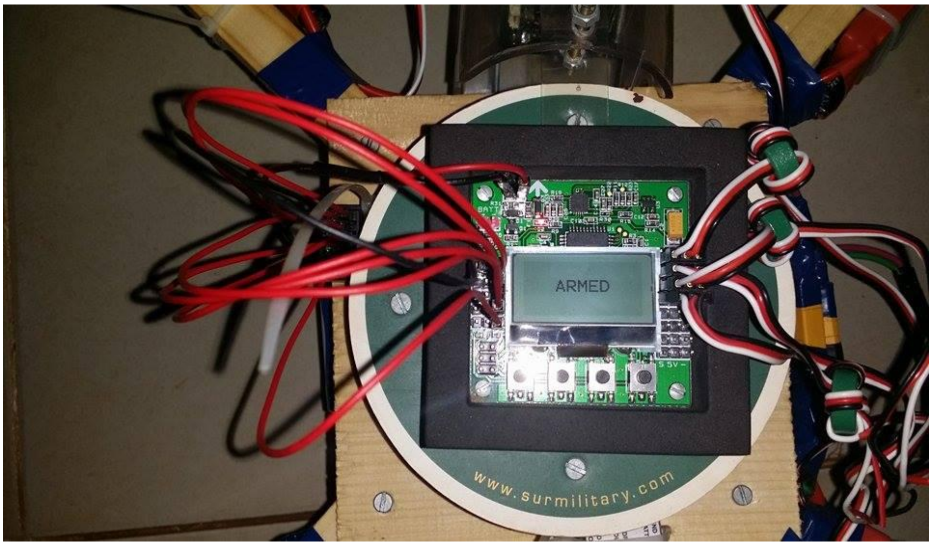


Figure 4.2 : Arming the KK2 board

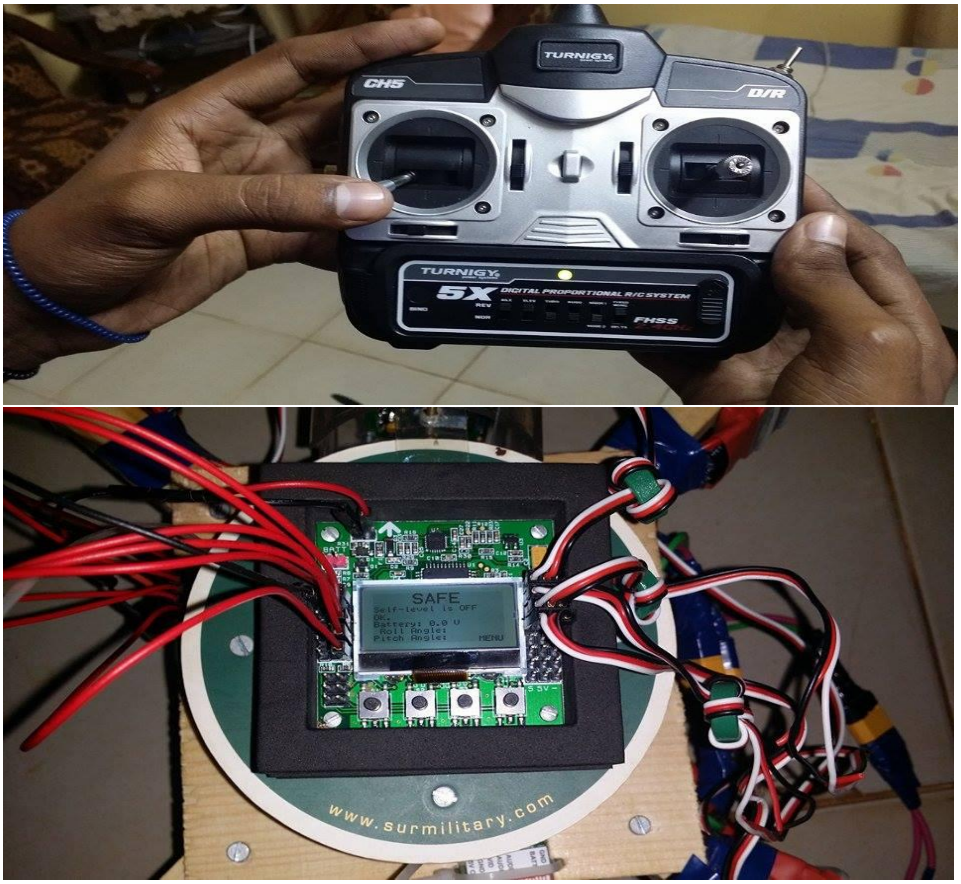


Figure 4.3 : disarming the KK2 board

4.3 Mass calculation

Here we will show and discus thee cases of flight operation and the relationship between mass , voltage, amps, and flight time.

4.3.1 Hovering

The quad-copter contains four rotors; each rotor produces a thrust force.

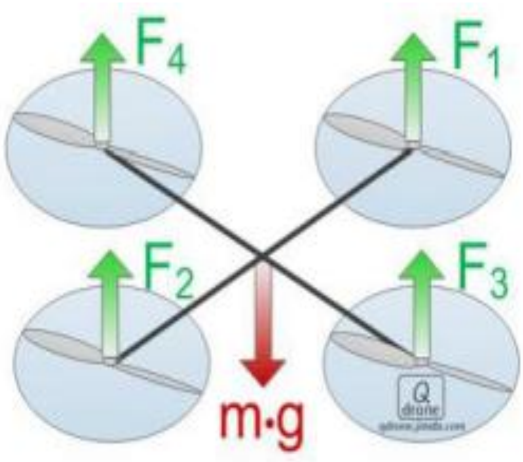


Figure (4.4): Quad-copter rotors

The summation of these forces gives the thrust produced by the quad-copters motors as shown by the equation (4.1)below:

$$TH = F_1 + F_2 + F_3 + F_4 \quad (4.1)$$

The total force must be equal to the weight of the vehicles in hovering case as shown in equation (4.2):

$$TH = m \times g \quad (4.2)$$

Where m is mass of the vehicle (kg) and g is the gravity 9.81 m/s^2.

Then we calculate the weight of each part of the vehicles as shown

In table (4.1) .

Table (4.1): vehicles Mass estimation

Part	Weight (g)
(4) D2826-6 out runner brushless motor	50x4
(4) Turnigy plush 40amp Electric Speed Controller (ESC)	33x4
Frame	500.3
KK2.1.5 Multi-Rotor control board	22
Battery	347
Camera & camera transmitter	92.2
RC radio receiver	6.5
Total	**1300**

Figure 4.4 : quad copter weight

So the required hovering force

$TH = m \times g = \ 1.3 * 1000 \ \times 9.81 = 12753$ N

From the manual of the motor we find that:

(a) the max pull of one motor by a 7x4 prop is 960 g , so for four motor equal 960x4=3840g.

So the max force by all motors = 3840x9.81=37670.4 N ⟶ (4.3)

(b) 1 volte make the motor runs at 2200 rpm , so for max power from 3S battery it will run at 2200x11.1=24420 rpm ⟶ (4.4)

From equations (4.3) and (4.4) we find :

24420 rpm ⟶ 37670.4 N

(X) rpm ⟶ N

After we calculate the weight of the vehicles the hovering speed :

X = (12753 x 24420)/37670.4= 8267.1875 rpm

And that is the required hovering speed per motor ,

4.3.2 climbing case

If the speed per motor become grater than this speed , the vehicles will be in climbing case .

4.3.3 declining case

If the speed per motor become smaller than this speed , the vehicles will be in declining case .

Note : if we want to find the required voltage for any speed we use the next equation

the required voltage = rpm/2200 .

so the required hovering voltage = 8267.1875 /2200 = 3.7578 v .

If we increase this voltage the vehicles will be in climbing case , and if we decrease it the vehicles will be in declining case .

4.3.4 Flight time

After collecting all quadcopter parts , the main consideration before we go and fly is the flight time .

flight time **:** that’s mean how much the vehicles can be flying before the battery be empty .

Flight time (min) = (battery capacity / drain amps)* 60 (4.5)

The drained current is consumed by the motors. There are 4 motors on the flight state. The battery capacity is measured by the amperes per hour.

From the manual of the motor we find that in full speed at (11.1 v) the max power per motor equal 342 watt , so the drain amp per motor equal:

Drain amp per motor = 342 / 11.1 = 30.8 amp (assume it 30 A)

- ✓ **Flight time at full speed**

Then the flight time when every motor draw 30 amp at max speed equal:

(Our battery capacity is 4A)

Flight time = (4 / 30*4)*60 = 1.947368421 (2 min almost) . We can recognized that the flight time increases with low power conceptions .

4.4 Software implementation

To maintain the stability of the aircraft and control the direction of movement, there are many stages to be implemented and shown in flowchart:

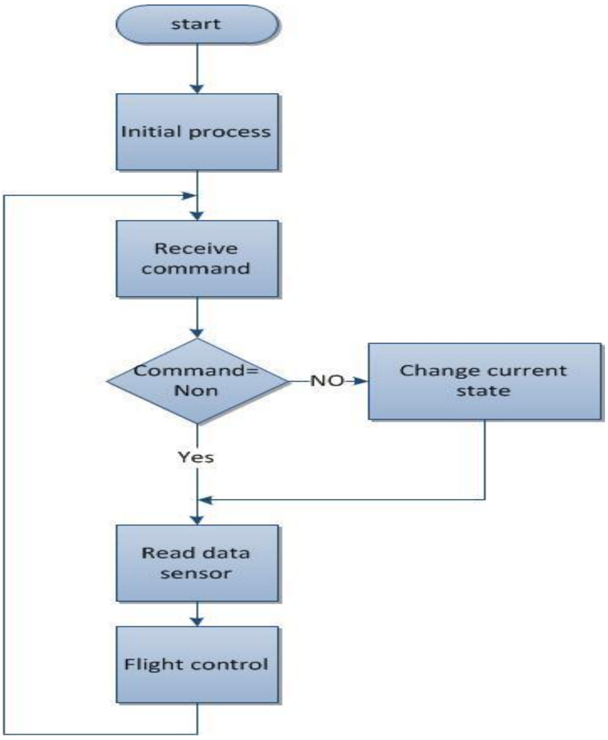


Figure 4.6**:** Quad-copter Software implementation

4.4.1 Initial process

This stage performs at once when the quad-copter starts working to calibrate accelerometer, gyroscope and calibrate ESC for all motors.

4.4.2 Receive Process

In our project we choose RF as medium to send and receive commands from user to quad-copter.

In this process we receive different commands to control the behavior of quad-copter and the commands are:

1- up and down

2- left and right

3- forward and backward.

The following flowchart illustrates this process

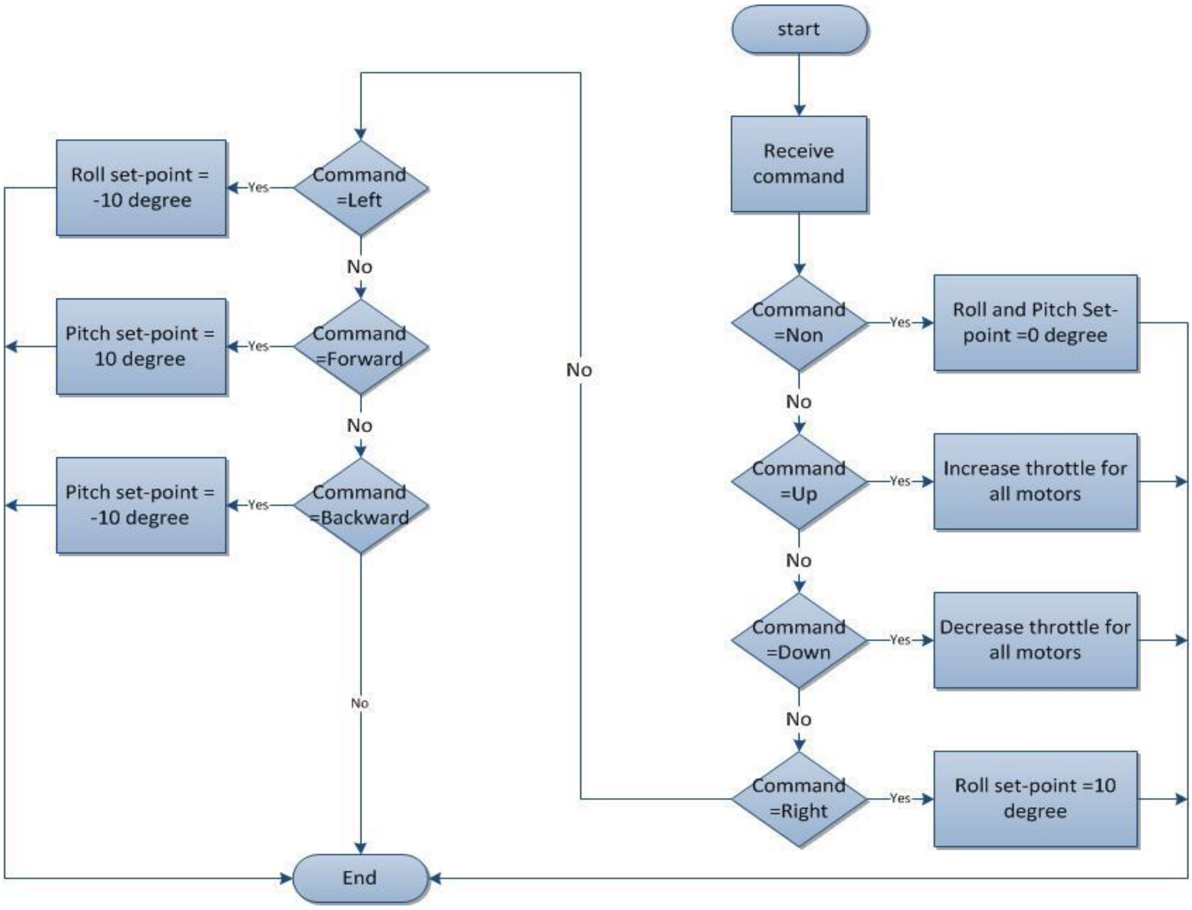


Figure 4.7: Receive Process

4.4.3 Flight control

This is a very important stage because it is responsible to keep the quad-copter stable.

The following flowchart illustrates this process

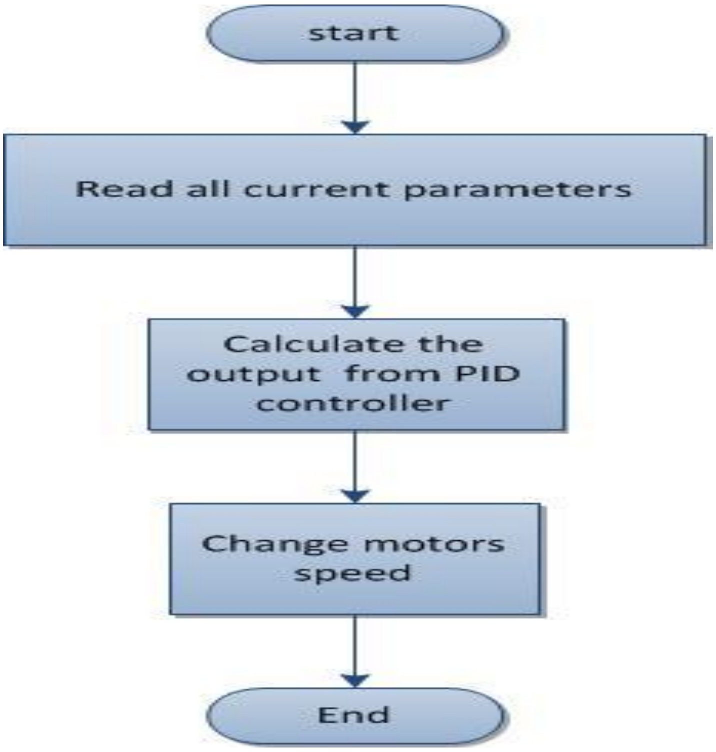


Figure 4.8: Flight control Process

- ✓ **Exeplanation**

Read the set-point for roll direction(X-axis) and set-point for pitch direction(Y-axis) and the current angles for roll and pitch. Also, read the values of Kp,Ki,Kd and then use these data as input to PID controller which calculate the correct output depend on current state , and use these gains to change motors speed .

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

The chapter summarizes the project overcomes in relation to the project objectives that were outlined. This section concludes with recommendations for the future direction that the project should take .

General objective is to make a practical design of a multi-rotor craft called Quad copter .

Wood has been selected to be the best choice of craft frame considering its low cost. And The right components have been chosen perfectly like out runner brushless motor, 4000mah-3S-30C lipo(lithium polymer)back battery for its flight durability, Electric Speed Controller (ESC) for controlling of the motors,KK2.1.5 Multi-Rotor control board, Radio Control system for the wireless controlling also the camera is wirelessly connected broadcasting video to the receiver. Live video can be seen in screen or TV.

5.2 Recommendations

We have faced many problems during the construction of this vehicle and we recommend to take them into consideration in future work .

- ✓ A stronger and lighter material for the body frame can be used like carbon fiber.
- ✓ A larger capacity must be used to attain a longer flight time with its maximum throttle.
- ✓ Using stronger propellers to attain more stable torque and reduce the loss in power.

- ✓ Having a longer range remote control to obtain a wide flying distance.
- ✓ Having another small battery specifically for the camera to obtain more stable sending signal to camera receiver.

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