# Project Report of QuadCopter

1 year ago by Mohammad Saad 13



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## 1. INTRODUCTION

Humans are fascinated by levitation. The reason is probably that the world we are living in is three-dimensional. However, human beings live and move mainly in two dimensions. It seems that humans have a very strong drive to overcome their biological limits. This leads to build machines that enable them to move in three-dimensional space, e.g., airplanes and helicopters. No matter how complicated the geographical feature is, it doesn't become a trouble if it flies in the air. What's more, it is possible to use it even in a considerably severe region. And it can be controlled remotely to carry out a wide range of investigations. Unmanned Aerial Vehicles (UAVs) are crafts capable of flight without an onboard pilot. They can be controlled remotely by an operator or can be controlled autonomously via pre-programmed flight paths.

A quad-rotor helicopter (i.e. QUADCOPTER) is an aircraft whose lift is generated by four rotors. Control of such a craft is accomplished by varying the speeds of the four motors relative to each other. Quad-rotor crafts naturally demand a sophisticated control system in order to allow for balanced flight. Uncontrolled flight of a quad-rotor would be virtually impossible by one operator, as the dynamics of such a system demand constant adjustment of four motors simultaneously. The goal of our project is to design and construct a **Spycopter**, quad-copter capable of Indoor-outdoor flight and hover with an onboard wireless camera used for remote surveillance and control. Through the use of an integrated control system, this vehicle would be capable of autonomous operation, including take-off, hover, and landing capabilities, controlled remotely by an operator and let the view the real-time footage captured by the camera.

### 1.1 BLOCK DIAGRAM OF THE SYSTEM

The working of the system is as follows as explained through figure 1.1 and figure 1.2:

When the system is switched on, the receiver starts listening to the transmitting frequency (here 2.4 GHz).The transmitter gives commands for throttle. yaw, pitch and roll which is interpreted by the 4 channels of the receiver used. The PWM signals are forwarded to an 8 channel PWM to PPM convertor. The PPM signal from the converter is send to the ARDUIMU at pin no.12. This PPM signal is processed by the IMU controller n 4 PWM outputs for the four motors are output from pin no.14, 15, 16, 17. This PWM signals are given to Electronic Speed Controller which also receive a battery connection each of 11 volts. The ESC switches the supply across the motor coils to run it at a specified speed. The sensors continuously monitor the orientation of the Quad copter in air. Accelerometer and Gyroscope are in build on the ARDUIMU and Magnetometer is added externally. Whenever a tilt is encountered it is compensated using Tilt compensation algorithm. The speeds of the motors are varied accordingly to stabilize the Quad copter.

The camera transmits a video on 1.2 GHz channel which is received and displayed on a laptop or computer using a T.V Tuner card. This video can also be recorded.

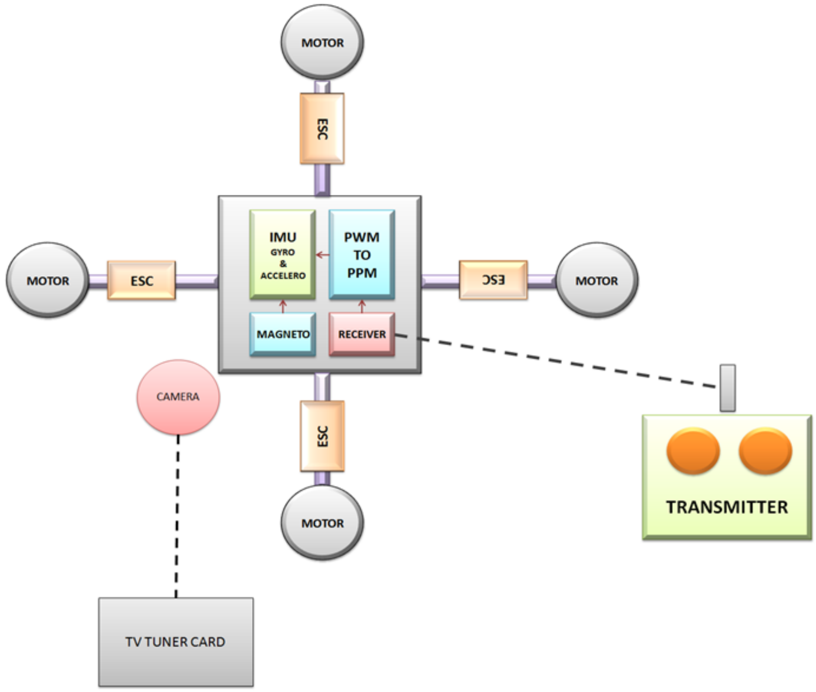


**FIGURE 1.1: BLOCK DIAGRAM OF THE SYSTEM**

## 1.2 CIRCUIT DIAGRAM OF THE SYSTEM

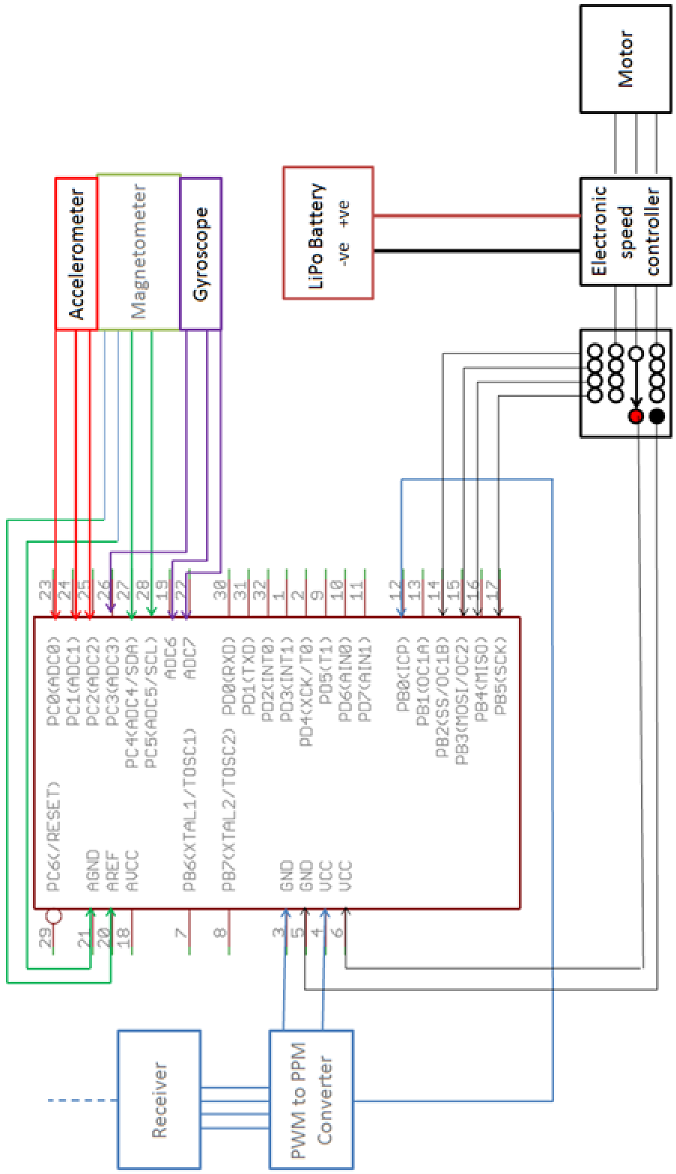


**FIGURE 1.2:** **CIRCUIT DIAGRAM OF THE SYSTEM**

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## 2. LITERATURE SURVEY

According to Samir Bouabdallah's paper on Design and Control of an Indoor Micro Quadrotor, recent progress in sensor technology,[1] data processing and integrated actuators has made the development of miniature monitoring robots fully possible. Micro VTOL1 systems represent a useful class of flying robots because of their strong capabilities for small-area monitoring and building exploration. This paper describes the approach that has been taken to micro VTOL evolving towards full autonomy, and presents the mechanical design, dynamic modelling, sensing, and control of indoor VTOL autonomous robot OS43.

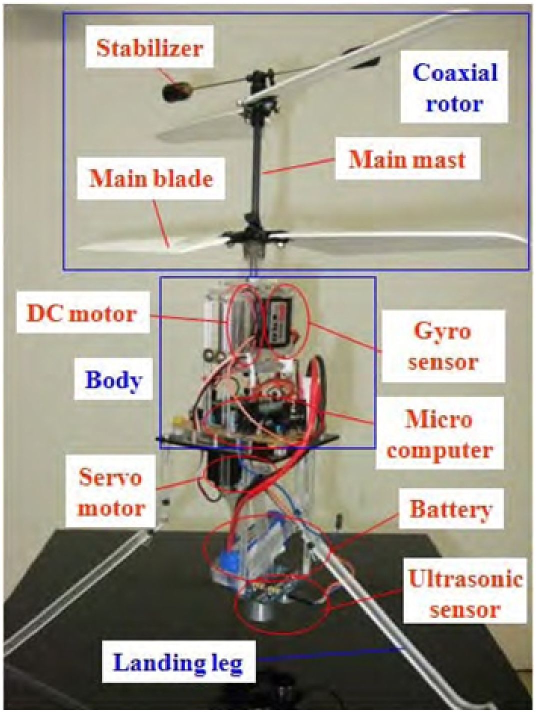
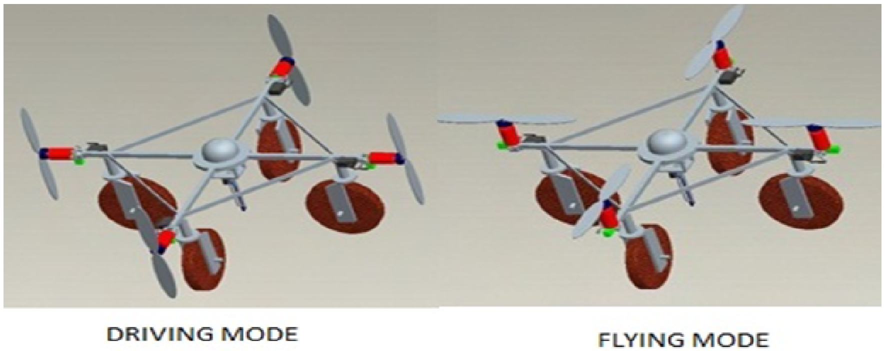



**FIGURE 2.1: COAXIAL QUADCOPTER**

According to X Deng's paper on Attitude Control for a Micro mechanical Flying Insect Including Thorax and Sensor Models,[2] recent development on the design of the flight Simulation and control system for a Micromechanical Flying Insect (MFI). High level attitude control is considered. Compared to previous works, here the recently developed dynamical model for the thorax actuators and various sensor models to close the control loop. Specifically, a new wing kinematic parameterization method was developed to generate feasible wing motions based on the available thorax model. Compared to our previous method, this parameterization schemes ensures the boundedness and smoothness of the thorax input torques while decoupling the average roll, pitch, yaw torques in the body frame. A nominal state-space LTI model in hover was identified through linear estimation and a LQG controller was designed. Sensor models such as haltere, magnetic compass, and ocelli were included inside the closed loop system and the simulations shows stable hovering and steering manoeuvres.

According to Wei Wang and Gang Song, et al[2006] paper on Autonomous Control for Micro-Flying Robot and Small Wireless Helicopter X.R.B,[3] autonomous control for Micro-Flying Robot and small helicopter X.R.B. In case of natural disaster like earthquake, a MAV will be very effective for surveying the site and environment in dangerous area or narrow space, where human cannot access safely. In addition, it will be a help to prevent secondary disaster. This paper is concerned with autonomous hovering control, guidance control of, and automatic takeoff and landing control of X.R.B.

According to Felipe Bohorquez, paper on Design, Analysis and Hover performance of a Rotary Wing Micro Air Vehicle [4], An initial design concept for a micro-coaxial rotorcraft using custom manufacturing techniques and commercial off-the-shelf components is discussed. Issues associated with the feasibility of achieving hover and fully functional flight controls at small scale for a coaxial rotor configuration are addressed. Results from this initial feasibility study suggest that it is possible to develop a small scale coaxial rotorcraft weighing approximately 100 gm, and that moment control is sufficient for roll, yaw and lateral trim. A prototype vehicle was built and its rotors were tested in a custom hover stand used to measure thrust and power. A blade element momentum theory (BEMT) model of the rotor was implemented, and airfoil characteristics were estimated from the rotor tests. The model showed that profile drag accounts for 45% of the losses as opposed to 30% in full-scale helicopters. The radio controlled vehicle was flown untethered with its own onboard power source and exhibited good flight stability and control dynamics.




**<u>FIGURE 2.2:</u> SCHEMATIC DRIVING AND FLYING MODES**


**<u>FIGURE 2.3:</u> ACTUAL MODEL SHOWING DRIVING AND FLYING MODES**

According to Seung Ho Jeong and Seul Jung, et al [2010], Novel Design and Position Control of an Omni-directional Flying Automobile,[5] This paper presents a new concept of a flying and driving vehicle with a quad rotor structure. Design and control of an Omni-directional quad rotor vehicle called Omni-Flymobile are presented. It is a form of a quad rotor copter with four wheels known as a kind of a quad rotor helicopter which has four actuating fans. Omni-Flymobile is designed for both the capability of flying in the air and driving on the ground.

The Omni-Flymobile can be transformed into a vehicle that navigates on the ground. A tilting mechanism of the Omni-Flymobile allows converting a flying mode to a driving mode or vice versa. Manoeuvring control of the Omni-quarto Flymobile can be performed by controlling speed of each fan. Experimental studies of the Omni-Flymobile are presented to show the feasibility of a flying and driving vehicle as a future concept car.

According to Bora Erginer and Erdinç Altuğ, et al [2007] , paper on Modelling and PD control of a quad rotor VTOL vehicle present a model of a four rotor vertical take-off and landing (VTOL) unmanned air vehicle known as quad rotor aircraft.[6] And we explained its control architecture including vision based control. Quad rotors have generated considerable interest in both the control community due to their complex dynamics and military because of their advantages over regular air vehicles. The proposed dynamical model which comprises gyroscopic effects and its control strategies can be source for future works.

According to Hun-ok Lim and Shoji Machida, et al [2010] paper on Mechanism and Control of Coaxial Double Contra-Rotation Flying Robot,[7] describes the design and implementation of an on-line fingerprint verification system which operates in two stages: minutia extraction and minutia matching which is much faster and more reliable, is implemented for extracting features from an input fingerprint image captured with an on-line inkless scanner. For minutia matching, an alignment-based elastic matching algorithm has been developed. This algorithm is capable of finding the correspondences between minutiae in the input image and the stored template without resorting to exhaustive search and has the ability of adaptively compensating for the nonlinear deformations and inexact pose transformations between fingerprints. The system has been tested on two sets of fingerprint images captured with inkless scanners. The verification accuracy is found to be acceptable.

According to Madani, T, Benallegue, al [2006] paper on Back stepping Control for a Quad rotor Helicopter,[8]This paper presents a nonlinear dynamic model for a quad rotor helicopter in a form suited for back stepping control design. Due to the under-actuated property of quad rotor helicopter, the controller can set the helicopter track three Cartesian positions (x,y,z) and the yaw angle to their desired values and stabilize the pitch and roll angles. The system has been presented into three interconnected subsystems. The first one representing the under-actuated subsystem, gives the dynamic relation of the horizontal positions (x,y) with the pitch and roll angles. The second fully-actuated subsystem gives the dynamics of the vertical position z and the yaw angle. The last subsystem gives the dynamics of the propeller forces. A back stepping control is presented to stabilize the whole system. The design methodology is based on the Lyapunov stability theory. Various simulations of the model show that the control law stabilizes a quad rotor with good tracking.

Kıvrak, Arda Ozgur ‘s Thesis reviews the Design of Control Systems for a Quad rotor Flight Vehicle Equipped with Inertial Sensors in detail[9]. The control system is developed in Matlab/Simulink and real time implementation is achieved by using Simulink Real Time Windows Target utility. Linear Quadratic Regulator is designed for the stabilization of the attitude and shown to work in real time. The hardware consists of the data acquisition card, DC motor drivers, sensor set, the DC motors, and the Dragan Flyer V Ti structure.

**FIGURE 2.4: DRAGAN FLYER**

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## 3. QUAD-COPTER CONCEPTS

### 3.1 QUAD-COPTER THEORY

Our Quad-copter uses four propellers, each controlled by its own motor and electronic speed controller. Using accelerometers we are able to measure the angle of the Quad-copter in terms of X, Y, and Z and accordingly adjust the RPM of each motor in order to self-stabilize its self. The Quad-copter platform provides stability as a result of the counter rotating motors which result in a net moment of zero at the center of the Quad-copter.

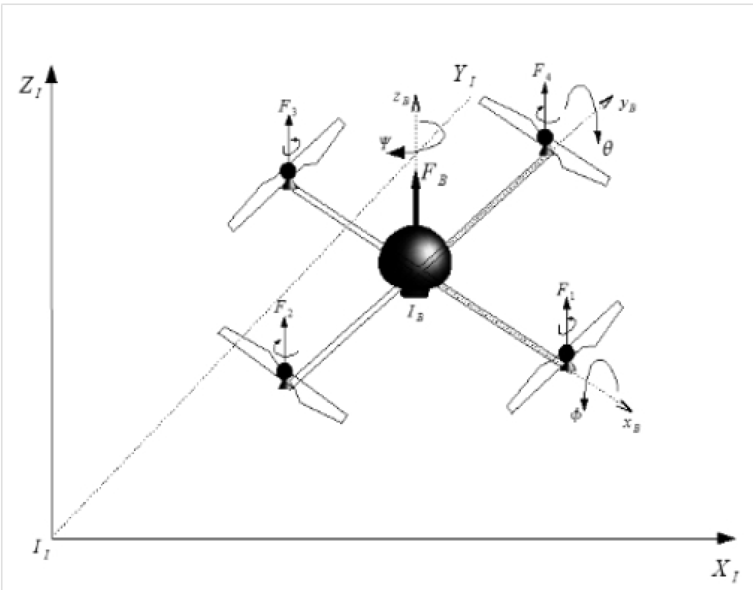

Figure 3.1: shows net moment at f3=0

Using this principle we are able to adjust the speed (RPM as a function of the voltage provided to the motor) of each individual motor in order to correctly manipulate Quad-copter's yaw, pitch, and roll. Pitch and roll can be controlled by changing the speed of the appropriate motors, while yaw control involves delicate balancing of all four motor functions in order to change the moment force applied to the quad.

- **YAW ANGLE**: The angle between an aircraft's longitudinal axis and its line of travel, as seen from above.

- **PITCH ANGLE**: The angle between an object's rotational axis, and a line perpendicular to its orbital plane.

  **ROLL ANGLE**: The angle of rotation of a vehicle about its longitudinal axis.

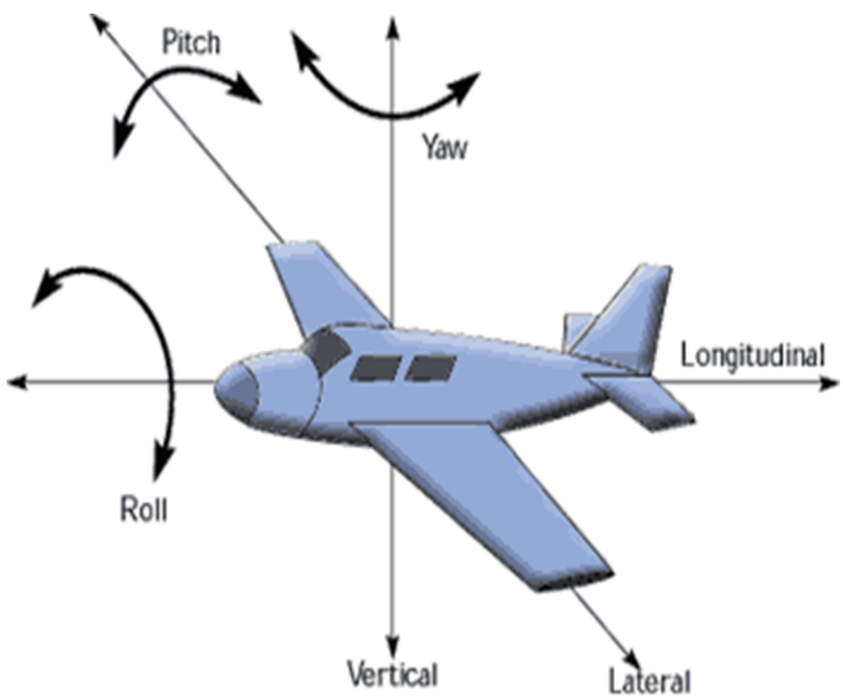


**Figure 3.2**: SHOWS PITCH, ROLL & YAW FOR AIRCRAFT

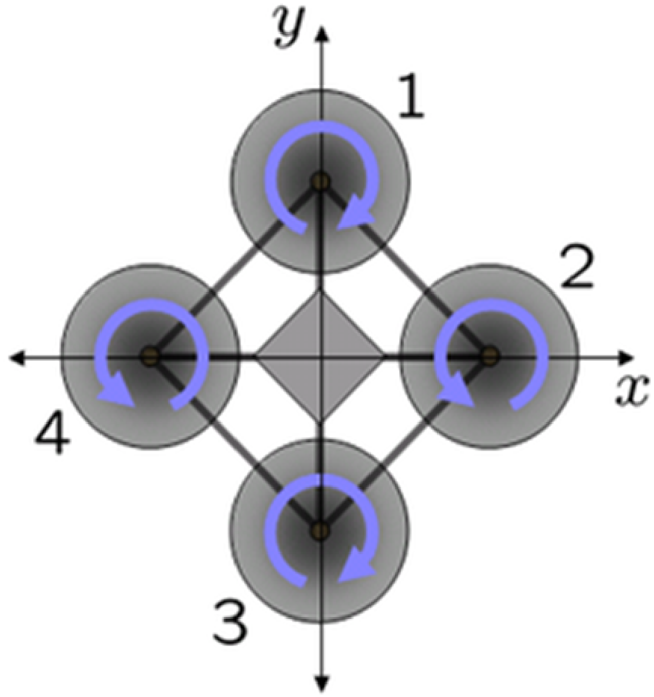


**FIGURE 3.3:** SHOWS DIRECTION OF ROTATION OF MOTORS

As you can see from the above given figure 3, two of the motors i.e. motor 1 and 3 are rotating in a clockwise direction and the other two motors i.e. motor 2 and 4 are rotating in anti-clockwise direction so as to ensure the perfect balance at the center of the quad-copter.

### 3.2 THE KINETIC PRINCIPLE OF QUAD-COPTER

Unlike common helicopters that have variable pitch angle, the quad copter obtains the expected speed by its fix pitch rotors whose speed is variable. The basic kinetic diagram is shown below. The vertical movement of quad copter could be realized by adjustments of the speeds of all four rotors at the same time. The movement along the X direction depends on the inclination on Y whose angle could be adjust by slowing down the speeds of rotors 1 and 2, speeding up rotors 3 and 4.The inclination also generate the acceleration along X direction. The movement along the Y direction depends on the inclination on X analogously.

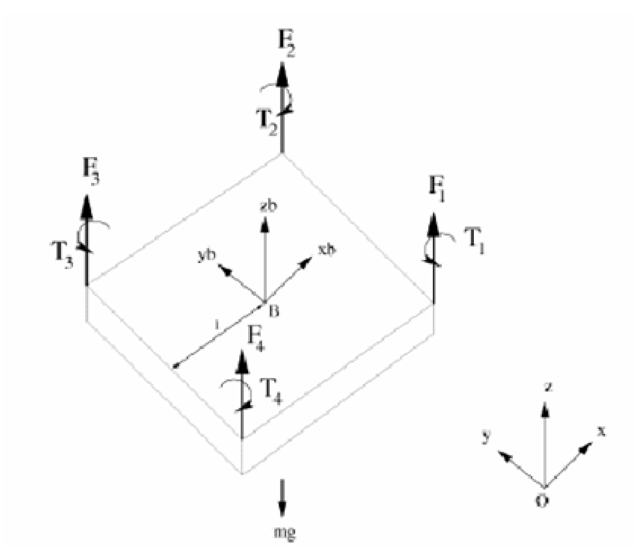


**FIGURE 3.4:** SHOWS THE UPWARD THRUST PRODUCED BY ALL MOTORS

Yaw movement is achieved by imbalance of the moments generated by the four rotors. The common helicopter has a stroke oar which could balance the moment generated by the main rotor. However, the quad copter could balance the moments only by each other. The imbalance of the moments, if calculated precisely, could generate expected yaw movement. For example, if we want the quad copter turn clockwise, the speeds of rotor 2 and 4 should be accelerate to overcome the moments generated by rotor 1 and 3. A good controller should meet the requirement that the quad copter should remain its altitude and pitch angle when the yaw angle is turning to its expected value.

### 3.3 PROPELLERS

A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and air or water is accelerated behind the blade. Propeller dynamics can be modeled by both Bernoulli's principle and Newton's third law. A propeller is often colloquially known as screw both in aviation and maritime.

Aircraft propellers convert rotary motion from piston engines or turboprops to provide propulsive force. They may be fixed or variable pitch. Early aircraft propellers were carved by hand from solid or laminated wood with later propellers being constructed from metal. The most modern propeller designs use high-technology composite materials.

#### 3.3.1 AIRFOIL

An airfoil or aero foil is the shape of a wing or blade (of a propeller, rotor or turbine) or sail as seen in cross-section.

An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag. Subsonic flight airfoils have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, often with asymmetric camber. Foils of similar function designed with water as the working fluid are called hydrofoils.

The lift on an airfoil is primarily the result of its angle of attack and shape (in particular its camber). When either is positive, the resulting flow field about the airfoil has a higher average velocity on the upper surface than on the lower surface. This velocity difference is necessarily accompanied by a pressure difference, via Bernoulli's principle for incompressible inviscid flow, which in turn produces the lift force. The lift force can also be related directly to the average top/bottom velocity difference, without invoking the pressure, by using the concept of circulation and the Kutta-Joukowski theorem.

#### 3.3.2 STRUCTURE OF AN AIRFOIL

**Angle of attack** is the angle between the lifting body's reference line (chord) and the oncoming flow.

**The chord** of an airfoil is the imaginary straight line drawn through the airfoil from its leading edge to its trailing edge.

**Camber** is the asymmetry between the top and the bottom surfaces of an airfoil.

**The trailing edge** is the back of the airfoil—the place at which the airflow over the upper surface of the airfoil joins the airflow over the lower surface of the airfoil.

**The leading edge** is the "front" of the airfoil—the portion that meets the air first.

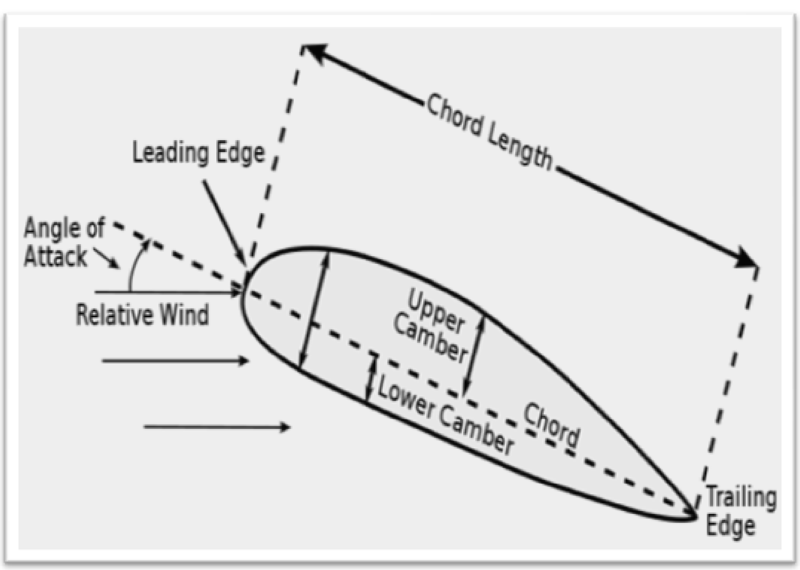


**FIGURE 3.5:** STRUCTURE OF AIRFOIL

#### 3.3.3 PRINCIPLE AND WORKING

The principle and working of a propeller is based on Bernoulli's Principle & Newton's Third Law.

Bernoulli's principle states that for an inviscid flow, an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy.

Newton's third law states that every action has an equal and opposite reaction.

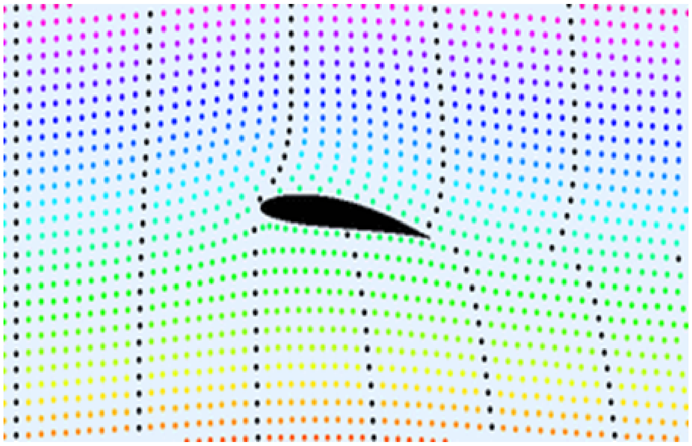

**FIGURE 3.6**: air speed variations on an airfoil

An aerofoil is shaped so that air flows faster over the top than under the bottom. There is, therefore, a greater pressure below the aerofoil than above it. This difference in pressure produces the lift.

Lift coefficient is a dimensionless coefficient that relates the lift generated by an aerodynamic body such as a wing or complete aircraft, the dynamic pressure of the fluid flow around the body, and a reference area associated with the body.

### 3.3.4 AERODYNAMIC FORCES ACTING ON THE AIRFOIL

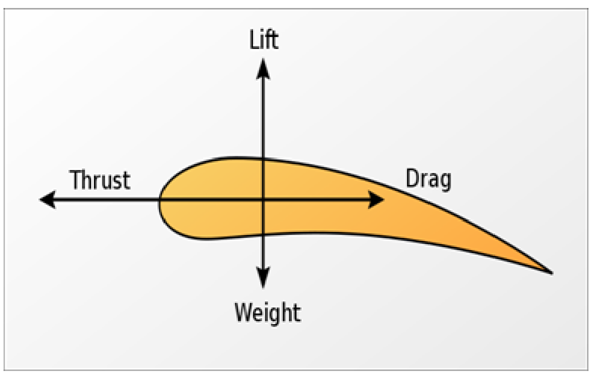


**FIGURE 3.7**: forces acting on an airfoil

Lift and drag are considered to be the two aerodynamic forces that are acting upon the airfoil as shown in the above figure.

**Lift** is defined to be the component of this force that is perpendicular to the oncoming flow direction.

**Drag** is defined to be the component of the surface force parallel to the flow direction. In fluid dynamics, drag (sometimes called air resistance or fluid resistance) refers to forces that oppose the relative motion of an object through a fluid (a liquid or gas).

### 3.3.5 PITCH OF A PROPELLER

**Pitch of a propeller** is normally described as the distance travelled per rotation, assuming there is no slip.Low pitch yields good low speed acceleration (and climb rate in an aircraft) while high pitch optimizes high speed performance and economy.

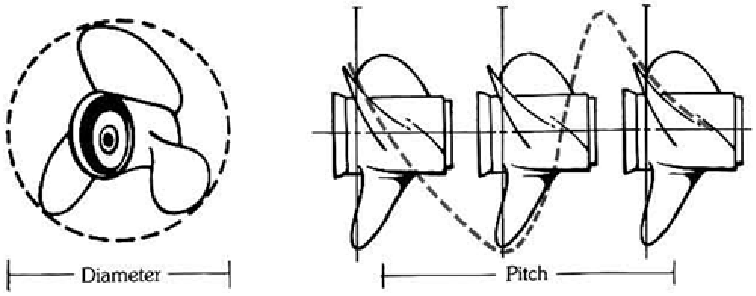


**FIGURE 3.8:** pitch of a propeller

Blade pitch or simply pitch refers to turning the angle of attack of the blades of a propeller or helicopter rotor into or out of the wind to control the production or absorption of power. Wind turbines use this to adjust the rotation speed and the generated power. A propeller of a ship uses this effect to control the ship's speed without changing the rotation of the shaft and to increase the efficiency of streaming fluids. In aircraft, blade pitch is usually described as "coarse" for a high angle of attack, and "fine" for a low angle of attack. Blade pitch is normally described in units of distance/rotation assuming no slip. Blade pitch acts much like the gearing of the final drive of a car.

Low pitch yields good low speed acceleration (and climb rate in an aircraft) while high pitch optimizes high speed performance and economy. Because the velocity of a propeller blade varies from the hub to the tip, they must be of twisted form in order for the pitch to remain constant along the length of the blade. This is typical of all but the crudest propellers. It is quite common in aircraft for the propeller to be designed to vary pitch in flight, optimizing both cruise and takeoff performance.

### 3.4 PROPELLERS USED:

We have used 3 Blade, 9×5 pitch rotating and counter rotating propellers. Benefits of using a 3 blade propeller over 2 blades is that we get more blade area because of which the blade can transfer more power onto the air, thus providing more lift. We are using two different kinds of blades one rotating in clockwise directions and other rotating in anti-clockwise direction, thus producing force in opposite directions.

**FIGURE 3.9:** **3** Blade CR Prop 9 x 5.0 HD9050RX3

## 4. MODULATION

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### 4.1 PULSE WIDTH MODULATION (PWM)

**Pulse Width Modulation** is a way of simulating an analog output by varying HIGH and LOW signals at intervals proportional to the value. Width of each pulse varies according to the amplitude of the analog signal.

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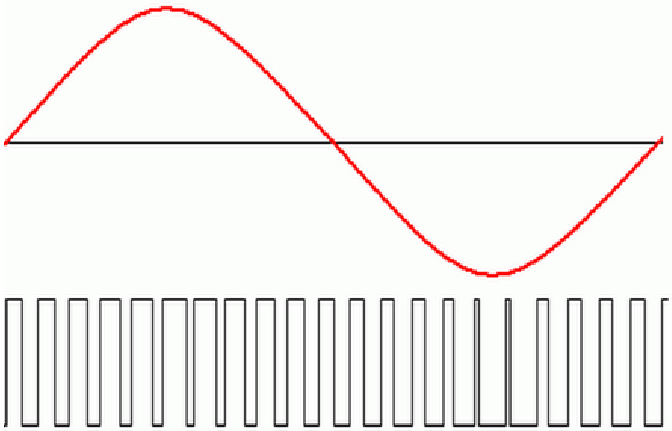

**FIGURE 4.1:** pulse width modulation

Pulse-width modulation, or pulse-duration modulation, is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches. The term duty cycle describes the proportion of ‘on’ time to the regular interval or ‘period’ of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is.

**Duty Cycle:**

In a periodic event, duty cycle is the ratio of the duration of the event to the total period.

Duty cycle

Where,

τ is the duration that the function is active

T is the period of the function.

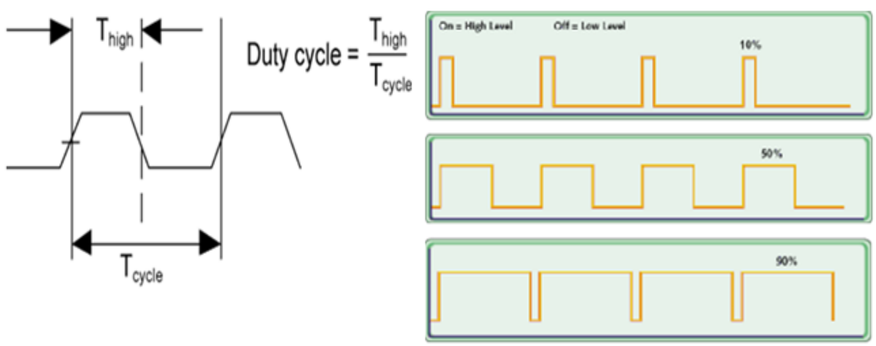


**FIGURE 4.2**: duty cycle

### 4.2 PULSE POSITION MODULATION (PPM)

**Pulse-position modulation** is a form of signal modulation in which M message bits are encoded by transmitting a single pulse in one of 2M possible time-shifts. This is repeated every T seconds, such that the transmitted bit rate is M/T bits per second.

Pulse position modulation (PPM) is a pulse modulation technique that uses pulses that are of uniform height and width but displaced in time from some base position according to the amplitude of the signal at the instant of sampling.

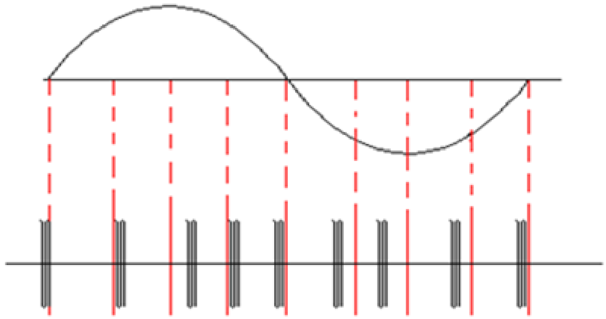

**FIGURE 4.3**: pulse position modulation

### 4.3 PWM TO PPM CONVERSION IN A QUAD-COPTER

PWM refers to a pulse width modulation signal, where the width of each pulse changes according to the amplitude of an analog signal. PPM on the other hand refers to a pulse position modulation signal, where the width of each pulse remains the same, but each pulse is displaced by a certain position based on the analog signal amplitude. The basic need for conversion of a PWM signal received from a transmitter into a PPM signal arises due to the fact that the main controller board used (ArduIMU) on a quad-copter cant process a PWM signal and hence a converter is required to convert a PWM signal to a PPM signal. The conversion of a PWM signal to a PPM signal is as explained in the below figure -:

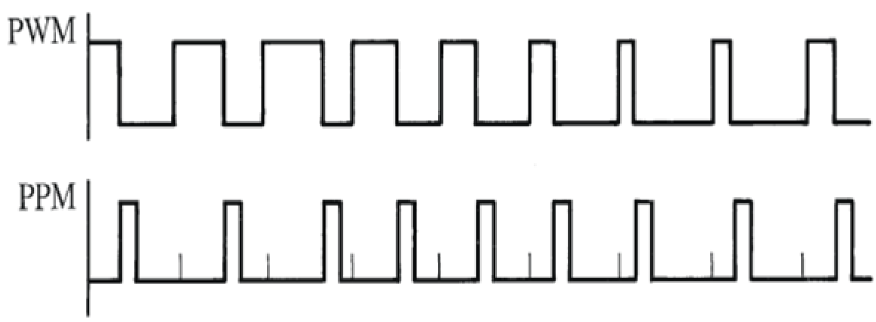


**FIGURE 4.4:** Pwm to ppm conversion

### 4.4 CHIP USED FOR CONVERSION (PWM TO PPM):

The best way to read RC signals is PPM, which is a sequential stream where each channel is output in turn on a single wire. Paparazzi team designed a board that will convert up to 8 channels of regular PWM servo signals to one PPM signal, with no RC hacking required. This improved & reduced PPM encoder board, based on a paparazzi design, plugs into the servo output ports on an R/C receiver and encodes them into a PPM pulse suitable for the paparazzi autopilot.

### 4.5 BLOCK DIAGRAM

Integration of atmega328p encoder (PWM TO PPM) with the main board (ARDUIMU V2). Atmega328p converts the PWM signal received from RC transmitter into a PPM signal and sends it as input to main board as shown in the figure below.

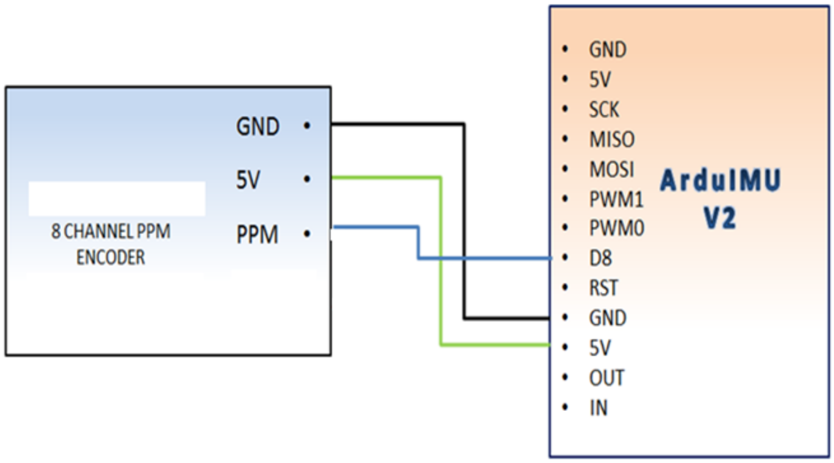


**FIGURE 4.5:** block diagram for Pwm to ppm conversion

### 4.6 RADIO TRANSMITTER AND RECEIVER

#### 4.6.1 TRANSMITTER (TX)

In electronics and telecommunications a radio transmitter is an electronic device which, with the aid of an antenna, produces radio waves. The transmitter itself generates a radio frequency alternating current, which is applied to the antenna. When excited by this alternating current, the antenna radiates radio waves. The term transmitter is usually limited to equipment that generates radio waves for communication purposes; or radiolocation, such as radar and navigational transmitters. A transmitter can be a separate piece of electronic equipment, or an electrical circuit within another electronic device. A transmitter and receiver combined in one unit is called a transceiver.

The term transmitter is often abbreviated “XMTR” or “TX” in technical documents. The purpose of most transmitters is radio communication of information over a distance. The information is provided to the transmitter in the form of an electronic signal, such as an audio (sound) signal from a microphone, a video (TV) signal from a TV camera, or in wireless networking devices a digital signal from a computer. The transmitter combines the information signal to be carried with the radio frequency signal which generates the radio waves, which is often called the carrier. This process is called modulation.

A radio transmitter is an electronic circuit which transforms electric power from a battery or electrical mains into a radio frequency alternating current, which reverses direction millions to billions of times per second. The energy in such a rapidly-reversing current can radiate off a conductor (the antenna) as electromagnetic waves (radio waves).

#### 4.6.2 RECEIVER (RX)

A radio receiver is an electronic circuit that receives its input from an antenna, uses electronic filters to separate a wanted radio signal from all other signals picked up by this antenna, amplifies it to a level suitable for further processing, and finally converts through demodulation and decoding the signal into a form usable for the consumer, such as sound, pictures, digital data, measurement values, navigational positions, etc. Demodulation is the act of extracting the original information-bearing signal from a modulated carrier wave. A demodulator is an electronic circuit that is used to recover the information content from the modulated carrier wave.

The receiver in information theory is the receiving end of a communication channel. It receives decoded messages/information from the sender, who first encoded them. Sometimes the receiver is modeled so as to include the decoder. Real-world receivers like radio receivers cannot be expected to receive as much information as predicted by the noisy channel coding theorem.

#### 4.6.3 HKT6A TRANSMITTER

HKT6A transmitter is used is 6 channel, FM modulating with a 2.4 GHz frequency band, the frequency at which it transmits the modulated signal. the signal transmitted by the transmitter is received by a HKT6A receiver which de-modulates the signal to get the original signal.

**SPECIFICATIONS:**

6 CHANNEL

FM MODULATION TYPE

2.4GHZ FREQUENCY BAND

POWER RESOURCE 1.5V * 8 ''AA'' BATTERY

GFSK PROGRAM TYPE

LED VOLTAGE DISPLAY

WEIGHT : 575g

SIZE : 189*97*218 mm

26 mm ANTENNA LENGTH

**4.6.4 MODES OF A TRANSMITTER**

Modes of a transmitter hk-t6a specify the working of the transmitter, where the left gauge upward movement specifies the throttle necessary for the lift. The left gauge left-right movement specifies the yaw angle. Further the right gauge upward movement is for controlling the pitch and the left-right movement to control the roll. All the above explained specifies the modes of transmitter necessary for controlling the quad-copter in the air. The mode has been specified in the figure 4.7.


**FIGURE 4.6:** hkt6a transmitter – mode of operation

A radio transmitter is an electronic circuit which transforms electric power from a battery or electrical mains into a radio frequency alternating current, which reverses direction millions to billions of times per second. The energy in such a rapidly-reversing current can radiate off a conductor (the antenna) as electromagnetic waves (radio waves).

Transmitter is used to modulate a original signal onto the carrier wave, thus generating radio waves that are transmitted to the receiver, which upon receive De-modulates the signal and retrieve the original intended signal.

**4.6.5 HK-T6A RECEIVER**

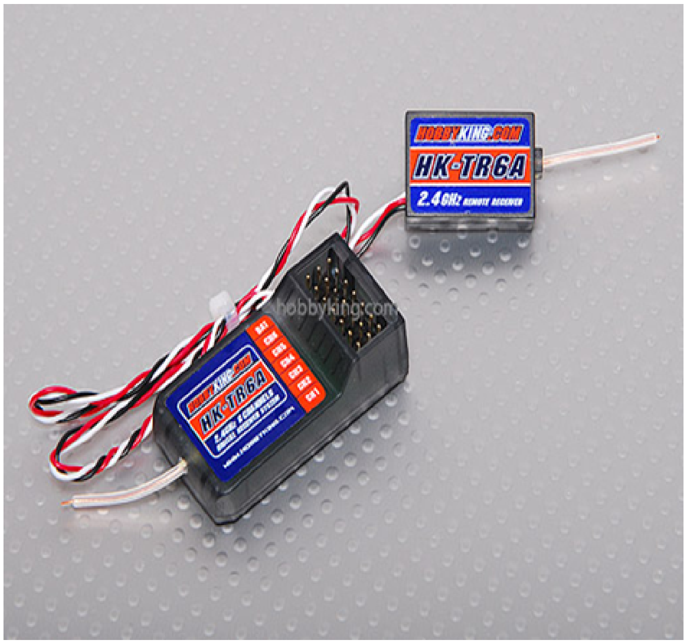


**FIGURE 4.7:** hkt6a Receiver

.

**SPECIFICATIONS**:

6 CHANNEL

FM MODULATION TYPE

2.4GHZ FREQUENCY BAND

POWER RESOURCE 1.5V * 4 ''AA'' BATTERY

GFSK PROGRAM TYPE

WEIGHT : 12g

SIZE : 45*23*13.5 mm

### 4.6.6 PRACTICAL CIRCUIT DIAGRAM

The figure below shows the various motors connected to a 6 channel receiver. The receiver reads the PWM signal and provides it to the motors. The PWM signal is provided by the transmitter and read on by the receiver.

## 5. ARDU-IMU

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### 5.1 WHAT IS ARDUINO?

**Arduino** is an open-source single-board microcontroller, descendant of the open-source Wiring platform, designed to make the process of using electronics in multidisciplinary projects more accessible. The hardware consists of a simple open hardware design for the Arduino board with an Atmel AVR processor and on-board I/O support. The software consists of a standard programming language compiler and the boot loader that runs on the board.

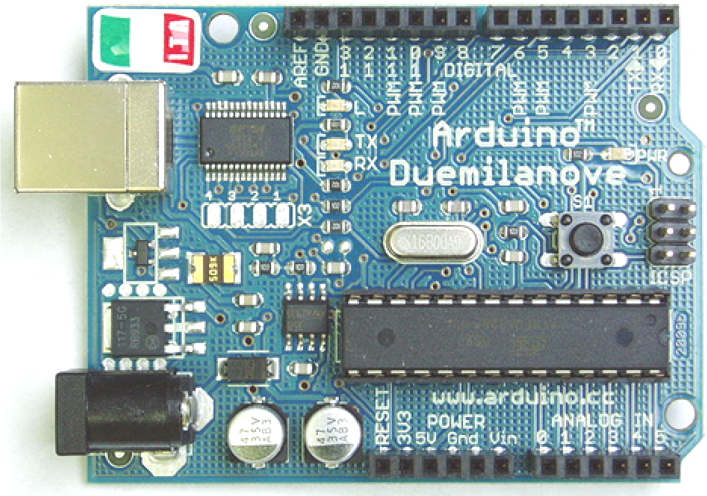


**FIGURE 5.1:** arduino

### 5.2 Ardu-IMU

ArduIMU is an Inertial Measure Unit (sensors and hardware filter circuitry) plus an Arduino-compatible processor that can run our Attitude Heading Reference System (AHRS) code, based on Bill Premerlani's DCM algorithm. This hardware consists of a 3 axis accelerometer and three gyro sensors, dual power regulator (3.3v and 5v), GPS port, an Atmega328@16mhz and a lot of status LED's. It's the cheapest IMU-AHRS on the market!

### 5.3 IMU (Inertial Measure Unit):

An inertial measurement unit, or IMU, is an electronic device that measures and reports on a craft's velocity, orientation, and gravitational forces, using a combination of accelerometers and gyroscopes. IMUs are typically used to maneuver aircraft, including UAVs, among many others, and spacecraft, including shuttles, satellites and Landers.

The IMU is the main component of inertial navigation systems used in aircraft, spacecraft, watercraft, and guided missiles among others. In this capacity, the data collected from the IMU's sensors allows a computer to track a craft's position, using a method known as dead reckoning.

**FIGURE 5.2:** arduiMU

### 5.4 AHRS (Attitude Heading Reference System):

An Attitude Heading Reference System consists of sensors on three axes that provide heading, attitude and yaw information for aircraft. They are designed to replace traditional mechanical gyroscopic flight instruments and provide superior reliability and accuracy.

AHRS consist of either solid-state or MEMS gyroscopes, accelerometers and magnetometers on all three axes. The key difference between an IMU and an AHRS is the addition of an on-board processing system in an AHRS which provides solved attitude and heading solutions versus an IMU which just delivers sensor data to an additional device that solves the attitude solution.

AHRS have proven themselves to be highly reliable and are in common use in commercial and business aircraft. AHRS are typically integrated with Electronic Flight Information Systems (EFIS) (which are the central part of so-called glass cockpits) to form the Primary Flight Display. AHRS can be combined with air data computers to form an "air data, attitude and heading reference systems" (ADAHRS), which provide additional information such as airspeed, altitude and outside air temperature.

### 5.5 FEATURES

Flat Design.

Low cost.

3 Axis Accelerometer.

3 Axis Gyroscopes.

Arduino Compatible.

Source Code included and Open Source!

Power LED (Green).

Status LEDs (Red, Blue, Yellow).

1 SPI port.

1 I2C port (possible expansion shield with magnetometers).

Two PWM outputs (for servos).

GPS port.

Protection diode.

Serial port output with servo standard connector for easy interface with any device (Ground, 5V, TX-OUT)

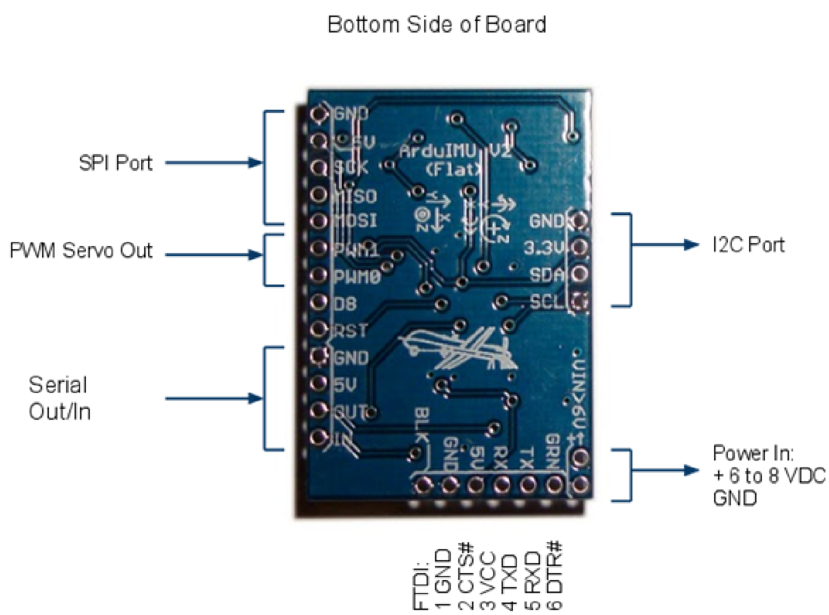


**FIGURE 5.3:** arduimu v2 PIN DESCRIPTION

### 5.6 THEORY OPERATION

ArduIMU uses gyros, accelerometers, and magnetometer to maintain a model of the board's orientation in space. This is not as simple a problem as integrating the roll rates from the gyros. As a simple illustrative example, consider an airplane flying level to the north that first bank (rolls) 90 degrees to the right and then pitches 90 degrees. mathematical algorithm called the Direction Cosine Matrix (DCM) to

take sensor data from the gyros, accelerometers. The airplane would be flying horizontally to the east in a 90 degree bank orientation. If instead the airplane pitched up 90 degrees first, then banked 90 degrees the airplane would be flying straight up. We cannot just keep track of how much roll and pitch have occurred and know the orientation of the aircraft.

For this simplified explanation here are the essential components of the algorithm.

The Direction Cosine Matrix is a 3 by 3 numerical matrix (array)

The gyro data is used in a time step integration to update the DCM matrix

Data from the accelerometers and magnetometer is used to correct for errors that creep in to the DCM matrix. These errors arise from drift in the gyros as well as numerical errors due to quantization of the gyro signals and rounding errors in the computations.

Pitch, roll and yaw can be computed from the elements of the direction cosine matrix.

ArduIMU outputs a serial data stream.

### 5.6.1 DIRECTION COSINE MATRIX (DCM)

The orientation of a body in 3 dimensions is represented with respect to orthogonal right-handed triad and of unit vectors fixed to its body (representing the three axes of the object's coordinate system) using direction cosine matrix. An example where rotation representation is used is in computer vision, where an automated observer needs to track a target. Let's consider a rigid body, with an orthogonal right , , and of unit vectors fixed to its body (representing the three axes of the object's coordinate system). The basic problem is to specify the orientation of this triad, and hence the rigid body, in terms of the reference coordinate system (in our case the observer's coordinate system).

### 5.6.2 ROTATION MATRIX

The above mentioned triad of unit vectors is also called a basis. Specifying the coordinates (scalar components) of this basis in its current (rotated) position, in terms of the reference (non-rotated) coordinate axes, will completely describe the rotation. The three unit vectors , and which form the rotated basis each consist of 3 coordinates, yielding a total of 9 parameters. These parameters can be written as the elements of a matrix , called a rotation matrix. Typically, the coordinates of each of these vectors are arranged along a column of the matrix.

Rotation matrix is given by:

### 5.6.3 COORDINATE TRANSFORM: ROTATION OF AXES

Consider counter clockwise (positive) rotation, **R (**q), about z-axis (out of paper). The components of x' and y' in terms of the old x and y are given by the direction cosines, (Think of x', or y', as just some vector).

For coordinate transforms, R (q) = a, it is easiest to remember what the appropriate Direction cosines, aij, are from the following aid:

With,

**a11=ax'x=cos Ɵx'x** ,……(1)

**a12=ax'y=cos Ɵx'y,** ,……(2)

**a21=ay'x=cos Ɵy'x,** ,……(3)

**a22=ay'y=cos Ɵy'y.** ,……(4)

The coordinate rotation, **R (Ɵ),** from "OLD" to "NEW" is the direction cosine matrix:

If,

Φ = ROLL ANGLE.

Ɵ = PITCH ANGLE.

Ψ = YAW ANGLE.

## 5.7 SENSORS

A **sensor** is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. For example, a mercury-in-glass thermometer converts the measured temperature into expansion and contraction of a liquid which can be read on a calibrated glass tube. A thermocouple converts temperature to an output voltage which can be read by a voltmeter. For accuracy, most sensors are calibrated against known standards.

### 5.7.1 GYROSCOPE

A gyroscope is a device for measuring or maintaining orientation, based on the principles of conservation of angular momentum. The first commercially available surface-micromachined angular rate sensors with integrated electronics, they are smaller—with lower power consumption, and better immunity to shock and vibration—than any gyros having comparable functionality. This genuine breakthrough is possible only because of the Analog Devices proprietary integrated micro electro-mechanical system (iMEMS) process, proven by use in millions of automotive accelerometers.

#### 5.7.1.1 PRODUCT DESCRIPTION

Gyroscopes are used to measure angular rate—how quickly an object turns. The rotation is typically measured in reference to one of three axes: yaw, pitch, or roll.

Figure shows a diagram representing each axis of sensitivity relative to a package mounted to a flat surface. A gyroscope with one axis of sensitivity can also be used to measure other axes by mounting the gyro differently, as shown in the right-hand diagram. Here, a yaw-axis gyro, such as the ADXRS150 or ADXRS300, is mounted on its side so that the yaw axis becomes the roll axis.

Depending on how a gyro normally sits, its primary axis of sensitivity can be one of the three axes of motion: yaw, pitch, or roll. The ADXRS150 and ADXRS300 are yaw-axis gyros, but they can measure rotation about other axes by appropriate mounting orientation. For example, at the right: a yaw-axis device is positioned to measure roll.

As an example of how a gyro could be used, a yaw-axis gyro mounted on a turntable rotating at 33 1/3 rpm (revolutions per minute) would measure a constant rotation of 360° times 33 1/3 rpm divided by 60 seconds, or 200°/s. The gyro would output a voltage proportional to the angular rate, as determined by its sensitivity, measured in millivolts per degree per second (mV/°/s). The full-scale voltage determines how much angular rate can be measured, so in the example of the turntable, a gyro would need to have a full-scale voltage corresponding to at least 200°/s. Full-scale is limited by the available voltage swing divided by the sensitivity. One practical application is to

measure how quickly a car turns by mounting a gyro inside the vehicle; if the gyro senses that the car is spinning out of control, differential braking engages to bring it back into control. The angular rate can also be integrated over time to determine angular position—particularly useful for maintaining continuity of GPS-based navigation when the satellite signal is lost for short periods of time.

### 5.7.1.2 CORIOLIS ACCELARATION

Analog Devices' ADXRS gyros measure angular rate by means of Coriolis acceleration. The Coriolis Effect can be explained as follows, starting with Figure 2. Consider yourself standing on a rotating platform, near the center. Your speed relative to the ground is shown as the blue arrow lengths in Figure 2. If you were to move to a point near the outer edge of the platform, your speed would increase relative to the ground, as indicated by the longer blue arrow. The rate of increase of your tangential speed, caused by your radial velocity, is the Coriolis acceleration.

If Ω is the angular rate and r the radius, the tangential velocity is Ωr. So, if r changes at speed, v, there will be a tangential acceleration Ωv. This is half of the Coriolis acceleration. There is another half from changing the direction of the radial velocity giving a total of 2Ωv (see the Appendix). If you have mass, M, the platform must apply a force, 2MΩv, to cause that acceleration, and the mass experiences a corresponding reaction force.

Coriolis acceleration example. A person moving northward toward the outer edge of a rotating platform must increase the westward speed component (blue arrows) to maintain a northbound course. The acceleration required is the Coriolis acceleration.

The ADXRS gyros take advantage of this effect by using a resonating mass analogous to the person moving out and in on a rotating platform. The mass is micromachined from polysilicon and is tethered to a polysilicon frame so that it can resonate only along one direction.

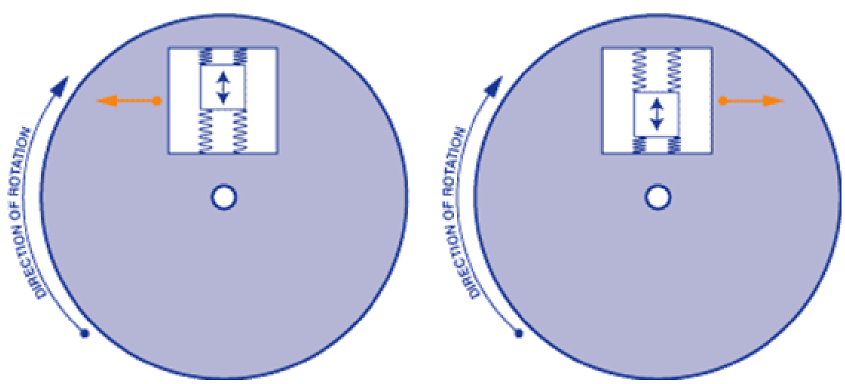


**FIGURE 5.9:** coriolis effect on resonating mass

Figure shows that when the resonating mass moves toward the outer edge of the rotation, it is accelerated to the right and exerts on the frame a reaction force to the left. When it moves toward the center of the rotation, it exerts a force to the right, as indicated by the orange arrows.

To measure the Coriolis acceleration, the frame containing the resonating mass is tethered to the substrate by springs at 90° relative to the resonating motion, as shown in Figure 17. This figure also shows the

Coriolis sense fingers that are used to capacitively sense displacement of the frame in response to the force exerted by the mass, as described further on. If the springs have stiffness, K, then the displacement resulting from the reaction force will be 2 ΩvM/K.

It shows the complete structure, demonstrates that as the resonating mass moves, and as the surface to which the gyro is mounted rotates the mass and its frame experience the Coriolis acceleration and is translated 90° from the vibratory movement. As the rate of rotation increases, so does the displacement of the mass and the signal derived from the corresponding capacitance change.It should be noted that the gyro may be placed anywhere on the rotating object and at any angle, so long as its sensing axis is parallel to the axis of rotation. The above explanation is intended to give an intuitive sense of the function and has been simplified by the placement of the gyro.

#### 5.7.1.3 CAPACITIVE SENSING

ADXRS gyros measure the displacement of the resonating mass and its frame due to the Coriolis effect through capacitive sensing elements attached to the resonator, as shown in Figures 4, 5, and 6. These elements are silicon beams inter-digitated with two sets of stationary silicon beams attached to the substrate, thus forming two nominally equal capacitors. Displacement due to angular rate induces a differential capacitance in this system. If the total capacitance is C and the spacing of the beams is g, then the differential capacitance is 2 ΩvMC/gK, and isdirectly proportional to the angular rate. The fidelity of this relationship is excellent in practice, with nonlinearity less than 0.1%.

The ADXRS gyro electronics can resolve capacitance changes as small as 12 × 10–21 farads (12 zeptofarads) from beam deflections as small as 0.00016 Angstroms (16 femtometers). The only

way this can be utilized in a practical device is by situating the electronics, including amplifiers and filters, on the same die as the mechanical sensor. The differential signal alternates at the resonator frequency and can be extracted from the noise by correlation.

The frame and resonating mass are displaced laterally in response to the Corioliseffect. The displacement is determined from the change in capacitance between the Coriolis sense fingers on the frame and those attached to the substrate.

### 5.7.2 MAGNETOMETER

A magnetometer is a scientific instrument used to measure the strength or direction of the magnetic field, either produced in the laboratory or existing in nature. The Earth’s magnetic field (the magnetosphere) varies from place to place, for various reasons such as inhomogeneity of rocks and the interaction between charged particles from the Sun and the magnetosphere. Magnetometers are a frequent component instrument on spacecraft that explore planets.

#### 5.7.2.1 USES

Magnetometers are used in ground-based electromagnetic geophysical surveys (such as magnetotellurics and magnetic surveys) to assist with detecting mineralization and corresponding

geological structures. Airborne geophysical surveys use magnetometers that can detect magnetic field variations caused by mineralization, using airplanes like the Shrike Commander.[1] Magnetometers are also used to detect archaeological sites, shipwrecks and other buried or submerged objects, and in metal detectors to detect metal objects, such as guns in security screening. Magnetic anomaly detectors detect submarines for military purposes.

They are used in directional drilling for oil or gas to detect the azimuth of the drilling tools near the drill bit. They are most often paired up with accelerometers in drilling tools so that both the inclination and azimuth of the drill bit can be found.

Magnetometers are very sensitive, and can give an indication of possible auroral activity before one can see the light from the aurora. A grid of magnetometers around the world constantly measures the effect of the solar wind on the Earth’s magnetic field, which is published on the K-index.

A three-axis fluxgate magnetometer was part of the Mariner 2 and Mariner 10 missions.[3] A dual technique magnetometer is part of the Cassini-Huygens mission to explore Saturn.[4] This system is composed of a vector helium and fluxgate magnetometers.[5] Magnetometers are also a component instrument on the Mercury MESSENGER mission. A magnetometer can also be used by satellites like GOES to measure both the magnitude and direction of a planet’s or moon’s magnetic field.

#### 5.7.2.2 FEATURES

Precision 3-axis Capability.

Factory Calibrated Analog Outputs.

40 micro-gauss to 2 gauss Dynamic Range.

Analog Output at 1 Volt/gauss (2.5V @ 0 gauss)

On-board +2.5 Volt Reference.

+6 to +15 Volt DC Single Supply Operation.

Very Low Magnetic Material Content.

-40° to 85°C Operating Temperature Range.

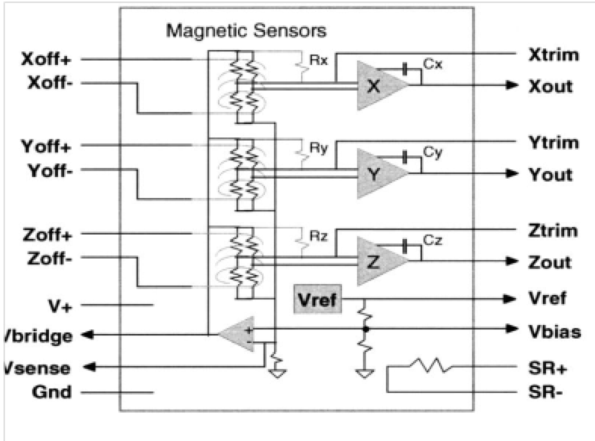


**FIGURE 5.12:** magneto resistive sensors in a magnetometer

### 5.7.3 ACCELEROMETER

An accelerometer is a device that measures the proper acceleration of the device. This is *not necessarily* the same as the coordinate acceleration (change of velocity of the device in space), but is rather the type of acceleration associated with the phenomenon of weight experienced by a test mass that resides in the frame of reference of the accelerometer device. For an example of where these types of acceleration differ, an accelerometer will measure a value when sitting on the ground, because masses there have weights, even though they do not change velocity. However, an accelerometer in gravitational free fall toward the center of the Earth will measure a value of zero because, even though its speed is increasing, it is in an inertial frame of reference, in which it is weightless.

#### 5.7.3.1 PHYSICAL PRINCIPLES

An accelerometer measures proper acceleration, which is the acceleration it experiences relative to free-fall and is the acceleration felt by people and objects. Put another way, at any point in space-time the equivalence principle guarantees the existence of a local inertial frame, and an accelerometer measures the acceleration relative to that frame. Such accelerations are popularly measured in terms of g-force.

#### 5.7.3.2 STRUCTURE

Conceptually, an accelerometer behaves as a damped mass on a spring. When the accelerometer experiences acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing. The displacement is then measured to give the acceleration.

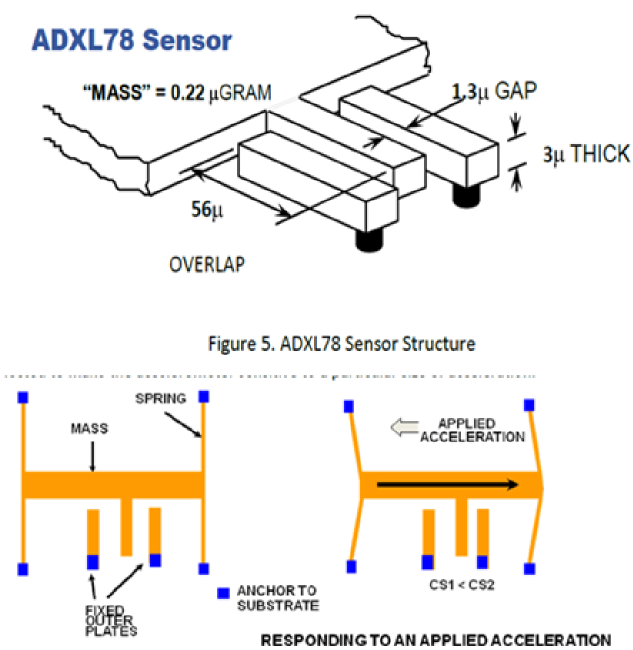


**FIGURE 5.13:** working of accelerometer

Capacitive accelerometers typically use a silicon micro-machined sensing element. Their performance is superior in the low frequency range and they can be operated in servo mode to achieve high stability and linearity.

#### 5.7.3.3 PARTS LIST (and functional description)

| Qty | Part Number | Functional Description |
|---|---|---|
| 1 | ADXL335 | Three-axis accelerometer |
| 1 | LPR530AL | Two-axis gyro |
| 1 | LY530ALH | One-axis gyro |
| 1 | HMC5843 | Three-axis magnetometer |

## 6. MOTORS

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### 6.1 DC MOTORS

A DC motor is an electric motor that runs on direct current (DC) electricity. In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. As you are well aware of from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.

A dc motor can be broadly classified into two distinguished types of motors namely -:

Brushed dc motor

Brushless dc motor

As per our project we will be concentrating more on the concept of brushless dc motor.

### 6.2 BRUSHED DC MOTOR

A brushed DC motor is an internally commutated electric motor designed to be run from a DC power source. The brushed dc electric motor generates torque directly from DC power supplied to the motor by using internal commutation, stationary permanent magnets, and rotating electrical magnets.

Like all electric motors or generators, torque is produced by the principle of Lorentz force, which states that any current-carrying conductor placed within an external magnetic field experiences a torque or force known as Lorentz force.

When a current passes through the coil wound around a soft iron core, the side of the positive pole is acted upon by an upwards force, while the other side is acted upon by a downward force. According to Fleming's left hand rule, the forces cause a turning effect on the coil, making it rotate. To make the motor rotate in a constant direction, "direct current" commutators make the

current reverse in direction every half a cycle (in a two-pole motor) thus causing the motor to continue to rotate in the same direction.

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A problem with the motor shown above is that when the plane of the coil is parallel to the magnetic field—i.e. when the rotor poles are 90 degrees from the stator poles—the torque is zero. In the pictures above, this occurs when the core of the coil is horizontal—the position it is just about to reach in the last picture on the right. The motor would not be able to start in this position. However, once it was started, it would continue to rotate through this position by inertia.

The figure 6.1 explains the working of a brushed DC Motor:

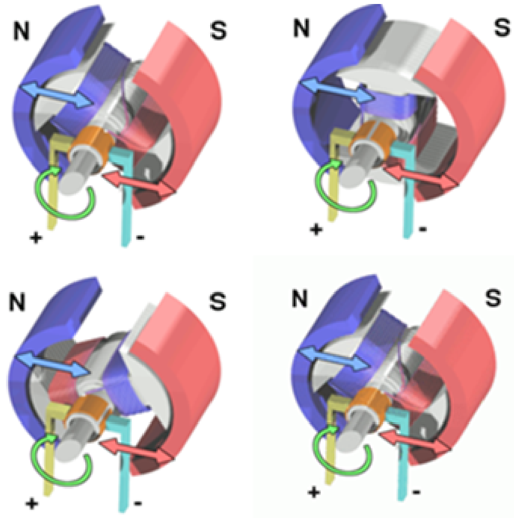


**FIGURE 6.1:** working of brushed motor

### 6.3 FLEMING'S LEFT HAND RULE

Fleming's left hand rule (for motors), is a visual mnemonics that is used for working out which way an electric motor will turn. The term was coined by John Ambrose Fleming in the late 19th century. When an electric current flows in a wire, and an external magnetic field is applied across that flow, the wire experiences a force perpendicular both to that field, and to the direction of the current flow. A left hand can be held, as shown in the illustration, so as to represent three mutually orthogonal axes on the thumb, first finger and middle finger. It is then just a question of remembering which finger represents which quantity (electric current, magnetic field and mechanical force), and whether the right hand should be used instead of the left.

### 6.4 BRUSHLESS DC MOTOR

**Brushless DC motors** (**BLDC motors**, **BL motors**) also known as **electronically commutated motors** (ECMs, EC motors) are synchronous electric motors powered by direct-current (DC) electricity and electronic commutation systems, rather mechanical commutators and brushes.

The current-to-torque and frequency-to-speed relationships of BLDC motors are linear. BLDC motors may be described as stepper motors, with fixed permanent magnets and possibly more poles on the rotor than the stator, or reluctance motors. The latter may be without permanent magnets, just poles that are induced on the rotor then pulled into alignment by timed stator windings. However, the term stepper motor tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined

angular position; this page describes more general BLDC motor principles, though there is overlap.Now the movement of the magnet in the center depends on the direction of flow of current in the coil as shown in the above figure. The continuous movement of the magnet is ensured by **Left hand rule for the coils.**

### 6.5 LEFT HAND RULE FOR THE COILS

The left hand rule states that Grasp the coil in your left hand, with your finger wrapped around in the direction of the current. Your thumb will point towards the north pole of the coil.

### 6.6 BRUSHLESS VS BRUSHED DC MOTOR

Limitations of brushed DC motors overcome by BLDC motors include lower efficiency and susceptibility of the commutator assembly to mechanical wear and consequent need for servicing, at the cost of potentially less rugged and more complex and expensive control electronics. A BLDC motor has permanent magnets which rotate and a fixed armature, eliminating the problems of connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system.

BLDC motors offer several advantages over brushed DC motors, including more torque per weight and efficiency, reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator, more power, and overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter.

The maximum power that can be applied to a BLDC motor is exceptionally high, limited almost exclusively by heat, which can weaken the magnets. A BLDC motor's main disadvantage is higher cost, which arises from two issues. First, BLDC motors require complex electronic speed controllers to run. Brushed DC motors can be regulated by a comparatively simple controller, such as a rheostat (variable resistor). However, this reduces efficiency because power is wasted in the rheostat. Second, some practical uses have not been well developed in the commercial sector. For example, in the Radio Control (RC) hobby, even commercial brushless motors are often hand-wound while brushed motors use armature coils which can be inexpensively machine-wound.

BLDC motors are often more efficient at converting electricity into mechanical power than brushed DC motors. This improvement is largely due to the absence of electrical and friction losses due to brushes. The enhanced efficiency is greatest in the no-load and low-load region of the motor's performance curve. Under high mechanical loads, BLDC motors and high-quality brushed motors are comparable in efficiency.

### 6.7 OUT-RUNNER MOTOR

The term **out-runner** refers to a type of brushless motor primarily used in electrically propelled, radio-controlled model aircraft. This type of motor spins its outer shell around its windings, much like motors found in ordinary CD-ROMs computer drives. In fact, CD-ROM motors are frequently rewound into brushless out-runner motors for small park flyer aircraft. Parts to aid in converting CD-ROM motors to aircraft use are commercially available.

Out-runners spin much slower than their in-runner counterparts with their more traditional layout (though still considerably faster than ferrite motors) while producing far more torque. This makes an out-runner an excellent choice for directly driving electric aircraft propellers since they eliminate the extra weight, complexity, inefficiency and noise of a gearbox.

Out-runner motors have quickly become popular and are now available in many sizes. They have also become popular in personal, electric transportation applications such as electric bikes and scooters due to their compact size and favorable power-to-weight ratios.

The stationary (stator) windings of an out-runner motor are excited by conventional DC brushless motor controllers. A direct current (switched on and off at high frequency for voltage modulation) is typically passed through three or more non-adjacent windings together, and the group so energized is alternated electronically based upon rotor position feedback.

The number of permanent magnets in the rotor does not match the number of stator poles, however. The difference between the number of magnet poles and the number of stator poles provides an effect that can be understood as similar to planetary gearing. The number of magnet poles divided by 2 gives the ratio of magnetic field rotation speed to motor rotation speed. Consequently the advance of the electromagnetic impulse around the motor axis proceeds much

faster than the rotor turns. With more magnet poles the maximum torque is increased, while the speed of rotor advance is decreased in proportion to the ratio of magnet poles to stator poles.

In an out-runner the outer shell constituting the magnets are rotated around the windings (coils).

An out runner is mounted below the surface of the quad consolidating the centre of gravity and providing more stability. The out runner is basically used to counter the inverse pendulum problem due to which if any stacking or mounting is done on top of the quad copter it can be stabilized thru out runners.

#### 6.7.1 OUTRUNNER WE HAVE USED


**FIGURE 6.5:** OUTRUNNER MOTOR

**TABLE 6.1: OUTRUNNER MOTOR SPECIFICATIONS**

| | |
|---|---|
| Kv (rpm/v) | 1000 |
| Weight (g) | 80 |
| Max Current (A) | 0 |
| Resistance (mh) | 0 |
| Max Voltage (V) | 11 |
| Power(W) | 300 |
| Shaft A (mm) | 4 |
| Length B (mm) | 37 |
| Diameter C (mm) | 28 |
| Can Length D (mm) | 22 |
| Total Length E (mm) | 58 |

### 6.8 ELECTRONIC SPEED CONTROLLER

The purpose of a motor speed controller is to take a signal representing the demanded speed, and to drive a motor at that speed. With the purpose to vary an electric motor's speed and direction ESCs are often used on electrically-powered radio controlled models. An ESC can be a stand-alone unit which plugs into the receiver's throttle control channel or incorporated into the receiver itself, as is the case in most toy-grade R/C vehicles. Some R/C manufacturers that install proprietary hobby-grade electronics in their entry-level vehicles, vessels or aircraft use onboard electronics that combine the two on a single circuit board.

#### 6.8.1 FUNCTION

Regardless of the type used, an ESC interprets control information not as mechanical motion as would be the case of a servo, but rather in a way that varies the switching rate of a network of field effect transistors, or FETs. The rapid switching of the transistors is what causes the motor itself to emit its characteristic high-pitched whine, especially noticeable at lower speeds. It also allows much smoother and more precise variation of motor speed in a far more efficient manner than the mechanical type with a resistive coil and moving arm once in common use.Most modern ESCs incorporate a battery eliminator circuit (or BEC) to regulate voltage for the receiver, removing the need for 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 results in a 50% duty cycle output signal that drives the motor at approximately half-speed. When presented with 2.0 ms input signal, the motor runs at full speed due to the 100% duty cycle (on constantly) output.

#### 6.8.2 HOW IS SPEED VARIED?

When we watch a film in the cinema, or the television, what we are actually seeing is a series of fixed pictures, which change rapidly enough that our eyes just see the average effect – movement. Now by switching the motor's supply on and off very quickly. If the switching is fast enough, the

motor doesn't notice it, it only notices the average effect. As the amount of time that the voltage is *on* increases compared with the amount of time that it is *off*, the average speed of the motor increases This *on-off* switching is performed by power MOSFETs. A MOSFET (Metal-Oxide-Semiconductor Field Effect Transistor).It is a device that can turn very large currents on and off under the control of a low signal level voltage.

If the supply voltage is switched fast enough, it won't have time to change speed much, and the speed will be quite steady. This is the principle of switch mode speed control. Thus the speed is set by PWM – Pulse Width Modulation. The graph above shows the speed of a motor that is being turned on and off fairly slowly:

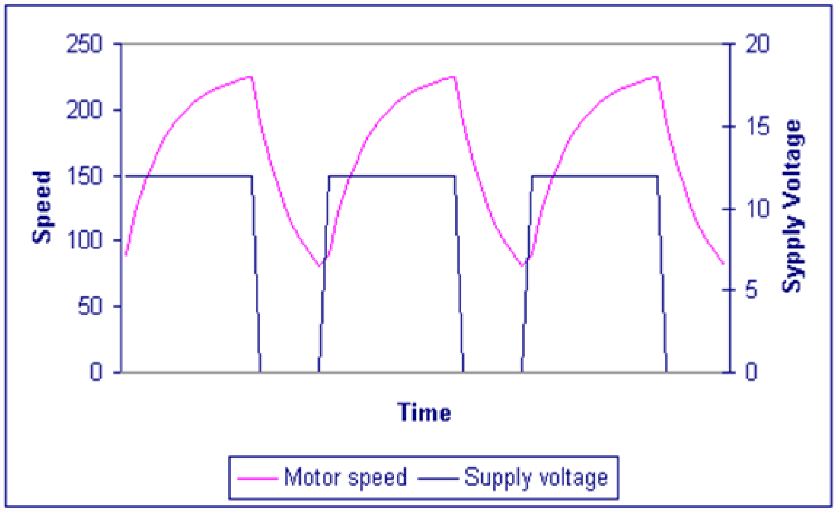


FIGURE 6.6: speed of motor that is being turned on and ofF slowly

Each switching on and off of the speed controller MOSFETs results in a little power loss. Therefore the greater the time spent switching compared with the static on and off times, the greater will be the resulting 'switching loss' in the MOSFETs. The higher the switching frequency, the more stable is the current waveform in the motors. The connection below shows the motor, esc and the battery.

### 6.8.3 SWITCHING CIRCUIT FOR MOTORS

**Figure shows how the stator coils are magnetized on supply of current**

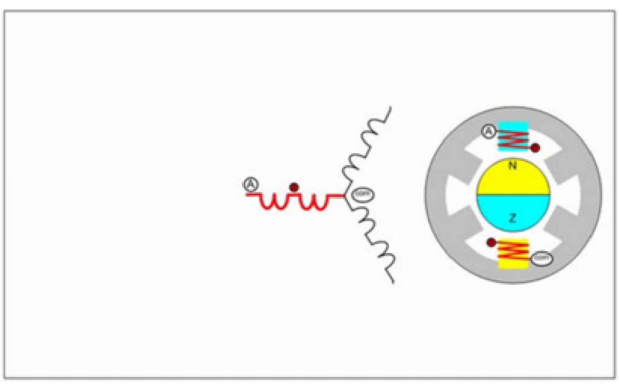

**FIGURE 6.7:** COIL LAYOUT and MAGNETIC ORIENTATION

-

## 7. SURVEILLANCE CAMERAS

### 7.1 IMAGE SENSORS

An image sensor is a device that converts an optical image to an electric signal. It is used mostly in digital cameras and other imaging devices. Early sensors were video camera tubes but a modern one is typically a charge-coupled device (CCD) or a complementary metal–oxide–semiconductor (CMOS) active pixel sensor.

### 7.2 WHAT IS CCD?

A charge-coupled device (CCD) is a device for the movement of electrical charge, usually from within the device to an area where the charge can be manipulated, for example conversion into a digital value. This is achieved by “shifting” the signals between stages within the device one at a time. CCDs move charge between capacitive bins in the device, with the shift allowing for the transfer of charge between bins. Often the device is integrated with an image sensor, such as a photoelectric device to produce the charge that is being read, thus making the CCD a major technology for digital imaging. Although CCDs are not the only technology to allow for light detection, CCDs are widely used in professional, medical, and scientific applications where high-quality image data is required.

### 7.3 BASIC OPERATION OF CCD

The charge packets (electrons, blue) are collected in potential wells (yellow) created by applying positive voltage at the gate electrodes (G). Applying positive voltage to the gate electrode in the correct sequence transfers the charge packets, as shown in figure 7.1.

In a CCD for capturing images, there is a photoactive region (an epitaxial layer of silicon), and a transmission region made out of a shift register (the CCD, properly speaking).

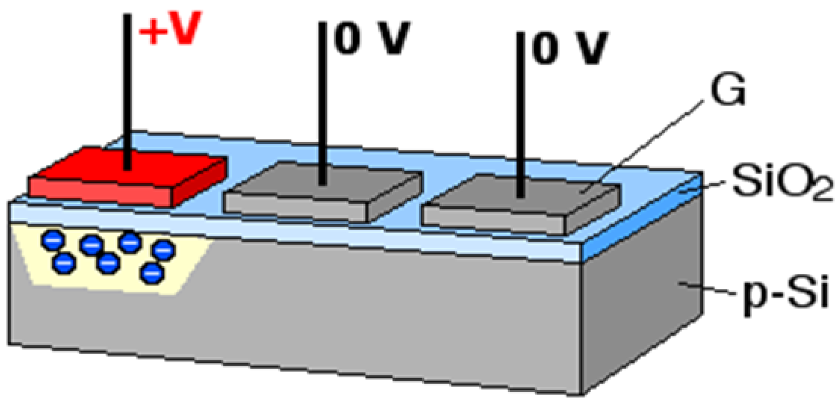


**FIGURE 7.1:** working of a ccd

An image is projected through a lens onto the capacitor array (the photoactive region), causing each capacitor to accumulate an electric charge proportional to the light intensity at that location. A one-dimensional array, used in line-scan cameras, captures a single slice of the image, while a two-dimensional array, used in video and still cameras, captures a two-dimensional picture corresponding to the scene projected onto the focal plane of the sensor. Once the array has been exposed to the image, a control circuit causes each capacitor to transfer its contents to its neighbor (operating as a shift register).

The last capacitor in the array dumps its charge into a charge amplifier, which converts the charge into a voltage. By repeating this process, the controlling circuit converts the entire contents of the array in the semiconductor to a sequence of voltages. In a digital device, these voltages are then sampled, digitized, and usually stored in memory; in an analog device (such as an analog video camera), they are processed into a continuous analog signal (e.g. by feeding the output of the charge amplifier into a low-pass filter) which is then processed and fed out to other circuits for transmission, recording, or other processing.

### 7.4 BAYER FILTER ON A CCD

#### 7.4.1 CCD color sensor

Digital color cameras generally use a Bayer mask over the CCD. Each square of four pixels has one filtered red, one blue, and two green (the human eye is more sensitive to green than either red or blue). The result of this is that luminance information is collected at every pixel, but the color resolution is lower than the luminance resolution.

Better color separation can be reached by three-CCD devices (3CCD) and a dichroic beam splitter prism that splits the image into red, green and blue components. Each of the three CCDs is arranged to respond o a particular color. Most professional video camcorders, and some semi-professional camcorders, use this technique. Another advantage of 3CCD over a Bayer mask device is higher quantum efficiency (and therefore higher light sensitivity for a given aperture size). This is because in a 3CCD device most of the light entering the aperture is captured by a sensor, while a Bayer mask absorbs a high proportion (about 2/3) of the light falling on each CCD pixel.

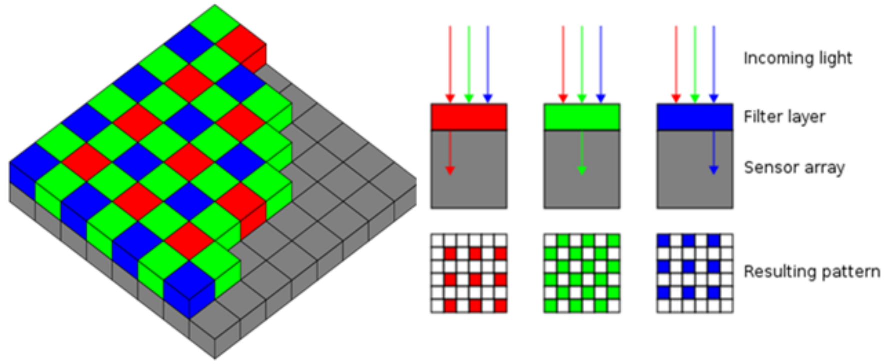


**FIGURE 7.2:** BAYER FILTER

For still scenes, for instance in microscopy, the resolution of a Bayer mask device can be enhanced by Micro scanning technology. During the process of color co-site sampling, several frames of the scene are produced. Between acquisitions, the sensor is moved in pixel dimensions, so that each

point in the visual field is acquired consecutively by elements of the mask that are sensitive to the red, green and blue components of its color. Eventually every pixel in the image has been scanned at least once in each color and the resolution of the three channels become equivalent (the resolutions of red and blue channels are quadrupled while the green channel is doubled).

### 7.4.2 CMOS

The CMOS active pixel sensor (APS) is a second generation solid state sensor technology that was invented and developed at JPL. The goal of the advanced imager technology effort at JPL has been the development of a "camera on a chip," which would have a full digital interface. Only digital power signals and power are input to the chip and only digital data is transmitted off chip. Miniaturization and simplification of the sensor electronics has high leverage for reducing system mass, volume and power. To achieve smaller and simpler sensor electronics will require the imaging instruments be highly integrated. By using CMOS APS technology low power, low volume, highly integrated imaging systems can now be realized. A complete imaging system would only require optics, a power supply, a CMOS APS imaging array with on-chip ADC(Analog to Digital Converter), and a microprocessor to upload the instructions to the imager and download the image data. CMOS APS technology utilizes active transistors in each pixel to buffer the photo-signal.

### 7.4.3 CMOS VS CCD

Today, most digital still cameras use either a CCD image sensor or a CMOS sensor. Both types of sensor accomplish the same task of capturing light and converting it into electrical signals.

A CCD is an analog device. When light strikes the chip it is held as a small electrical charge in each photo sensor. The charges are converted to voltage one pixel at a time as they are read from the chip. Additional circuitry in the camera converts the voltage into digital information.A CMOS chip is a type of active pixel sensor made using the CMOS semiconductor process. Extra circuitry next to each photo sensor converts the light energy to a voltage. Additional circuitry on the chip may be included to convert the voltage to digital data.

Neither technology has a clear advantage in image quality. On one hand, CCD sensors are more susceptible to vertical smear from bright light sources when the sensor is overloaded; high-end frame

transfer CCDs in turn do not suffer from this problem. CMOS can potentially be implemented with fewer components, use less power, and/or provide faster readout than CCDs. CCD is a more mature technology and is in most respects the equal of CMOS. CMOS sensors are less expensive to manufacture than CCD sensors.

In a CCD sensor, every pixel's charge is transferred through a very limited number of output nodes (often just one) to be converted to voltage, buffered, and sent off-chip as an analog signal. All of the pixel can be devoted to light capture, and the output's uniformity (a key factor in image quality) is high. In a CMOS sensor, each pixel has its own charge-to-voltage conversion, and the sensor often also includes amplifiers, noise-correction, and digitization circuits, so that the chip outputs digital bits. These other functions increase the design complexity and reduce the area available for light capture. With each pixel doing its own conversion, uniformity is lower. But the chip can be built to require less off-chip circuitry for basic operation.

CMOS cameras may require fewer components and less power, but they still generally require companion chips to optimize image quality, increasing cost and reducing the advantage they gain from lower power consumption. CCD devices are less complex than CMOS, so they cost less to design. CCD fabrication processes also tend to be more mature and optimized; in general, it will cost less (in both design and fabrication) to yield a CCD than a CMOS imager for a specific high-performance application. However, wafer size can be a dominating influence on device cost; the larger the wafer, the more devices it can yield, and the lower the cost per device. 200mm is fairly common for third-party CMOS foundries while third-party CCD foundries tend to offer 150mm.

The larger issue around pricing is sustainability. For some, the risk paid off and their volumes provided enough margins for viability. But others had to raise their prices, while still others went out of business entirely. High-risk startups can be interesting to venture capitalists, but imager customers require long-term stability and support. While cost advantages have been difficult to realize and on-chip integration has been slow to arrive, speed is one area where CMOS imagers can demonstrate considerable strength because of the relative ease of parallel output structures. This gives them great potential in industrial applications.

## 7.5 TUNER CARDS

A TV tuner card is a computer component that allows television signals to be received by a computer. Most TV tuners also function as video capture cards, allowing them to record television programs onto a hard disk.

The interfaces for TV tuner cards are most commonly either PCI bus expansion card or the newer PCI Express (PCIe) bus for many modern cards, but PCMCIA, Express Card, or USB devices also exist. In addition, some video cards double as TV tuners, notably the ATI All-In-Wonder series. The card contains a tuner and an analog-to-digital converter (collectively known as the analog front end) along with demodulation and interface logic. Some lower-end cards lack an onboard processor and, like a Win modem, rely on the system's CPU for demodulation.

### 7.5.1 TYPES OF TUNER CARDS

There are currently three kinds of tuner card on the market -:

Analog TV tuner

Hybrid TV tuner

Combo TV tuner

#### 7.5.1.1 ANALOG TV TUNER

Analog television cards output a raw video stream, suitable for real-time viewing but ideally requiring some sort of compression if it is to be recorded. More advanced TV tuners encode the signal to Motion JPEG or MPEG, relieving the main CPU of this load. Some cards also have analog input (composite video or S-Video) and many also provide FM radio.

#### 7.5.1.2 HYBRID TV TUNER

A hybrid tuner has one tuner that can be configured to act as an analog tuner or a digital tuner. Switching between the systems is fairly easy, but cannot be done immediately. The card operates as a digital tuner or an analog tuner until reconfigured.

#### 7.5.1.3 COMBO TV TUNER

This is similar to a hybrid tuner, except there are two separate tuners on the card. One can watch analog while recording digital, or vice versa. The card operates as an analog tuner and a digital tuner simultaneously. The advantages over two separate cards are cost and utilization of expansion slots in the computer. As many regions around the world convert from analog to digital broadcasts, these tuners are gaining popularity. Like the analog cards, the Hybrid and Combo tuners can have specialized chips on the tuner card to perform the encoding, or leave this task to the CPU. The tuner cards with this 'hardware encoding' are

generally thought of as being higher quality.[citation needed] Small USB tuner sticks have become more popular in 2006 and 2007 and are expected to increase in popularity. These small tuners generally do not have hardware encoding due to size and heat constraints.

While most TV tuners are limited to the radio frequencies and video formats used in the country of sale, many TV tuners used in computers use DSP, so a firmware upgrade is often all that's necessary to change the supported video format. Many newer TV tuners have flash memory big enough to hold the firmware sets for decoding several different video formats, making it possible to use the tuner in many countries without having to flash the firmware. However, while it is generally possible to flash a card from one analog format to another due to the similarities, it is generally not possible to flash a card from one digital format to another due to differences in decode logic necessary.

Many TV tuners can function as FM radios; this is because there are similarities between broadcast television and FM radio. The FM radio spectrum is close to (or even inside) that used by VHF terrestrial TV broadcasts. And many broadcast television systems around the world use FM audio. So listening to an FM radio station is simply a case of configuring existing hardware.

### 7.6 CAMERA USED:

Camera we have used is WS-309AS 1.2G Wireless Mini Camera

**Detailed Product Description:**

Features:
1) Transmitting unit:

a) 1/3″ or 1/4″ image sensor
b) System: PAL, CCIR, NTSC, EIA
c) Horizontal resolution: 380 TV lines
d) Output frequency: 1.2G, 2.4G
e) Transmission signal: video / audio
f) Linear transmission distance: 50 – 100m
2) Receiving unit:
a) Wireless audio / video receiver
b) Receiving frequency: 1.2G, 2.4G
c) Receiving signal: video / audio


**FIGURE 7.3:** WS-309AS 1.2G WIRELESS MINI CAMERA

### 7.7 T. V TUNER CARD USED:


**FIGURE 7.4:** TECHCOM TV TUNER CARD

## 8. LITHIUM POLYMER BATTERY

Lithium-ion polymer batteries, polymer lithium ion, or more commonly lithium polymer batteries (abbreviated Li-poly, Li-Pol, LiPo, LIP, PLI or LiP) are rechargeable batteries (secondary cell batteries). Normally batteries are composed of several identical secondary cells in parallel addition to increase the discharge current capability.

## 8.1 DESIGN ORIGIN

This type has technologically evolved from lithium-ion batteries. The primary difference is that the lithium-salt electrolyte is not held in an organic solvent but in a solid polymer composite such as polyethylene oxide or polyacrylonitrile. The advantages of Li-ion polymer over the lithium-ion design include potentially lower cost of manufacture, adaptability to a wide variety of packaging shapes, and ruggedness. Lithium-ion polymer batteries started appearing in consumer electronics around 1996.

## 8.2 TECHNOLOGY

Cells sold today as polymer batteries are pouch cells. Unlike lithium-ion cylindrical cells, which have a rigid metal case, pouch cells have a flexible, foil-type (polymer laminate) case. In cylindrical cells, the rigid case presses the electrodes and the separator onto each other; whereas in polymer cells this external pressure is not required because the electrode sheets and the separator sheets are laminated onto each other.

Since individual pouch cells have no strong metal casing, by themselves they are over 20% lighter than equivalent cylindrical cells. However, all Li-Ion cells expand at high levels of state of charge (SOC); if uncontained, this may result in delamination, and reduction of reliability and cycle life; the case of cylindrical cells provides that containment, while pouch cells, by themselves, are not contained. Therefore, to achieve the rated performance, a battery composed of pouch cells must include an overall, strong, external casing to retain its shape.Early in its development, lithium polymer technology had problems with internal resistance. Other challenges include longer charge times and slower maximum discharge rates compared to more mature technologies. Li-poly batteries typically

require more than an hour for a full charge. Recent design improvements have increased maximum discharge currents from two times to 15 or even 30 times the cell capacity (discharge rate in amperes, cell capacity in ampere-hours). In December 2007 Toshiba announced a new design offering a much faster rate of charge (about 5 minutes to reach 90%). These cells were released onto the market in March 2008 and are expected to have a dramatic effect on the power tool and electric vehicle industries, and a major effect on consumer electronics.

## 8.3 APPLICATION OF LIPO BATTERY

A compelling advantage of Li-poly cells is that manufacturers can shape the battery almost however they please, which can be important to mobile phone manufacturers constantly working on smaller, thinner, and lighter phones.

Li-poly batteries are also gaining favor in the world of radio-controlled aircraft as well as radio-controlled cars, where the advantages of both lower weight and greatly increased run times can be sufficient justification for the price. Some airsoft gun owners have switched to LiPo batteries due to the above reasons and the increased rate of fire they provide. However, lithium polymer-specific chargers are required to avoid fire and explosion. Explosions can also occur if the battery is short-circuited, as tremendous current passes through the cell in an instant. Radio-control enthusiasts take special precautions to ensure their battery leads are properly connected and insulated. Furthermore fires can occur if the cell or pack is punctured. Radio-controlled car batteries are often protected by durable plastic cases to prevent puncture. Speciallydesigned electronic motor speed controls are used to prevent excessive discharge and subsequent battery damage. This is achieved using a low voltage cutoff (LVC) setting that is adjusted to maintain cell voltage greater than (typically) 3 V per cell.

Li-poly batteries are also gaining ground in PDAs and laptop computers, such as Apple’s MacBook family, Amazon’s Kindle, Lenovo’s Think pad X300 and Ultra bay Batteries, the OQO series of palmtops, the HP Mini and Dell products featuring D-bay batteries. They can be found in small digital music devices such as iPods, Zunes, and other MP3 players and the Apple iPhone and iPad, as well as gaming equipment like Sony’s PlayStation 3 wireless controllers. They are desirable in applications where small form factors and energy density outweigh cost considerations.

## 8.4 STORAGE

Unlike certain other types of batteries, lithium polymer batteries can be stored for one or two months without significantly losing charge. However, if storing for long periods, manufacturers recommend discharging the battery to 40% of full charge. In addition, other sources recommend refrigerating (but not freezing) the cell.

## 8.5 LITHIUM POLYMER CHARGER

LiPoly batteries must be charged carefully. The basic process is to charge at constant current until each cell reaches 4.2 V; the charger must then gradually reduce the charge current while holding the cell voltage at 4.2 V until the charge current has dropped to a small percentage of the initial charge rate, at which point the battery is considered 100% charged. Some manufacturers specify 2%, others 3%, but other values are also possible. The difference in achieved capacity is minute.

### 8.6 LIPO BATTERY USED

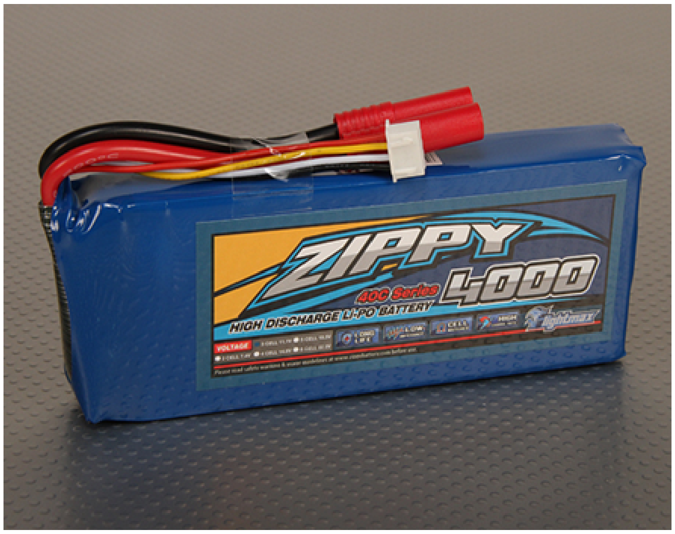


**FIGURE 8.1:** LIPO BATTERY

**BATTERY SPECIFICATION:**

| | |
|---|---|
| Capacity(mAh) | 4000 |
| Config(s) | 3 |
| Discharge(c) | 40 |
| Weight(g) | 351 |
| Max Charge Rate (C) | 2 |
| Length-A(mm) | 145 |
| Height-B(mm) | 50 |
| Width-C(mm) | 21 |

**TABLE 8.1:** LIPO BATTERY SPECIFICATIONS

### 8.7 LIPO BATTERY CHARGER USED

Lipo charger is used for charging the 1 to 6 cells lipo battery with a dedicated slot for each type. The display shows the amount of charge left in the battery and allows selecting the current required to charge the battery. The maximum current depends on the power source used, which may vary from 0.1A to 5A.


**FIGURE 8.2:** LIPO BATTERY CHARGER

There are two sets of wires provided with the charger. The battery can be charged in 3 modes that are,

Normal mode – in this mode the battery charging occurs using the specified current at a moderate rate.

It maintains the partial balance.

Fast mode – here the battery is charged at a faster rate.

Balanced mode – maintains a perfect balance between all the three cells being charged.

**Features:**

Microprocessor controlled

Delta-peak sensitivity

Individual cell balancing

Li-ion, LiPo and LiFe capable

Ni-Cd and NiMH capable

Large range of charge currents

Store function, allows safe storage current

Time limit function

Input voltage monitoring. (Protects car batteries at the field)

Data storage (Store up to 5 packs in memory)

**Specifications:**

Input Voltage: 11~18v

Circuit power: Max Charge: 50W / Max Discharge: 5W

Charge Current Range: .1~5.0A

Discharge current range: .1~1.0A

Ni-MH/NiCd cells: 1~15

Li-ion/Poly cells: 1~6

Pb battery voltage: 2~20v

Weight: 277g

Dimensions: 133x87x33mm

## 9. CONCLUSION AND SCOPE FOR FUTURE ENHANCEMENTS

### 9.1 CONCLUSION

As per the design specifications, the quad copter self stabilizes using the array of sensors integrated on it. It attains an appropriate lift and provides surveillance of the terrain through the camera mounted on it. It acts appropriately to the user specified commands given via a remote controller.

Its purpose is to provide real time audio/video transmission from areas which are physically in-accessible by humans. Thus, its functionality is monitored under human supervision, henceforth being beneficial towards military applications. It is easy to maneuver, thereby providing flexibility in its movement. It can be used to provide surveillance at night through the usage of infrared cameras. The system can further be enhanced for future prospects.

### 9.2 SCOPE FOR FUTURE ENHANCEMENTS

Future of a quad-copter is quite vast based on various application fields it can be applied to. Quad-copter can be used for conducting rescue operations where it's humanly impossible to reach. In terms of its military applications it can be more widely used for surveillance purposes, without risking a human life. As more automated quad-copters are being developed, there range of applications increases and hence we can ensure there commercialization. Thus quad-copter can be used in day to day working of a human life, ensuring their well-being.

With further study and advancement in technology, designers are quite sure that a quad-copter can be used for construction of huge towers and buildings. The main advantage in the future use of a quad-copter for various purposes is that risk to human life, may it be because of war or due to commercial accidents can be greatly avoided. The future of quad-copter sure is bright and not far ahead.

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7 Advertising Programs for Bloggers

### 13 Responses to “Project Report of QuadCopter”

**best mortgage uk**
August 22, 2013 at 4:09 am

Yes! Finally someone writes about k-index.

**Full service catering in orange county**
May 24, 2013 at 8:55 pm

I know this web site presents quality based content and additional material, is there any other website which
gives such information in quality?

**www.imleyelim.com**
August 8, 2013 at 3:57 pm

This is a topic which is close to my heart… Many thanks!
Where are your contact details though?

**planturl.com**
August 8, 2013 at 6:57 pm

This paragraph will help the internet people for setting up new blog or even a blog from start to end.

**forex**
August 11, 2013 at 10:12 pm

Awesome! Its truly awesome article, I have got much clear idea on the topic of from this post.

**austinhiphopscene.com**
August 11, 2013 at 10:15 pm

Hi there mates, its wonderful piece of writing regarding teachingand fully defined, keep it up all the time.

**trader les options binaires**
August 12, 2013 at 4:30 am

Hello, i believe that i noticed you visited my website so i got here to return the
want?.I am attempting to to find things to enhance my site!I
suppose its good enough to use a few of your concepts!!

**Micro Electro Mechanical Systems**
May 22, 2013 at 10:29 pm

I could not resist commenting. Very well written!

レアルマドリード 優勝
May 2, 2013 at 6:24 pm

General Secretary and everyone applauded the heroic spirit of the old scientist. The applause, the important contributions made for the elderly and sound, but also for the pursuit of the elderly and sound.

**is.gd**
April 27, 2013 at 6:23 pm

Which program is better and designing and creating an online magazine?
Joomla or WordPress?

**holiadopayfah**
April 21, 2013 at 5:06 pm

A tooth (plural teeth) is a mignonne, calcified, whitish order ground in the jaws (or mouths) of innumerable vertebrates and used to break down food. Some animals, explicitly carnivores, also use teeth for hunting or owing defensive purposes. The roots of teeth are covered by means of gums. Teeth are not made of bone, but to a certain extent of multiple tissues of varying density and hardness.
The community systematize of teeth is be like across the vertebrates, although there is of distinction modifying in their shape and position. The teeth of mammals get esoteric roots, and this design is also rest in some fish, and in crocodilians. In most teleost fish, manner, the teeth are partial to to the outer surface of the bone, while in lizards they are attached to the inner come up of the jaw during one side. In cartilaginous fish, such as sharks, the teeth are attached by means of rough ligaments to the hoops of cartilage that accumulate the jaw.

**Alina**
March 2, 2013 at 7:49 am

Awsum work

**How can I make money working from home with network marketing**
May 25, 2013 at 1:55 am

Pretty nice post. I simply stumbled upon your blog and wished to say that I have really enjoyed surfing around your blog posts. In any case I will be subscribing in your feed and I'm hoping you write again soon!