An Autonomous Quadrotor Flying Robot

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CHAPTER 1

INTRODUCTION

The HoverBot uses four rotor heads and four electric motors, making it whisper-quiet, easy-to-deploy, and even suitable for indoor applications. Without a skilled human pilot at the controls, the foremost problems in realizing a model helicopter-sized flying robot are stability and control. It is necessary to investigate the stability and control problems, define solutions to overcome these problems, and build a prototype vehicle to demonstrate the feasibility of the solutions. One of the main design goals was to obtain a high controlling frequency throughout the system. We have used in this project frequency of 2.4 GHZ. Four brushless DC motors of low weight and high rpm is being used along with four Propeller. High control frequency precludes the use of commercially available brushless motor controllers, such as those found in model aircrafts, as they only allow motor speed update rates of 2.4GHz. This controller has very low dead times and supports very dynamic movements. Intensive manual acrobatic flights with loops, flips, spins, sharp turns and combined maneuvers proofed the stability of the controller in extreme situations.

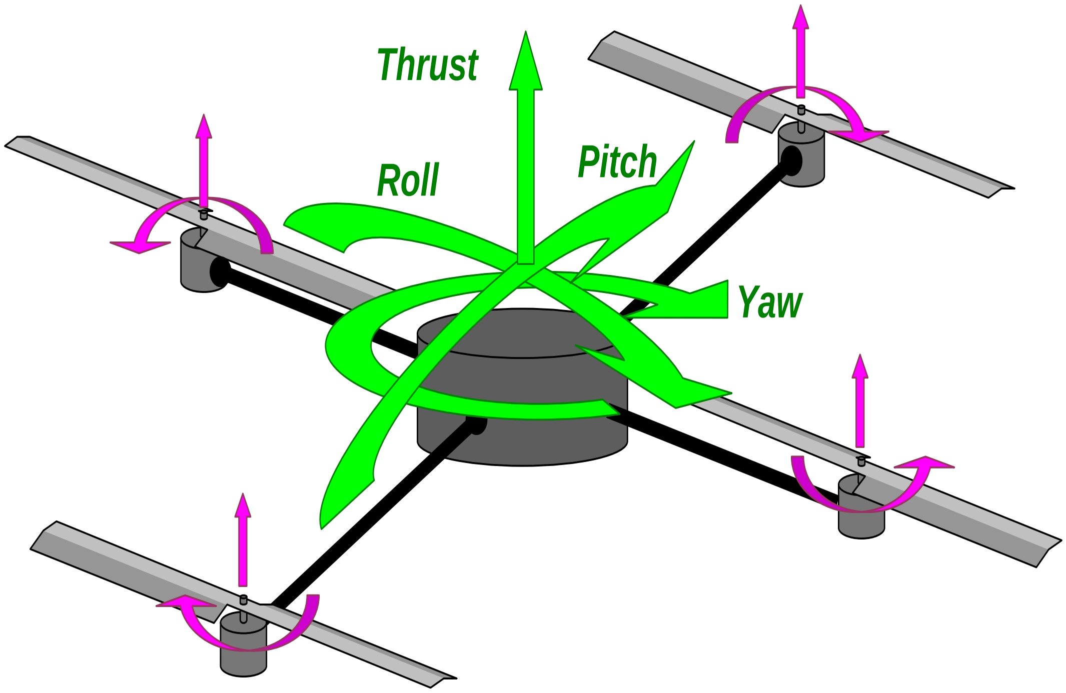


Figure. 1.1 Aerodynamic of Quadrotor

Having such a high control frequency allows us to create an extremely stable platform, even with payloads of up to 350g. Many applications for such a platform exist. The outstanding stability of the platform makes the integration of onboard and off board position tracking system possible. In this project we demonstrate the performance of the system using an external motion tracking system to provide closed loop position control. Cameras mounted on the platform also benefit from a stable image.

1.1 AIM OF THE PROJECT

The goal of this project is to create a semi-autonomous hovering platform, capable of vertical lift-off and landing without a launcher, and capable of stationary hovering at one location. It also has an advance feature of sensing of the gases exist in atmosphere along with wireless camera for continuous transmission of video to remote location.

1.2 BRIEF HISTORY

- **Oehmichen No.2**, 1920

Etienne Oehmichen experimented with rotorcraft designs in the 1920s. Among the six designs he tried, his helicopter No.2 had four rotors and eight propellers, all driven by a single engine. The Oehmichen No.2 used a steel-tube frame, with two-bladed rotors at the ends of the four arms. The angle of these blades could be varied by warping. Five of the propellers, spinning in the horizontal plane, stabilized the machine laterally. Another propeller was mounted at the nose for steering. The remaining pair of propellers were for forward propulsion. The aircraft exhibited a considerable degree of stability and controllability for its time, and made more than a thousand test flights during the middle 1920s. By 1923 it was able to remain airborne for several minutes at a time, and on April 14, 1924 it established the first-ever FAI distance record for helicopters of 360 m (390 yd). Later, it completed the first 1 kilometre (0.62 mi) closed-circuit flight by a rotorcraft.

- **de Bothezat Quadrator**, 1922

  Dr. George de Bothezat and Ivan Jerome developed this aircraft, with six bladed rotors at the end of an X-shaped structure. Two small propellers with variable pitch were used for thrust and yaw control. The vehicle used collective pitch control. It made its first flight in October 1922. About 100 flights were made by the end of 1923. The highest it ever reached was about 5 m (16 ft 5 in). Although demonstrating feasibility, it was, underpowered, unresponsive, mechanically complex and susceptible to reliability problems. Pilot workload was too high during hover to attempt lateral motion.

- **Convert wings Model "A" Quadrotor**, 1955

  This unique helicopter was intended to be the prototype for a line of much larger civil and military Quadrotor helicopters. The design featured two engines driving four rotors with wings added for additional lift in forward flight. No tail rotor was needed and control was obtained by varying the thrust between rotors. Flown successfully many times in the mid 1950s, this helicopter proved the Quadrotor design and it was also the first four-rotor helicopter to demonstrate successful forward flight. Due to a lack of orders for commercial or military versions however, the project was terminated.

- **Curtiss-Wright VZ-7**, 1958

  The Curtiss-Wright VZ-7 was a VTOL aircraft designed by the Curtiss-Wright company for the US Army. The VZ-7 was controlled by changing the thrust of each of the four propellers

The foremost problem with model-sized helicopters is stability. All helicopters (large ones as well as model-sized ones) are dynamically instable because of the lack of damping [Saunders, 1975]. In the absence of natural damping (typically found in ground-based vehicles in the form of friction), a helicopter must be stabilized by the pilot. This task is easier for large helicopters, because they have a larger time constant. In model-sized helicopters the time-constant is very small, and stable hovering is difficult to achieve. For this reason, it takes model-helicopter pilots months and months of exercise and training to acquire the skill of manual stable hovering [Tradelius, 1991]. In a robotic model-sized helicopter, the difficulty of stabilizing the craft falls onto the onboard controller. Technologically, this is quite a challenge since the smaller time constants require a much faster response time, which, in turn, requires accurate motion sensors and fast computers. Yet, the model-sized helicopter is severely limited in its payload capacity and can only carry lightweight, less powerful computers and less accurate sensor systems. In our project we add a further dimension to the challenge by attempting to design an ***electrically powered*** flying platform. If successful, an electrically powered device would have very unique advantages for certain applications, because it would be suitable for indoor applications, Other potential applications are emergency response, as well as police and military applications. The only acceptable solution for most of these applications is an electrically powered platform. The disadvantage of electric power compared to gasoline power is the even further reduced payload capacity. We propose to overcome both the payload problem and the stability problem by implementing a unique four-rotor design. Four-rotor platforms are not a new idea see the history of vertical flight shows several attempts at implementing such designs (the earliest dating back to 1922 [Young, 1982]). As much as these attempts improved the overall payload capacity, they all found themselves discontinued because of the difficulty in manually controlling the four rotors. We believe that our proposed approach will overcome the problems of earlier 4-rotor designs and bring into existence an actually functioning, electrically powered, fully autonomous 4- rotor flying platform. Our preliminary experimental results to date show that the payload problem, although ever-present in all design considerations, is successfully addressed by the 4-rotor design. The focus of this proposal is therefore the question of stability. We believe that the results of our project will not only help create a flying robot, but they will also have direct bearing on the design of large (people carrying) 4-rotor rotorcrafts.

1.3 RECENT TREND AND DEVELOPMENT

Now days to design Autonomous four quadrator flying robot basically 2.4 GHZ frequency wit four brushless DC Motors are being used. DC motors are being used because of their high RPM and low weight. For monitoring purpose camera is being used which can be efficient in transmitting continuous video to the base remote receiver.

Stability is the main criteria, In model-sized helicopters this presents a formidable difficulty, because of the much smaller time-constants. This is the reason why model-helicopter pilots need months and months of training, just to keep their helicopters in stable hovering. Model helicopter pilots we talked to confirm that stabilizing a small model helicopter is even more difficult than stabilizing a larger model helicopter. So stability factor are overcome by balancing each propeller efficiently and making a efficient control system . The control system of the ***HoverBot*** is designed to allow either fully autonomous operation or remote operation by an ***unskilled*** operator. To either, the ***HoverBot*** will appear as an omnidirectional vehicle with 4 degrees of freedom: (1) up/down (2) sideways, (3) forward/backward, and (4) horizontal rotation. Up/down motion is easily controlled by collectively increasing or decreasing the power to all 4 motors.

The 4-rotor design of our proposed *HoverBot* C originally motivated by considerations of payload C appears to have one unique advantage over conventional helicopter designs: the **distributed** weight of the 4 rotor heads increases the moment of inertial and thereby the time constant of the system. To illustrate this point, we can roughly estimate that the moment of inertia, *J*, of a 6 kg conventional (single rotor) helicopter model around its longitudinal axis is *J* = 0.06 Kgm2. By comparison, the 4-rotor *HoverBot* with the same weight has a moment of inertia of *J* = 1.53 Kgm2 around its least favorable axis. In other words, the moment of inertial of the *HoverBot* is approximately 1.53/0.06 = 25 times larger than that of a comparable conventional helicopter. Since the time-constant J of the system is proportional to the square root of the moment of inertia (J % *J*2), the time-constant of the *HoverBot* is (25)2 = 5 times larger than that of the conventional helicopter design. Stabilization of this rotorcraft will be greatly facilitated by the much larger time constant.

Fig 1.2 Overview of Quadrotor

1.4 LITERATURE REVIEW

There is a fair amount of published research with regards to quad-rotor aircraft. In fact, there are many patents for designs similar to ours. Among them are a few “Four Propeller Helicopter” designs (Dammar, Michael. "Four Propeller Helicopter". US Patent D465196. November 2002.), some “Quad Tiltrotor” designs (DeTore, John A., Richard F. Spivey, Malcolm P. Foster, and Tom L. Wood. "Quad Tiltrotor." US Patent D453317. February 2002.), and various vertical lift aircrafts (Smart, R.C. "Vertical Lift Aircraft." US Patent 3185410. May 1965.) While the above mentioned four propeller helicopter and the Quad tilt-rotor patent applications do not include much information aside from the purpose of the craft and the orientation of the rotors, it is without a doubt that the crafts are similar to the quad-rotor UAV.

R.C. Smart's “Vertical Lift Aircraft,” on the other hand, includes operational details, such as basic information on the particular dynamics of that craft. In the world of higher education, there are a few members of academia who have published research on quad-rotor UAVs. Among them are Joseph F. Horn and Wei Guo of Pennsylvania State University (“Modeling and Simulation for the Development of a Quad-Rotor UAV Capable of Indoor Flight”), Ming Chen and Mihai Huzmezan of the University of British Columbia (“A Simulation Model and H8 Loop Shaping Control of a Quad Rotor

Unmanned Air Vehicle"), and Eryk Brian Nice of Cornell University ("Design of a Four Rotor Hovering Vehicle").

An attempt to search for similar projects on the market did not yield many results. Aside from a few overachieving hobbyists, there exist only a few commercially available products which take advantage of similar quad-rotor flight: the Silverlit X-UFO, the Draganflyer V Ti, and the Microdrones GmbH MD4-200. All three of these products use four rotors in conjunction with a control system that consists of three gyroscopes for feedback. The Microdrones GmbH MD4-200 and a particular model of the Draganflyer V Ti additionally have an onboard camera for reconnaissance purposes. However, as these crafts are designed as high-end hobbyist crafts, they also come with a fairly steep price tag, as the Draganflyer and the Microdrones products are upwards of $1500 or more. On a much larger, industrial scale, there is currently a project in development named the Bell Boeing Quad TiltRotor. It is a large-scale, government-sponsored, quad-rotor aircraft currently in development as a joint venture between Bell Helicopter Textron and Boeing Integrated Defense Systems. The project is the largest-scale of all the existing projects, and with a capacity of upwards of 150 passengers, far exceeds the size and span of any other similar project.

CHEPTER 2

THEORETICAL DETAIL

Quadrotor consists of two subsystems .a ground station that is responsible for flight control and data processing, and the aerial vehicle, which features a dual processor avionics system and carries a wide-angle video camera system and a high -resolution still camera.

Implementation is completely divided into two parts

1. Aerial Unit Implementation
2. Electronics Unit Implementation

2.1 AERIAL UNIT IMPLEMENTATION

This phase will hopefully facilitate the control of the aircraft as it will provide us with a better understanding of the overall system capabilities and limitations. The current chapter will guide us through the equations and techniques used to model our Quadrotor and its sensors, providing the mathematical basis for the application of the system dynamics in a simulation environment.

2.1.1 SYSTEM DYNAMICS

Writing the equations that portray the complex dynamics of an aircraft implies first defining the system of coordinates to use. Only two reference frames are required, an earth fixed frame and a mobile frame whose dynamic behaviour can be described relative to the fixed frame. The earth fixed axis system will be regarded as an inertial reference frame: one in which the first law of Newton is valid. Experience indicates this to be acceptable even for supersonic airplanes but not for hypersonic vehicles. We shall designate this reference frame by Oned (North-East-Down) because two of its axis (ux and uy) are aligned respectively with the North and East direction, and the third axis (uz) is directed down, aligned towards the center of the Earth (Figure 5.3) The mobile frame is designated by Oabc, or Aircraft- Body-Cantered, and has its origin coincident with the Quad rotor’s center of gravity (Figure 2.1 a, b).

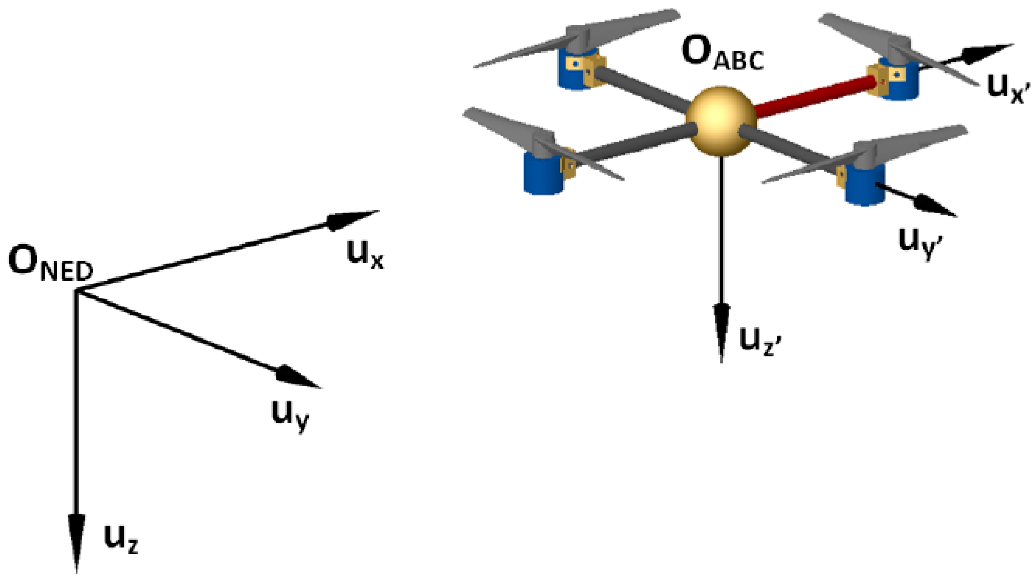


Figure 2.1 NED (a) and ABC (b) reference frames

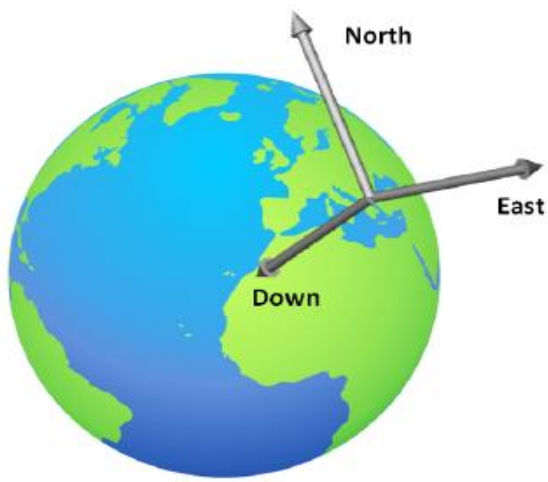


Figure 2.2 Visualization of the North-East-Down reference frame.

In control theory, knowledge about the dynamic behaviour of a given system can be acquired through its states. For a Quadrotor, its attitude about all 3 axis of rotation is known with 6 states: the Euler angles (Roll – Pitch – Yaw and the angular velocities around each axis of the OABC frame [P Q R]. Yet another 6 states are necessary: the position of the center of gravity (or COG) [X Y Z] and respective linear velocity components [U V W] relative to the fixed frame. In sum, the Quadrotor has 12 states that describe 6 degrees of freedom.

Unsurprisingly, we must deduce the equations describing the orientation of the mobile frame relative to the fixed one, which can be achieved by using a rotation matrix. This matrix results of the product between three other matrices R'(Ɵ), R'(ϕ) and R' (ψ), each of them representing the rotation of the ABC frame around each one of the ONED axis.

$$\mathrm{R}'(\phi)=\begin{bmatrix}1 & 0 & 0\\ 0 & \cos\phi & \sin\phi\\ 0 & -\sin\phi & \cos\phi\end{bmatrix}\ \mathrm{R}'(\theta)=\begin{bmatrix}\cos\theta & 0 & -\sin\theta\\ 0 & 1 & 0\\ \sin\theta & 0 & \cos\theta\end{bmatrix}\ \mathrm{R}'(\psi)=\begin{bmatrix}\cos\psi & \sin\psi & 0\\ -\sin\psi & \cos\psi & 0\\ 0 & 0 & 1\end{bmatrix}$$

$$\mathbf{S}=\mathrm{R}'(\phi)\,\mathrm{R}'(\theta)\,\mathrm{R}'(\psi)$$

$$\mathbf{S}=\begin{bmatrix}\cos\theta\cos\psi & \cos\theta\sin\psi & -\sin\theta\\ \sin\psi\sin\theta\cos\psi-\cos\phi\sin\psi & \cos\phi\cos\psi+\sin\phi\sin\theta\sin\psi & \sin\phi\cos\theta\\ \cos\phi\sin\theta\cos\psi+\sin\phi\sin\psi & \sin\theta\cos\phi\sin\psi-\sin\phi\cos\psi & \cos\theta\cos\phi\end{bmatrix}$$

Where S is the rotation matrix that expresses the orientation of the coordinate frame Oabc relative to the reference frame Oned.

To mathematically write the movement of an aircraft we must employ Newton's second law of motion. As such, the equations of the net force and moment acting on the Quad rotor's body (respectively Fnet and Mnet) are provided:

$$\mathbf{F}_{net}=\frac{d}{dt}\left[m\mathbf{v}\right]_B+\boldsymbol{\omega}'\times\left[m\mathbf{v}\right]_B$$

$$\mathbf{M}_{net}=\frac{d}{dt}[\mathbf{I}\boldsymbol{\omega}']_B+\boldsymbol{\omega}'\times\left[\mathbf{I}\boldsymbol{\omega}'\right]_B$$

Where I is the inertia matrix of the Quadrotor, v is the vector of linear velocities and w' the vector of angular velocities. If the equation of Newton's second law is to be as complete as possible, we should add extra terms such as the Coriolis, Euler and aerodynamic forces (e.g. wind), but to keep the model simple, and also because the

Quadrotor is not supposed, at this stage, to go very far away from the ground station, these forces will not be incorporated in the modelling process. The force of gravity (Fg) is too significative to be neglected, thus it is defined by:

$$\mathbf{F}_g = m\mathbf{S}\begin{bmatrix} 0 & 0 & g \end{bmatrix}^T = mg\begin{bmatrix} -\sin\theta & \cos\theta\sin\phi & \cos\theta\cos\phi \end{bmatrix}_B^T$$

The force of gravity together with the total thrust generated by the propellers (FP) have therefore to be equal to the sum of forces acting on the quadrotor:

$$\mathbf{F}_g + \mathbf{F}_P = \mathbf{F}_{net}$$

Put the values of Fg , Fp and Fnet we can write the vector of linear accelerations acting on the vehicle's body:

$$\begin{bmatrix} \dot{U} \\ \dot{V} \\ \dot{W} \end{bmatrix} = \frac{1}{m}\begin{bmatrix} F_{Px} \\ F_{Py} \\ F_{Pz} \end{bmatrix} + g\begin{bmatrix} -\sin\theta \\ \cos\theta\sin\phi \\ \cos\theta\cos\phi \end{bmatrix} - \begin{bmatrix} QW - RV \\ RU - PW \\ PV - QU \end{bmatrix}$$

Where [FPx FPy FPz] are the vector elements of FP . Assuming the aircraft is in a hovered flight, in such a scenario there are forces acting only in the z axis of Quadrotor, corresponding to the situation where we have the engines trying to overcome the force of gravity to keep the aircraft stable at a given altitude:

$$F_{Pz} = -(T_1 + T_2 + T_3 + T_4)$$

Note that the minus sign means the lifting force is acting upwards, away from the surface (note that the positive axis of the ONED is point downwards).

Working now on Newton's second law for rotation, the inertia matrix is given by:

$$\mathbf{I} = \begin{bmatrix} I_{11} & -I_{12} & -I_{13} \\ -I_{21} & I_{22} & -I_{23} \\ -I_{31} & -I_{32} & I_{33} \end{bmatrix}$$

Assuming the Quadrotor is a rigid body with constant mass and axis aligned with the principal axis of inertia, then the tensor I becomes a diagonal matrix containing only the principal moments of inertia:

$$\mathbf{I} = \begin{bmatrix} I_{11} & 0 & 0 \\ 0 & I_{22} & 0 \\ 0 & 0 & I_{33} \end{bmatrix}$$

Put the values of I into Mnet

$$\mathbf{M}_{net} = \begin{bmatrix} I_{11} & 0 & 0 \\ 0 & I_{22} & 0 \\ 0 & 0 & I_{33} \end{bmatrix} \begin{bmatrix} \dot{P} \\ \dot{Q} \\ \dot{R} \end{bmatrix} + \begin{bmatrix} P \\ Q \\ R \end{bmatrix} \times \begin{bmatrix} I_{11} & 0 & 0 \\ 0 & I_{22} & 0 \\ 0 & 0 & I_{33} \end{bmatrix} \begin{bmatrix} P \\ Q \\ R \end{bmatrix}$$

Consequently, we will have:

$$\mathbf{M}_{net} = \begin{bmatrix} I_{11}\dot{P} \\ I_{22}\dot{Q} \\ I_{33}\dot{R} \end{bmatrix} + \begin{bmatrix} (I_{33} - I_{22})\, QR \\ (I_{11} - I_{33})\, RP \\ (I_{22} - I_{11})\, PQ \end{bmatrix}$$

$$\begin{bmatrix} \dot{P} \\ \dot{Q} \\ \dot{R} \end{bmatrix} = \begin{bmatrix} \frac{M_x}{I_{11}} \\ \frac{M_y}{I_{22}} \\ \frac{M_z}{I_{33}} \end{bmatrix} - \begin{bmatrix} \frac{(I_{33}-I_{22})QR}{I_{11}} \\ \frac{(I_{11}-I_{33})RP}{I_{22}} \\ \frac{(I_{22}-I_{11})PQ}{I_{33}} \end{bmatrix}$$

Information on the moments acting on the aircraft can be provided by:

$$M_x = (T_4 - T_2)\, d_{cg}$$

$$M_y = (T_1 - T_3)\, d_{cg}$$

$$M_z = (T_1 + T_3 - T_2 - T_4)\, K_{TM}$$

where dcg is the distance to the aircrafts COG and KTM is a constant that relates moment and thrust of a propeller.

2.1.2 Kinematic equations and Euler angles

In this section we will study the kinematics of the Quadrotor. The first stage of kinematics analysis consists of deriving position to obtain velocity. Let us then consider the position vector r , which indicates the position of the origin of the OABC frame relative to Oned:

$$\overrightarrow{\mathbf{r}} = X\,\overrightarrow{\mathbf{i}} + Y\,\overrightarrow{\mathbf{j}} + Z\,\overrightarrow{\mathbf{k}}$$

If we derive each of the components in r we can obtain the instantaneous velocity of Oabc relative to Oned:

$$\dot{\overrightarrow{\mathbf{r}}} = \dot{X}\,\overrightarrow{\mathbf{i}} + \dot{Y}\,\overrightarrow{\mathbf{j}} + \dot{Z}\,\overrightarrow{\mathbf{k}}$$

To find out the components of the aircraft’s linear velocity v0 in the fixed frame we can use

$$\begin{bmatrix} U \\ V \\ W \end{bmatrix} = \mathbf{S} \begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix}$$

where we can take full advantage of the orthogonality of S, meaning its inverse is equal to its transpose

$$\begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} = \mathbf{S}^T \begin{bmatrix} U \\ V \\ W \end{bmatrix}$$

$$\begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} = \begin{bmatrix} \cos\theta\cos\psi U + (\sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi)V + (\cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi)W \\ \cos\theta\sin\psi U + (\cos\phi\cos\psi + \sin\phi\sin\theta\sin\psi)V + (\sin\theta\cos\phi\sin\psi - \sin\phi\cos\psi)W \\ -\sin\theta U + \sin\phi\cos\theta V + \cos\theta\cos\phi W \end{bmatrix}$$

The flight path of the Quadrotor in terms of [X Y Z] can be found by integration . To perform this integration, the Euler angles Θ, ϕ and ψ and must be known. However, the Euler angles themselves are functions of time: the Euler rates Θ', ϕ' and ψ' depend on the body axis angular rates P, Q and R. To establish the relationship between [Θ', ϕ' and ψ'] and [P Q R] the following equality must be satisfied:

$$\overrightarrow{\omega} = P\overrightarrow{i} + Q\overrightarrow{\mathbf{j}} + R\overrightarrow{\mathbf{k}} = \dot{\phi} + \dot{\theta} + \dot{\psi}$$

Note that although it may appear that the Euler rates are the same as angular velocities, this is not the case. If a solid object is rotating at a constant rate, then its angular velocity w will be constant, however the Euler rates will be varying because they depend on the instantaneous angles between the coordinate frame of the body and the inertial reference system (e.g. between Oabc and Oned). The Euler angle sequence is made up of three successive rotations: Roll, Pitch and Yaw. In other words, the angular rate ϕ' needs one rotation, Θ'needs two and ψ' needs three:

$$\overrightarrow{\omega} = R(\phi)R(\theta)R(\psi)\begin{bmatrix} 0 \\ 0 \\ \dot{\psi} \end{bmatrix} + R(\phi)R(\theta)\begin{bmatrix} 0 \\ \dot{\theta} \\ 0 \end{bmatrix} + R(\phi)\begin{bmatrix} \dot{\phi} \\ 0 \\ 0 \end{bmatrix}$$

Therefore:

$$\begin{bmatrix} P \\ Q \\ R \end{bmatrix} = \begin{bmatrix} 1 & 0 & -\sin\theta \\ 0 & \cos\phi & \sin\phi\cos\theta \\ 0 & -\sin\phi & \cos\theta\cos\phi \end{bmatrix} \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

Solving for the Euler angular rates yields the desired differential equations

$$\begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = \mathbf{T} \begin{bmatrix} P \\ Q \\ R \end{bmatrix}$$

$$\mathbf{T} = \begin{bmatrix} 1 & \tan\theta\sin\phi & \tan\theta\cos\phi \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi/\cos\theta & \cos\phi/\cos\theta \end{bmatrix}$$

Where T is the matrix that relates the body-fixed angular velocity vector w and the rate of change of the Euler angles.

2.1.3 Quaternion differential equations

A problem with the implementation of Euler angles ψ ,Θ, and ϕ is that for Θ = 90 the Roll angle ϕ loses its meaning. In other words, if the aircraft pitches up 90 degrees, the aircraft roll axis becomes parallel to the yaw axis, and there is no axis available to accommodate yaw rotation (one degree of freedom is lost). This phenomenon is designated by gimbal lock. In simulations where complete looping maneuvers may have to be performed that is not acceptable. To overcome this problem, the so called quaternion method may be used. Quaternions are vectors in four-dimensional space that offer a mathematical notation that allows the representation of three dimensional rotations of objects. Quaternions also avoid the problem of gimbal lock and, at the same time, are numerically more efficient and stable when compared with traditional rotation matrices S. A rotation quaternion is then presented by:

$$\mathbf{q} = \begin{bmatrix} \cos(\varepsilon/2) \\ \sin(\varepsilon/2)\, n_1 \\ \sin(\varepsilon/2)\, n_2 \\ \sin(\varepsilon/2)\, n_3 \end{bmatrix}$$

Where q represents a rotation about the unit vector [n1 n2 n3] through an angle ε. The time derivative of the rotation quaternion is also provided by

$$\dot{\mathbf{q}} = \frac{1}{2}\mathbf{\Omega}_q \mathbf{q} + \gamma \mathbf{q} = \frac{1}{2}\begin{bmatrix} 0 & -P & -Q & -R \\ P & 0 & R & -Q \\ Q & -R & 0 & -P \\ R & Q & -P & 0 \end{bmatrix}\begin{bmatrix} q_0 \\ q_1 \\ q_2 \\ q_3 \end{bmatrix} + \gamma \begin{bmatrix} q_0 \\ q_1 \\ q_2 \\ q_3 \end{bmatrix}$$

$$\gamma = 1 - \left(q_1^2 + q_2^2 + q_3^2 + q_4^2\right)$$

For practical reasons, the initialization of q requires that we express the quaternion components in terms of Euler angles because doing it with quaternions is not so straightforward.

Therefore, expressing the quaternion vector elements as a function of Euler angles yields

$$\begin{cases} q_0 = \cos\left(\frac{\psi}{2}\right)\cos\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) + \sin\left(\frac{\psi}{2}\right)\sin\left(\frac{\theta}{2}\right)\sin\left(\frac{\phi}{2}\right) \\ q_1 = \cos\left(\frac{\psi}{2}\right)\cos\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) - \sin\left(\frac{\psi}{2}\right)\sin\left(\frac{\theta}{2}\right)\sin\left(\frac{\phi}{2}\right) \\ q_2 = \cos\left(\frac{\psi}{2}\right)\sin\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) + \sin\left(\frac{\psi}{2}\right)\cos\left(\frac{\theta}{2}\right)\sin\left(\frac{\phi}{2}\right) \\ q_3 = \sin\left(\frac{\psi}{2}\right)\cos\left(\frac{\theta}{2}\right)\cos\left(\frac{\phi}{2}\right) - \cos\left(\frac{\psi}{2}\right)\sin\left(\frac{\theta}{2}\right)\sin\left(\frac{\phi}{2}\right) \end{cases}$$

Otherwise, if we want to extrapolate the Euler angles from the quaternion differential equations we can achieve just that by taking intermediate steps of the rotation tensor S and relate them with the elements of the rotation quaternion matrix, rather than calculating them from the quaternion directly:

$$\mathbf{S}_q = \begin{bmatrix} q_0^2+q_1^2-q_2^2-q_3^2 & 2(q_1q_2+q_0q_3) & 2(q_1q_3-q_0q_2) \\ 2(q_1q_2-q_0q_3) & q_0^2-q_1^2+q_2^2-q_3^2 & 2(q_2q_3+q_0q_1) \\ 2(q_1q_3+q_0q_2) & 2(q_2q_3-q_0q_1) & q_0^2-q_1^2-q_2^2+q_3^2 \end{bmatrix}$$

Where Sq is the quaternion equivalent of the rotation matrix . The Euler angles can therefore be calculated by using:

$$\begin{bmatrix} \phi \\ \theta \\ \psi \end{bmatrix} = \begin{bmatrix} \arctan\left(\frac{2(q_2q_3+q_0q_1)}{q_0^2-q_1^2-q_2^2-q_3^2}\right) \\ \arcsin\left(-2(q_1q_3-q_0q_2)\right) \\ \arctan\left(\frac{2(q_2q_3+q_0q_1)}{q_0^2+q_1^2-q_2^2-q_3^2}\right) \end{bmatrix}$$

In analogy to [X’, Y’, Z’] we can also get the absolute velocity using the quaternion rotation tensor

$$\begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} = \mathbf{S}_q^T \begin{bmatrix} U \\ V \\ W \end{bmatrix}$$

To employ the quaternion method we must first use the initial Euler angles in (q0,q1,q2,q3), and use the resulting quaternion elements in Sq. It is also possible to combine the previous quaternion equations with the dynamics equations to compose the vehicle acceleration on the aircraft local frame.

$$\mathbf{F}_g = m\mathbf{S}_q \begin{bmatrix} 0 & 0 & g \end{bmatrix}^T = mg \begin{bmatrix} 2(q_1q_3-q_0q_2) & 2(q_2q_3+q_0q_1) & q_0^2-q_1^2-q_2^2+q_3^2 \end{bmatrix}_B^T$$

$$\begin{bmatrix} \dot{U} \\ \dot{V} \\ \dot{W} \end{bmatrix} = \frac{1}{m}\begin{bmatrix} F_{Px} \\ F_{Py} \\ F_{Pz} \end{bmatrix} + g\begin{bmatrix} 2(q_1q_3-q_0q_2) \\ 2(q_2q_3+q_0q_1) \\ q_0^2-q_1^2-q_2^2+q_3^2 \end{bmatrix} - \begin{bmatrix} QW-RV \\ RU-PW \\ PV-QU \end{bmatrix}$$

2.1.4 Moment of Inertia

Mass and its geometric distribution in an aircraft is something of extreme importance because it affects the entire dynamics of the system. Then, after building the Quadrotor, it is time to evaluate some of its most important features like its moments of inertia and mass.

We will assume the inertia matrix is diagonal and positive-definite, with the purpose of simplifying the calculations and also due to the particular symmetric geometry of Quadrotors. As such, the calculation of inertia moments will only include the geometry and mass of the motors, as well as their geometric position on the Quadrotor.

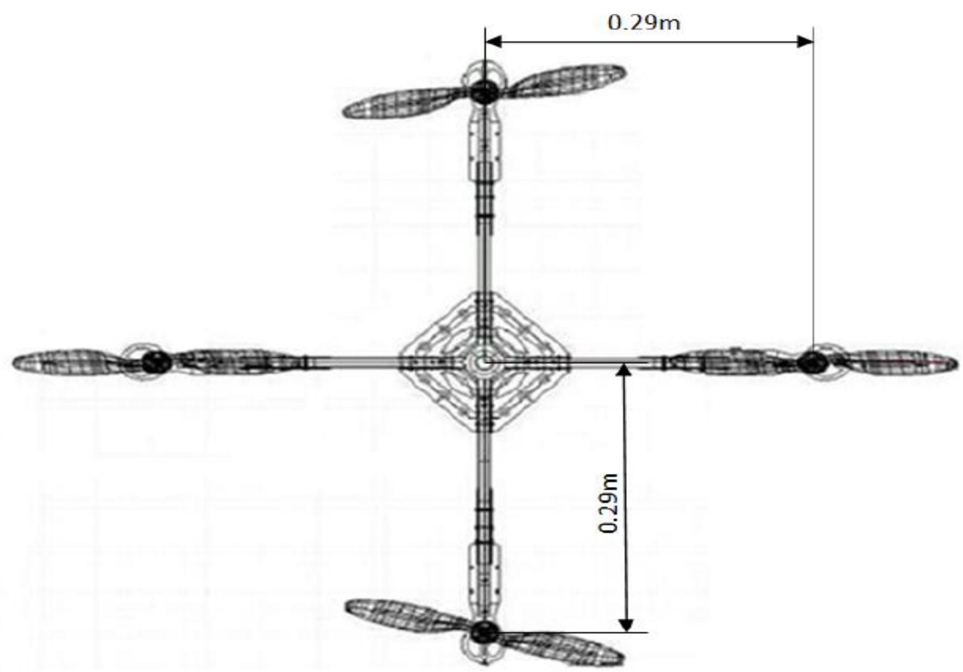


Figure 2.3 Distance from the motors to the center of gravity

Each motor weights approximately 0.048kg. Other important variables related to the aircraft such as the elements of each motor inertia tensor (lx, ly and lz) can be consulted in table 5.1

Table 2.1 Quadrotor's mass and main geometric variables

Ix(m)	0.0288
Iy(m)	0.0288
Iz(m)	0.026
Dcg(m)	0.29
m(kg)	0.82

It follows that the inertia matrix elements of the aircraft are:

$$\begin{cases} I_{x_1} = I_{x_3} = \frac{1}{12} m_m (l_y^2 + l_z^2) = 6.0218 \times 10^{-6}\ kg.m^2 \\ I_{x_2} = I_{x_4} = \frac{1}{12} m_m (l_y^2 + l_z^2) + m_m d_{cg}^2 = 0.004\ kg.m^2 \\ I_{11} = 2I_{x_1} + 2I_{x_2} = 0.0081\ kg.m^2 \end{cases}$$

$$\begin{cases} I_{y_1} = I_{y_3} = \frac{1}{12} m_m (l_x^2 + l_z^2) + m_m d_{cg}^2 = 0.004\ kg.m^2 \\ I_{y_2} = I_{y_4} = \frac{1}{12} m_m (l_x^2 + l_z^2) = 6.0218 \times 10^{-6}\ kg.m^2 \\ I_{22} = 2I_{y_1} + 2I_{y_2} = 0.0081\ kg.m^2 \end{cases}$$

$$\begin{cases} I_{z_1} = I_{z_2} = I_{z_3} = I_{z_4} = \frac{1}{12} m_m (l_x^2 + l_y^2) + m_m d_{cg}^2 = 0.004\ kg.m^2 \\ I_{33} = 4I_{z_1} = 0.0162\ kg.m^2 \end{cases}$$

And the inertia matrix itself is:

$$\mathrm{I} = \begin{bmatrix} I_{11} & 0 & 0 \\ 0 & I_{22} & 0 \\ 0 & 0 & I_{33} \end{bmatrix} = \begin{bmatrix} 0.0081 & 0 & 0 \\ 0 & 0.0081 & 0 \\ 0 & 0 & 0.0162 \end{bmatrix} kg.m^2$$

2.1.5 Calculation of center of gravity

It has been clear so far that we have assumed the Quadrotor to have its center of gravity located in the center of the XY plane of the Oabc reference frame. Nonetheless it is also important to calculate its position along the Z axis because we will need it to know the relative position of the accelerometer in the next section. This task was carried out in the most practical way possible through the use of the software, in which some of the most heavy parts of the Quadrotor were modeled (e.g. motors, sensors, main battery and aluminum beams) and assembled.

2.2 ELECTRONICS UNIT

2.2.1 Ground station and Vision system implementation

Vision is one of the most important senses for the UAV as it provides for path planning, obstacle avoidance, visual tracking and target matching. Vision is achieved by a camera, which takes in pictures and feeds them to a vision processing software. Thus after a picture has been analyzed the vehicle can take decisions on how to maneuver and perform further processing.

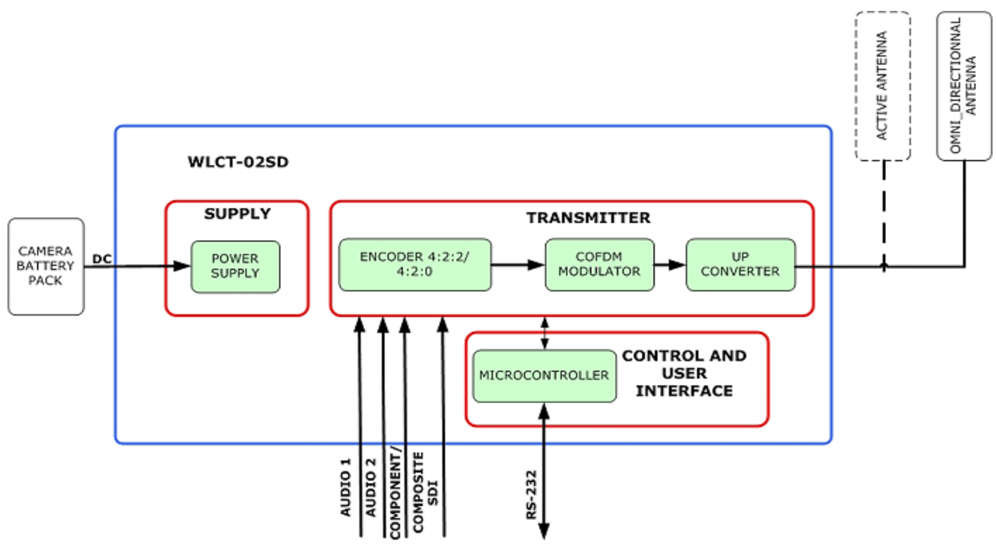


Figure 2.4 Vision System

2.2.2 Remote Control

A radio communication system requires two tune circuits each at the transmitter and receiver, all four tuned to the same frequency. The transmitter is an electronic device which, usually with the aid of an antenna, propagates an electromagnetic signal such as radio, television, or other telecommunication. For a fixed frequency transmitter one commonly used method is to use a resonant quartz crystal in a Crystal oscillator to fix the frequency. Where the frequency has to be variable several options can be used.

2.2.3Block Diagram

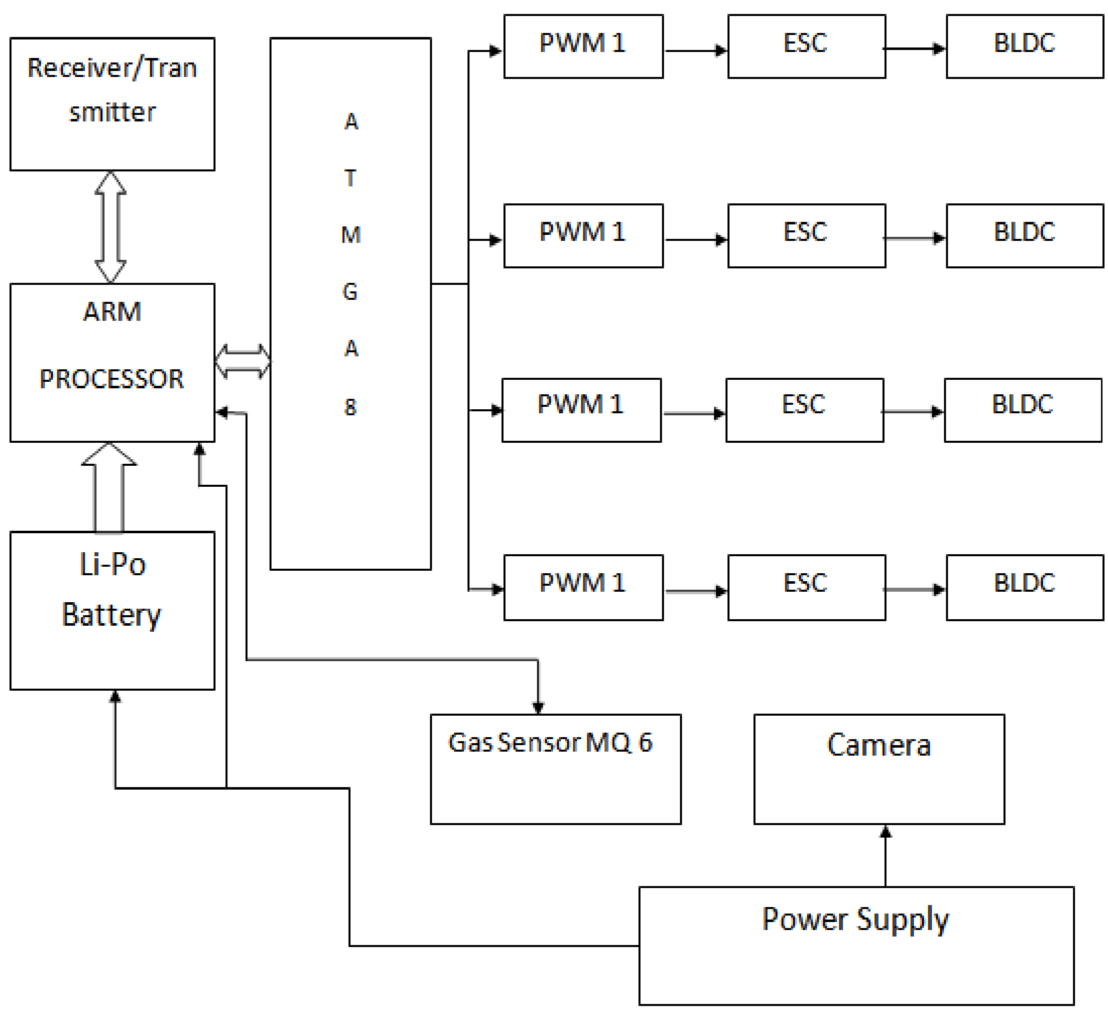


Fig 2.5 Block Diagram

2.4 WORKING

We propose to develop an electrically powered rotorcraft. To date, electrical power has been found unsuitable for rotorcrafts, except for the very lightest of modelhelicopters.

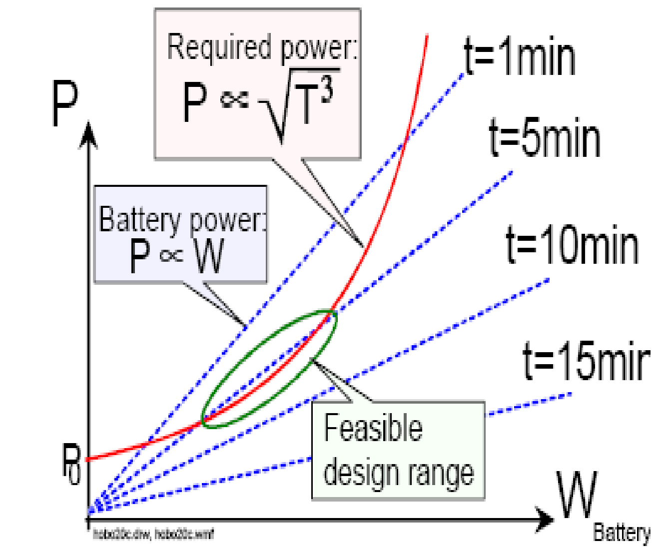


Figure 3:
Power vs. Weigh chart for electric rotorcrafts.

Fig 2.6 Block Diagram

The reason for this can be explained with a few first approximation design guidelines for rotorcrafts. As a rule of thumb, the power *P* required developing thrust (i.e., lifting capacity) *T* is given by *P* α √*T3* This function is sketched in the Power vs. Weight chart of Fig. The offset *P*0 represents the power required for lifting the motors and structure. The battery power vs. battery weight (for agiven maximum flight duration) is plotted as a group of dotted lines, each for a given flight duration. Because of the non-linear nature of Eq. electric helicopters cannot be scaled: It is impossible to simply design around a larger motor and larger battery, to get a larger (read: stronger rotorcraft). As Fig. shows in principle, there is only a small range of feasible designs. Commercially available model helicopters demonstrate this principle: only extremely lightweight (2 - 3 lb) models with 5-6 minutes flight duration are available. These models use ultra-light building materials and control elements. A robotic rotor-craft would need an onboard computer and sensors, in addition to the conventional radio-control components. For this reason, we conclude that it is unfeasible to build a robotic rotorcraft based on current electric power model helicopter technology. To overcome this seemingly inherent limitation, we propose to design a multiple rotor platform, called the HoverBot. In principal, the HoverBot can be considered as four individual electric model helicopters, linked together at their tails. While this design slightly increases the weight of the structure, its advantage is that certain components needed in every conventional model helicopter (such as gyros and the receiver and its power source) can be shared among the four units, and so can special components for autonomous operation (such as a computer board, more gyros, and other sensors). In preliminary experimental battery endurance tests, we achieved 3-minute flights with our prototype HoverBot and conventional NiCad battery packs. The tests were somewhat flawed by inferior charging equipment that wouldn't allow optimal charging of the cells. Rotor blade loading, power transmission and motors were also far from optimal in our early experiments. We expect that by the end of a three-year project, we will have improved on these factors to achieve flight times of 4 – 5 minutes with standard NiCad batteries. More important, new battery technologies promise additional two to threefold improvement in weight-to-charge ratios. Driven by the rapidly expanding market of notebook computers, more powerful nickel-hydrate batteries are already in use, which provide 1.5 – 2 times higher energy densities, and recently Byte magazine [Byte, 1993, March, p. 24) reported on the development of new lithium-iron batteries that promise 3 times longer operation than Alkaline batteries of the same size2.

2.4.1 Four-Rotor Design

In the earlier days of vertical flight experimentation (before the development of the ingenious cyclic/collective pitch concept C which is now used by all modern helicopters) developers looked at the intuitively easy control functionality of 4-rotor designs. While some of these prototypes did indeed fly, none ever made it into production. The reason most often quoted was the fact that the 4-rotor machines were difficult to control and stabilize: With manual controls, the pilot would have to coordinate at least four control parameters (for example, the pitch of the rotor blades), which were rather counter-intuitive (see “principle of operation,” below). Another reason to consider multiple rotors is to achieve larger pay-load capacities then what is possible with single rotor designs. The reason for this is the fact that the thrust of a rotary wing is proportional to the square root of the area swept through by the rotor. This area is also called the rotor 2Ultimately, of course, we are interested in weight-to-energy ratios. Yet, the literature quoted size to energy ratios (relative to existing products). We quote these examples here to show the feasibility of electric power, while the focus of the proposal is on the stability and control problem. disk. I other words, the larger the rotor disk, the more thrust is developed. Obviously, there are technical limitations to the maximal size of the rotor disk. Multiple rotors multiply the effective rotor disk area, although there are, of course, losses. Most notably are losses caused by the additional weight of the structure and losses due to turbulent interaction of the air underneath the disks. Nonetheless, tandem rotor designs are clearly superior to single rotor helicopters in terms of pay-load capacity Lightbody and Poyer, 1990].

2.4.2 Control of the HoverBot

The control system of the HoverBot is designed to allow either fully autonomous operation or remote operation by an unskilled operator. To either, the HoverBot will appear as an omnidirectional vehicle with 4 degrees of freedom: (1) up/down (2) sideways, (3) forward/backward, and (4) horizontal rotation. Up/down motion is easily controlled by collectively increasing or decreasing the power to all 4 motors. Control over (2) can be achieved as explained in Fig: For example, increasing the power to the two left rotors lifts the left side up and generates a thrust component to the left. Consequently, the HoverBot moves to the right. By the same principle, adding power to the two rear rotors causes the HoverBot to fly forward. The implementation of horizontal rotation control is less obvious:

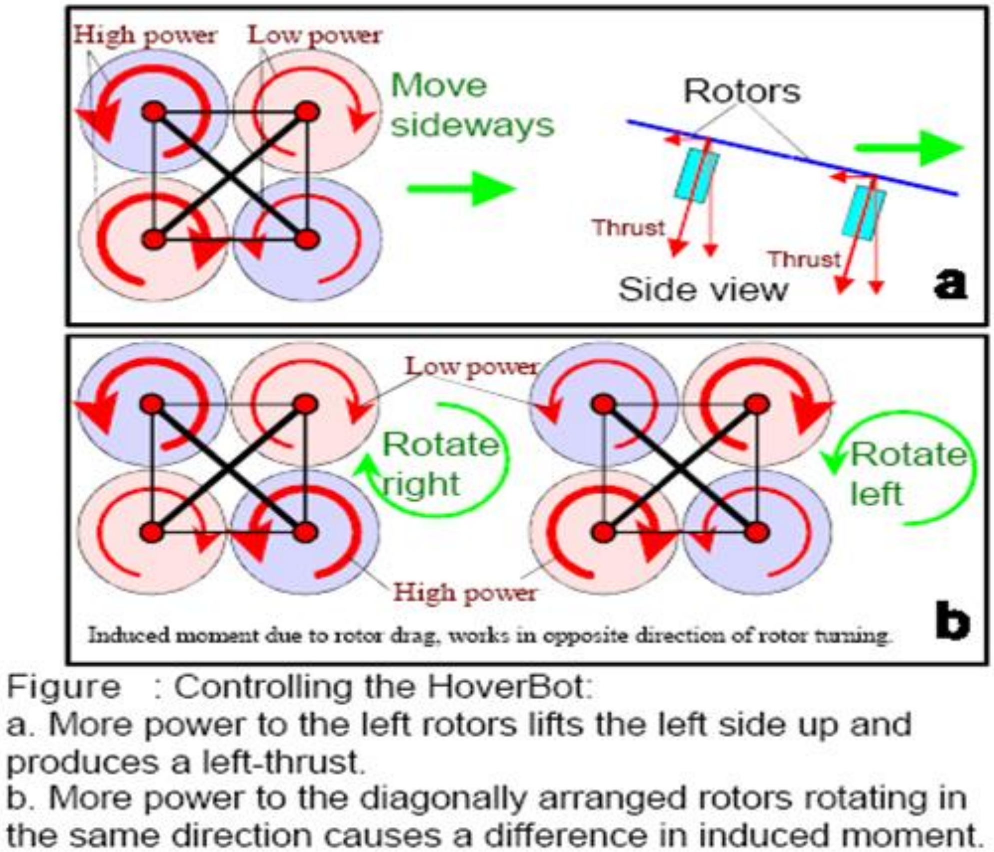


Figure 2.7 Controllling of Quad rotor

When a rotor turns, it has to overcome air resistance. The reactive force of the air against the rotor causes a reactive moment called the "induced moment". The induced moment acts on the rotor in the direction opposite to the rotation of the rotor.

As everyone knows, conventional helicopters require the tail-rotor to counteract the induced moment. In the HoverBot both sets of diagonal rotors turn in opposite directions (as indicated by the opposite direction of the arrows in Fig).

As long as all rotors experience the same induced moment, which is mostly a function of speed of rotation and rotor blade pitch, the sum of all induced moments is zero and there is no horizontal rotation. If one set of rotors, for example the one that turns counter-clockwise in Fig. 4, increase their rotational speed or their pitch, the resultant net induced moment will cause the HoverBot to rotate clockwise.

It is important to note that because of the diagonal arrangement, this operation has no effect on translation in x or y direction. The effect on up/down motion can be compensated by reducing the pitch or speed of the other diagonal pair, although in practice this is not quite so easy without some sort of feedback control.

2.4.3 Stability

We believe that stability is the foremost challenge for any effort to build a model-sized robotic rotorcraft. As explained before, in the absence of natural damping, all rotorcrafts must be constantly stabilized by the pilot or auto-pilot. In model-sized helicopters this presents a formidable difficulty, because of the much smaller time-constants. This is the reason why model-helicopter pilots need months and months of training, just to keep their helicopters in stable hovering. Model helicopter pilots we talked to confirm that stabilizing a small model helicopter is even more difficult than stabilizing a larger model helicopter.

2.4.4 Larger Time-Constant With the Proposed HoverBot

The 4-rotor design of our proposed *HoverBot* C originally motivated by considerations of payload C appears to have one unique advantage over conventional helicopter designs: the **distributed** weight of the 4 rotor heads increases the moment of inertial and thereby the time constant of the system. To illustrate this point, we can roughly estimate that the moment of inertia, *J*, of a 6 kg conventional (single rotor) helicopter model around its longitudinal axis is *J* = 0.06 Kgm2. By comparison, the 4-rotor *HoverBot* with the same weight has a moment of inertia of *J* = 1.53 Kgm2 around its least favorable axis. In other words, the moment of inertial of the *HoverBot* is approximately 1.53/0.06 = 25 times larger than that of a comparable conventional helicopter. Since the time-constant J of the system is proportional to the square root of the moment of inertia (J % *J*2), the time-constant of the *HoverBot* is (25)2 = 5 times larger than that of the conventional helicopter design. Stabilization of this rotorcraft will be greatly facilitated by the much larger timeconstant.

2.5 THE DUAL CONTROL APPROACH

Another important advantage of our 4-rotor design is the control flexibility gained from the use of four independent motors. As we explained, the *HoverBot* can be fully controlled by controlling the thrust of the four rotors. In conventional helicopters thrust is controlled in two different ways: a) by adjusting the motor power and b) by adjusting the rotor blade pitch (the angle of attack of the rotor blades). Adjusting the motor power is usually not an efficient means of control, because gasoline powered engines do not respond quickly enough (especially with the large inertia of the rotor) to the pilot's commands. By contrast, adjusting the rotor pitch has an **immediate** effect on the thrust: a larger pitch angle increases the thrust. However, a larger pitch angle also increases the power needs of the rotor and must therefore be accompanied by an increase in motor power. Because of the kinetic energy stored in the rotor, the increase in motor power does not have to be available immediately, a short delay is acceptable. Thus, the immediate action of pitch control combined with the slightly delayed action of motor power control works well. In normal-sized helicopters (without automatic control), determination of the proper mixture between pitch increase and motor power increase is left to the skill of the pilot. The problem is different in the *HoverBot*.

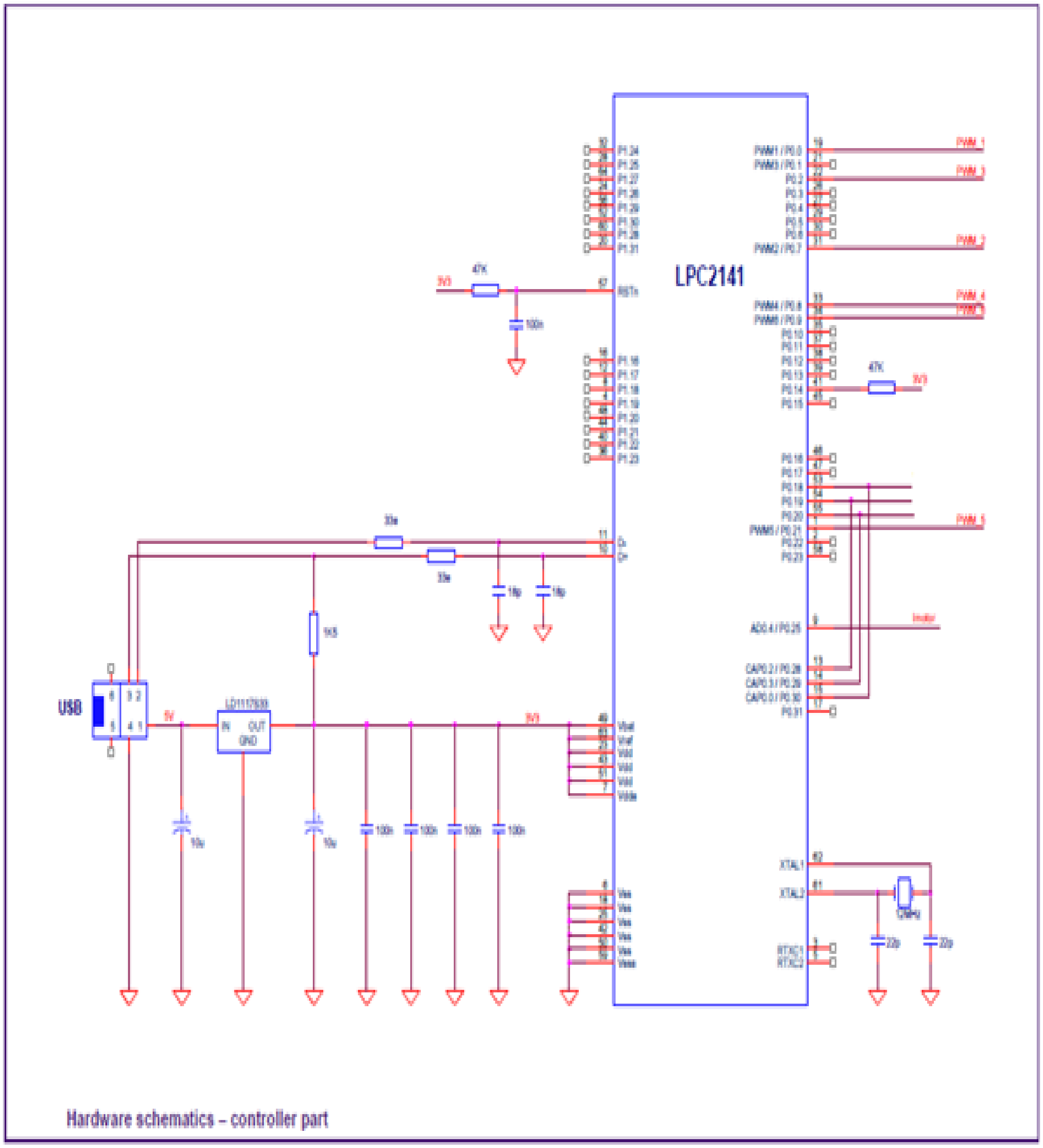
Here, controlling the motor power is somewhat more effective because we use electric motors. We found that we can perform the typical control functions (up/down, forward/backward and sideways tilting, rotation) just by controlling the rotor thrust. However, in our system the craft must also be **stabilized** by varying the rotor thrust. In our experimental system we found that the thrust control must react at least ten times faster in order to *dampen* undesirable oscillations caused by external disturbances. Thus, we propose a *dual control approach*, in which fast-acting pitch control is the primary means for damping and stabilizing, and motor power control is the primary means for controlling the steady state thrust and thus the motion of the *HoverBot*.

In practice, both control actions are strongly interrelated. Any control signal going to, say, the front left motor must also generate a secondary control signal that affects the pitch actuator of the front left rotor, and vice versa. The exact nature of this interaction is extremely difficult to determine analytically. The interaction is highly non-linear and there are numerous parameters that are practically impossible to measure. Our focus in the proposed work will be to develop experimentally a new controller capable of performing this complicated stability and control task.

CHAPTER 3

HARDWARE DESIGN

3.1 Hardware schematics



Hardware schematics – controller part

Figure 3.1 Hardware schematics

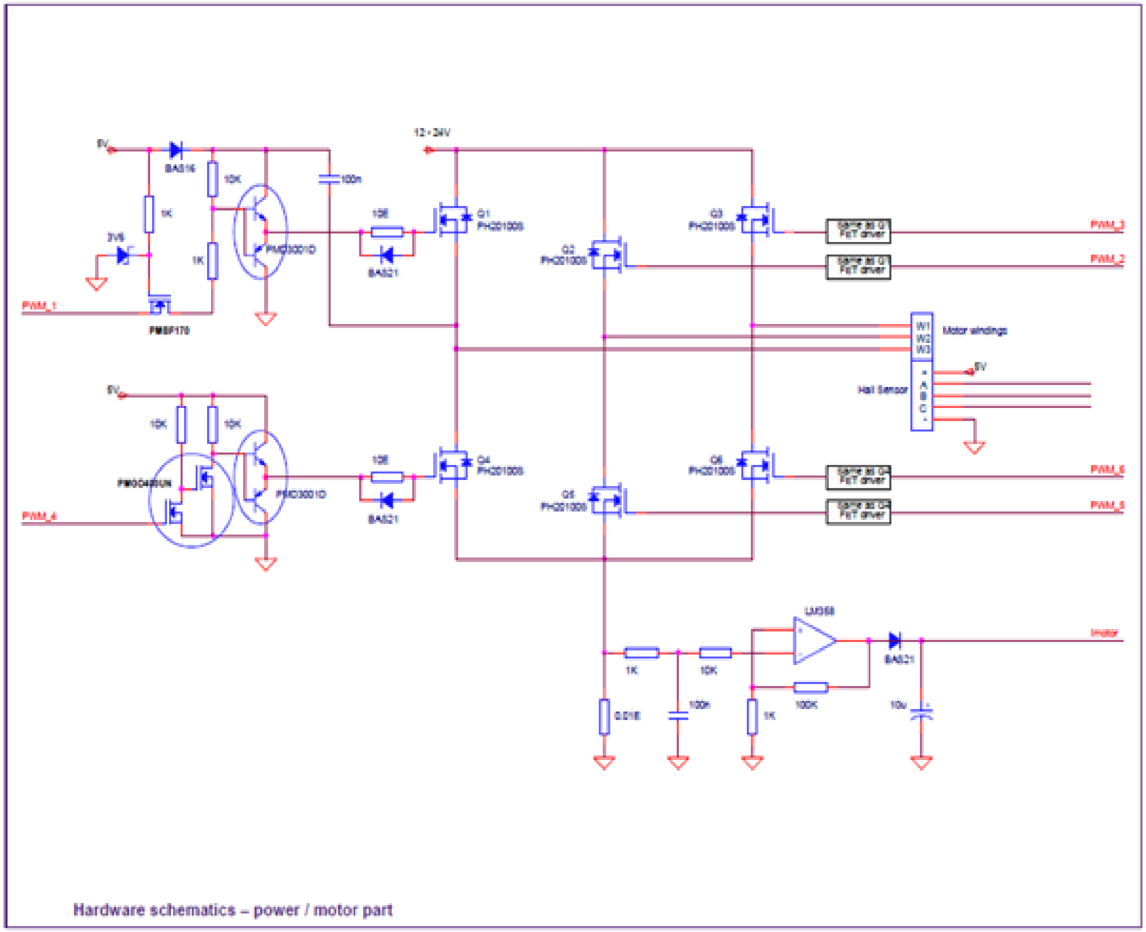


Figure 3.2 Motor Connections

3.2 ARM7TDMI (LPC2141) MICROCONTROLLER

The LPC2141/42/44/46/48 microcontrollers are based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine microcontroller with embedded high speed flash memory ranging from 32 kB to 512 kB. A 128-bit wide memory interface and a unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty.

A superior performance as well as their tiny size, low power consumption and a blend of on-chip peripherals make these devices ideal for a wide range of applications. Various 32-bit timers, 10-bit ADC and PWM features through output match on all timers, make them particularly suitable for industrial control. Main reason to use the LPC2141 for this reference design is the on-chip USB interface, which is used to communicate with a PC GUI (Graphical User Interface) controlling the motor.

Due to their tiny size and low power consumption, LPC2141/42/44/46/48 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. Serial communications interfaces ranging from a USB 2.0 Full-speed device, multiple UARTs, SPI, SSP to I^2C-bus and on-chip SRAM of 8 kB up to 40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers suitable for industrial control and medical systems.

Key features

- 16-bit/32-bit ARM7TDMI-S microcontroller in a tiny LQFP64 package.
- 8 kB to 40 kB of on-chip static RAM and 32 kB to 512 kB of on-chip flash memory.
- 128-bit wide interface/accelerator enables high-speed 60 MHz operation.
- In-System Programming/In-Application Programming (ISP/IAP) via on-chip boot loader software. Single flash sector or full chip erase in 400 ms and programming of 256 bytes in 1 ms.
- EmbeddedICE RT and Embedded Trace interfaces offer real-time debugging with the on-chip RealMonitor software and high-speed tracing of instruction execution.
- USB 2.0 Full-speed compliant device controller with 2 kB of endpoint RAM.
- In addition, the LPC2146/48 provides 8 kB of on-chip RAM accessible to USB by DMA.
- One or two (LPC2141/42 vs. LPC2144/46/48) 10-bit ADCs provide a total of 6/14 analog inputs, with conversion times as low as 2.44 μs per channel.

- Single 10-bit DAC provides variable analog output (LPC2142/44/46/48 only).
- Two 32-bit timers/external event counters (with four capture and four compare channels each), PWM unit (six outputs) and watchdog.
- Low power Real-Time Clock (RTC) with independent power and 32 kHz clock input
- Multiple serial interfaces including two UARTs (16C550), two Fast I^2C-bus (400 kbit/s), SPI and SSP with buffering and variable data length capabilities.
- Vectored Interrupt Controller (VIC) with configurable priorities and vector addresses.
- Up to 45 of 5 V tolerant fast general purpose I/O pins in a tiny LQFP64 package.
- Up to 21 external interrupt pins available.
- 60 MHz maximum CPU clock available from programmable on-chip PLL with settling time of 100 µs.
- On-chip integrated oscillator operates with an external crystal from 1 MHz to 25 MHz.
- Power saving modes include Idle and Power-down.
- Individual enable/disable of peripheral functions as well as peripheral clock scaling for additional power optimization.
- Processor wake-up from Power-down mode via external interrupt or BOD.
- Single power supply chip with POR and BOD circuits:
- CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V tolerant I/O pads.

3.3 CAMERA AND SOUND SYSTEM

Wireless security cameras are closed-circuit television (CCTV) cameras that transmit a video and audio signal to a wireless receiver through a radio band. Many wireless security cameras require at least one cable or wire for power; "wireless" refers to the transmission of video/audio. However, some wireless security cameras are battery-powered, making the cameras truly wireless from top to bottom. This is positioned on the Aerial Unit. Thus whenever the Quadrotor air borne it pick up the images by microcontroller instructions and send images on the ground station.

Main features

1. It has built in wireless receiving and recording ability.
2. It comes with a 2.4 GHz Wireless Button Camera (Since 2.4 GHz is a free frequency so it doesn't require taking and license from the Govt.)
3. Its memory can be enhanced by inserting an optional 4 GB SD Card.
4. Real time recording with date and time stamping.
5. Great for investigation or surveillance.

3.4 MQ-6 SEMICONDUCTOR SENSOR FOR LPG

Sensitive material of MQ-6 gas sensor is SnO_2, which with lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity is more higher along with the gas concentration rising. Please use simple electro circuit, Convert change of conductivity to correspond output signal of gas concentration.

MQ-6 gas sensor has high sensitity to Propane, Butane and LPG, also response to Natural gas. The sensor could be used to detect different combustible gas, especially Methane; it is with low cost and suitable for different application.

Features:-

* Good sensitivity to Combustible gas in wide range

* High sensitivity to Propane, Butane and LPG

* Long life and low cost

* Simple drive circuit

Application

* Domestic gas leakage detector

* Industrial Combustible gas detector

* Portable gas detector

Structure and configuration:-

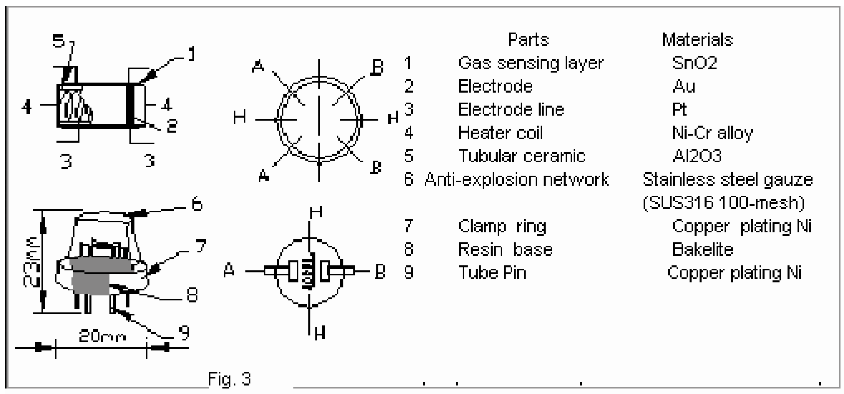


Figure 3.3 Structure and configuration

Structure and configuration of MQ-6 gas sensor is shown as Fig. 3, sensor composed by micro AL2O3 ceramic tube, Tin Dioxide (SnO2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-4 have 6 pin, 4 of them are used to fetch signals, and other 2 are used for providing heating current.

3.5 ELECTRONIC SPEED CONTROLLER

An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically-powered radio controlled models.

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. ESCs are normally rated according to maximum current, for example, 25 amperes or 25 A. Generally the higher the rating, the larger and heavier the ESC tends to be which is a factor when calculating mass and balance in airplanes. Many modern ESCs support nickel metal hydride and lithium ion polymer batteries with a range of input and cut-off voltages. The type of battery and number of cells connected is an important consideration when choosing a Battery eliminator circuit (BEC), whether built into the controller or as a stand-alone unit. A higher number of cells connected will result in a reduced power rating and therefore a lower number of servos supported by an integrated BEC.

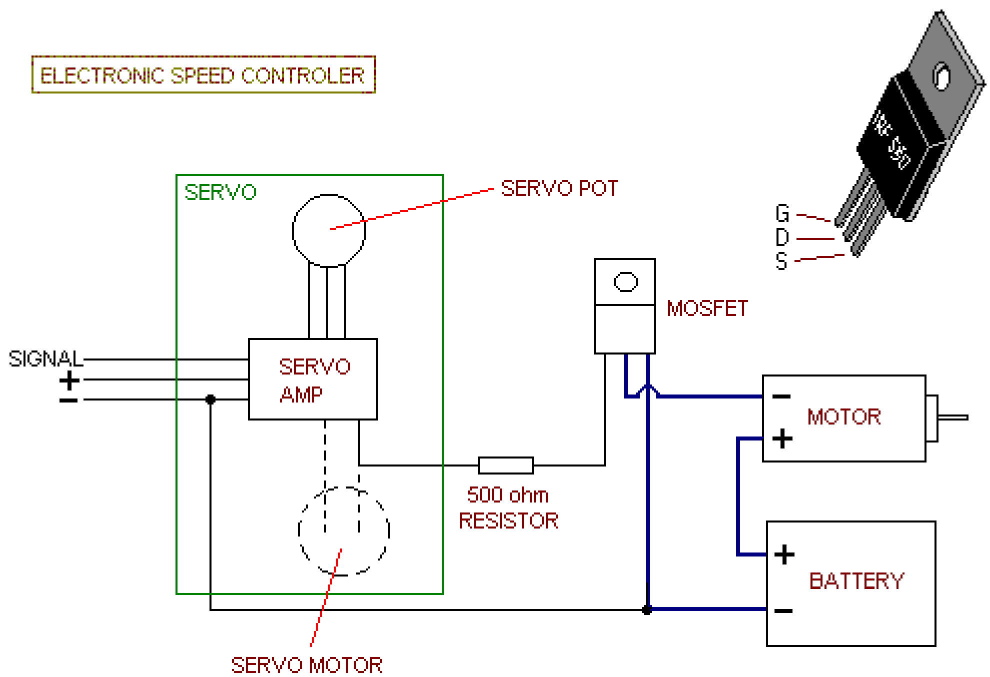


Figure 3.4 Connections of ESC

These speed controllers features the following functionality

1. Smooth motor start.
2. Compatible with 98% of brushless motors.
3. 200 step throttle resolution.
4. Support 2-10 pole in/out runners.

3.6 Motors and propellers

An electric motor converts electrical energy into mechanical energy.

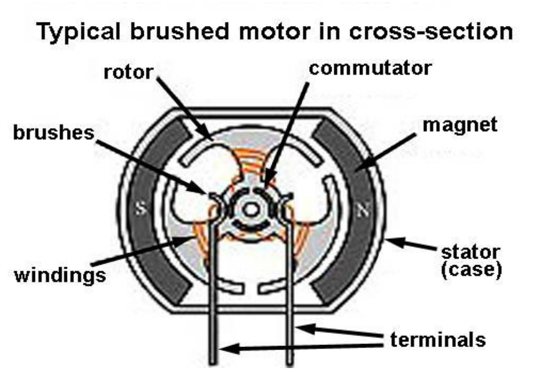


Figure 3.5 Cross section view of brushless motor

- Most electric motors operate through interacting magnetic fields and current-carrying conductors to generate force, although electrostatic motors use electrostatic forces. Here brushless motors are used these are synchronous electric motors powered by direct-current (DC) electricity and having electronic commutation systems, rather than mechanical commutators and brushes.
- Propeller are basically used for hovering.

3.7 BRUSHLESS DC MOTOR

Brushless DC motors consist of a permanent magnet rotor with a three-phase stator winding. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. Typically three Hall sensors are used to detect the rotor position and commutation is based on these sensor inputs. Brushless DC (BLDC) motors are rapidly gaining popularity. They offer longer life and less maintenance than conventional brushed DC motors. Some other advantages over brushed DC motors and induction motors are: better speed versus torque characteristics, noiseless operation and higher speed ranges. And in addition, the ratio of torque delivered to the size of the motor is higher, making them useful in applications where space and weight are critical factors.

In a brushless DC motor, the electromagnets do not move; instead, the permanent magnets rotate and the three-phase stator windings remain static. This gets around the problem of how to transfer current to a moving rotor. In order to do this, the brush-commutator assembly is replaced by an intelligent electronic “controller”. The controller performs the same power distribution as found in a brushed DC motor, but is using a solid-state circuit rather than a commutator/brush system.

The speed and torque of the motor depend on the strength of the magnetic field generated by the energized windings of the motor, which depend on the current through them. Therefore adjusting the rotor voltage (and current) will change the motor speed.

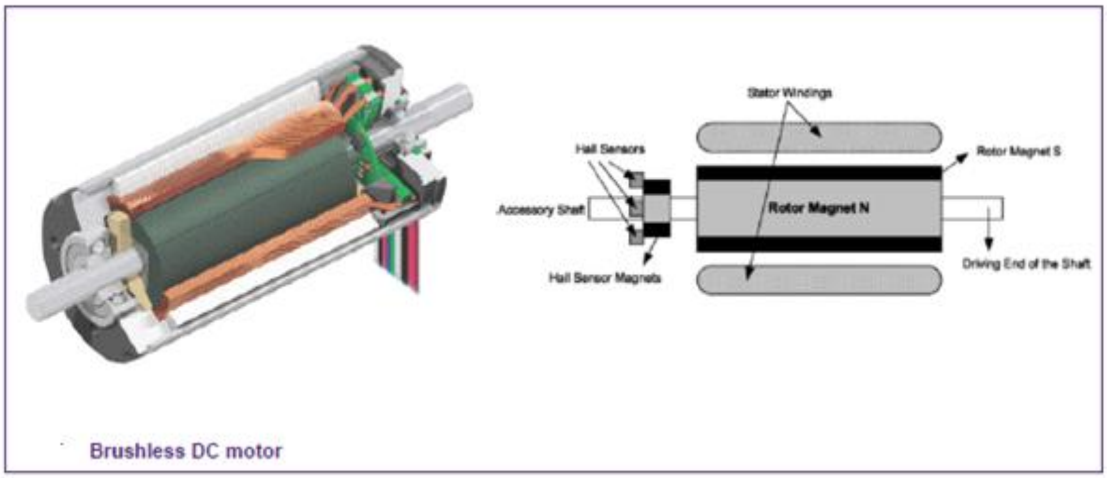


Figure 3.6 Internal schematic of BLDC

Specifications

1. Model:F2623-4500
2. KV(rpm/v):4500
3. Voltage(V):11.1
4. Motor Weight(g):30
5. APPROX No Load Current(A):2.3
6. No Load Speed(rpm):49840

7. Load Current(A):25.0
8. Load Speed(rpm):36500
9. Prop:2.5*2.5

3.7.1. How to control a brushless DC motor Rotation

A BLDC motor is driven by voltage strokes coupled with the given rotor position. These voltage strokes must be properly applied to the active phases of the three-phase winding system so that the angle between the stator flux and the rotor flux is kept close to 90° to get the maximum generated torque. Therefore, the controller needs some means of determining the rotor's orientation/position (relative to the stator coils.)

3.7.2 Speed control

By simply varying the voltage across the motor, one can control the speed of the motor. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be achieved easily by changing the duty cycle of the PWM signal.

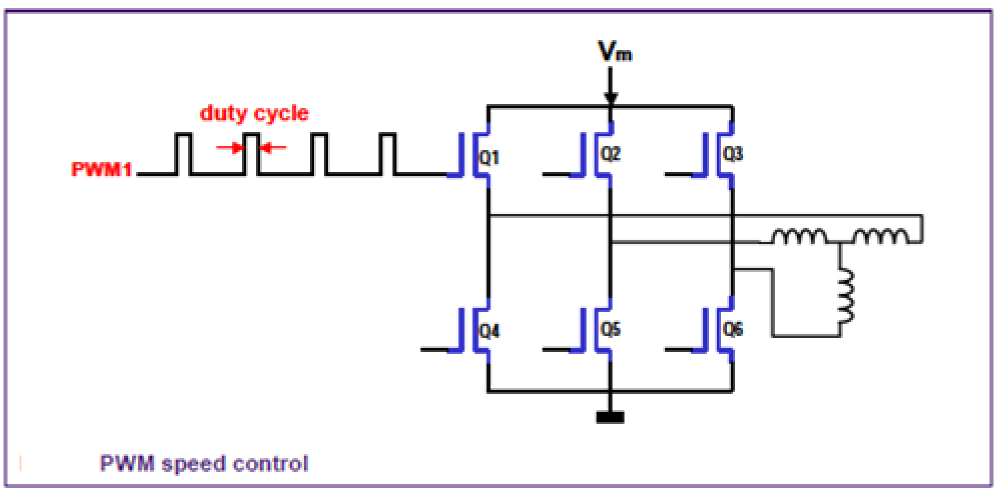


Figure 3.7 PWM Speed Control

Brushless DC (Direct Current) motors are most commonly used in easy to drive, variable speed and long life applications. They have become widespread and are available in all shapes and sizes from large-scale industrial models to small motors for light applications (such as 12 V BLDC motors).

APPLICATIOS

Air conditioners, electric pumps, fans, printers, robots, electric bikes, -doors, -windows, - sun roofs, -seats, mixers, food processors, blenders, vacuum cleaners, toothbrushes, razors, coffee grinders, etc.

3.8 RF MODULE

3.8.1 Transmitter and Receiver

A radio communication system requires two tune circuits each at the transmitter and receiver, all four tuned to the same frequency. The transmitter is an electronic device which, usually with the aid of an antenna, propagates an electromagnetic signal such as radio, television, or other telecommunication. For a fixed frequency transmitter one commonly used method is to use a resonant quartz crystal in a Crystal oscillator to fix the frequency. Where the frequency has to be variable several options can be used.

Figure 3.8 Receiver

Figure 3.9 Transmitter

Transmitter module is a electronic component using a variety of radio signals to remote control the target device which has a receiver module built-in. The remote distance can be very long and you don't need a line-of-sight remote controlling compared to remote controls using infrared technology

Features

- Complete RF Transceiver
- Onboard Data Encryption
- Automatic collision avoidance
- ‘Wake on Radio’ feature
- Low current consumption
- Wide Operating voltage 1.8 – 3.6 Volts
- Operating Frequency: 2.4 – 2.483 GHz
- Programmable Output Power and High Sensitivity
- Range up to 50 metres at +1dBm
- Data rate 1.2 – 500 kbps.

3.8.2 Wireless camera with receiver

WS-309AS Mini Wireless Color Audio

Wireless security cameras are closed-circuit television (CCTV) cameras that transmit a video and audio signal to a wireless receiver through a radio band. Many wireless security cameras require at least one cable or wire for power; "wireless" refers to the transmission of video/audio, Quadrotor can capture both audio and video by cctv wireless camera.

Figure 3.10 Wireless Camera

Figure 3.11 Working of Camera

Main features

1. It has built in wireless receiving and recording ability
2. It comes with a 2.4 GHz Wireless Button Camera (Since 2.4 GHz is a free frequency so it doesn't require taking and license from the Govt.)
3. Its memory can be enha0nced by inserting an optional 4 GB SD Card
4. Real time recording with date and time stamping.
5. Great for investigation or surveillance.
6. No extra power needed for the camera.

Technical Parameters of Transmitting Unit

- Video Camera Parts: 1/3" 1/4" Image Sensors
- System: PAL/CCIR NTSC/EIA
- Effective Pixel: PAL: 628X582 NTSC: 510X492
- Image Area:PAL: 5.78X4.19mm NTSC: 4.69X3.45mm
- Horizontal Definition: 380 TV Lines
- Scanning Frequency: PAL/CCIR: 50HZ NTSC/EIA: 60HZ
- Minimum Illumination: 3LUX
- Sensitivity: +18DB-AGL ON-OFF
- Output Electrical Level: 50MW
- Output Frequency: 1.2G/2.4G
- Linear Transmission Distance: 50-100M
- Voltage: DC+9V
- Current: 300mA
- Power Dissipation:<=640MW

Technical Parameters of Receiving Unit

- Wireless Audio Receiver
- Receiving Method:Electronic Frequency Modulation
- Reception Sensitivity: +18DB
- Receiving Frequency: 1.2G/2.4G
- Receiving Signal: Video, Audio
- Voltage: DC 12V
- Current: 500mA

3.9 LITHIUM BATTERY

This is high performance 3 cell Lithium Polymer rechargeable battery. It is rated at 11.1V, 1800mAh. It can give discharge current up to 36Amps (20C discharge). It is the most ideal battery for the robots which requires high current. It has separate connections for power output and balance charging.

Figure 3.12 Lithium battery

Specifications

1. Battery type: Lithium Polymer
2. Battery Voltage: 11.1V
3. Battery capacity: 2000mAh
4. Maximum constant discharge current: 36Amps (20C)
5. Maximum peak discharge (for 10 seconds): 54Amps (30C)
6. Maximum charging current: 3.6Amps (2C)
7. Number of cells: 3
8. Recommended battery cut of voltage: 9.9V.
9. Battery weight: 200gms
10. Dimensions: 70mm x 35mm x 25mm

3.10 PROPELLERS AND PROPELLER HUB

This is high performance 21.59x15cm Puller Propeller weighting just 13gms It is made up of glass filled Nylon for high strength and durability. It is a matched propeller for the 21.59x15cm Pusher Propeller for the Quadrotor (Quadcopter). This propeller gives guaranteed 1.246Kg thrust with the matched motor 1050Kv, 11.1V Brushless DC out runner motor.

Figure 3.13 A propeller with hub

It comes with adaptors for 3mm, 4mm, 4.5mm, 5mm, 6mm and 8mm motor shafts.

Specifications

1. Type: Puller propeller
2. Diameter: 21.59cm
3. Pitch: 15cm
4. Material: Glass filled Nylon
5. Weight: 13gms

3.11 ESC

This is high performance 25Amp BLDC Motor Driver weighting just 26gms. It can work on 2 to 4 Cell Lithium Polymer batteries. Motor driver has built-in over temperature protection. With 1050Kv, 11.1V Brushless DC outrunner Motor and its match propellers can give 1.26Kgs to 1.62Kgs of thrust.

Figure 3.14 Electronic speed controls

Specifications

1. Weight 26gms
2. Average continuous current 25Amp
3. Maximum load 30Amp
4. Voltage 7.4 to 14.8V

3.12 REGULATOR IC 7805

The MC78XX/LM78XX/MC78XXA series of three terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible.

If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators these devices can be used with external components to btain adjustable voltages and

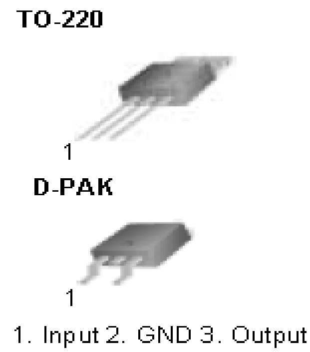


Figure 3.15 Regulator IC

Features

1. Output Current up to 1A
2. Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
3. Thermal Overload Protection
4. Short Circuit Protection
5. Output Transistor Safe Operating Area Protection.

Pin Description

Table 3.1 Pin Description

n No	**Function**	**Name**
1	Input voltage (5V-18V)	Input
2	Ground (0V)	Ground
3	Regulated output; 5V (4.8V-5.2V)	Output

CHAPTER 4

.HARDWARE AND SOFTWARE REQUIREMENTS

4.1 HARDWARE REQUIREMENTS

Table 4.1 Hardware Used

MODULE	QUANTITY
1. Lithium batteries	4
2. Propeller hub	4
3. ATMEGA-8 Microcontroller	2
4. Aluminium / balsa wood base	4
5. Propellers	4
6. RF Transmitter	1
7. RF Receiver	1
8. Brushless motors	4
9. ESC(Electronic speed controller)	4
10. Resistors	4
11. Capacitors	5
12. Diodes	4
13. Transistors	3
14. LEDS	4
15. Crystals oscillator	2
16. Switch	1
17. Regulator IC(7805)	1
18. ARM PROCESSOR	1
19. PC(programming and vision)	1
20. Television	1
21. Wireless camera	1
22. Camera Receiver	1

CHAPTER 5

ACTUAL PCB LAYOUT AND PCB DESIGN

5.1 INTRODUCTION OF PCB

PCB mean's printed circuit board PCB are one of the most important element in any electronic system. They accomplish the inter-connection the between components mounted on them in particular manner PCB consist of conductive circuit pattern which is applied to one or both sided of an insulating base copper is Most Widely used for conductor material aluminum nickel, silver, brass are used for same special application.

The thickness of conducting material depends upon the current carrying capacity of circuits Thus a thicker conductor layer will have more current carrying capacity one the PCB is manufactured, the current carrying capacity is depends on the which of conductor track.

Function of PCB

The printed circuit board usually serves three distinct Functions are as follows

1) It provides mechanical support for the components mounted on it.
2) It provides necessary electrical interconnections.
3) It acts as heat sink i.e. it provides a conduction path leading to removal of most of the heat generates in the circuits.

Advantages of PCB:-

1) PCB's have controllable and predicable electrical mechanical properties.
2) Rapid production is possible.
3) Time is saved since it avoids wiring connections production to another
4) Weight is reduced.
5) Soldering is done in one operation instead of individual connection between component and wires.
6) Cost is less.

5.2 TYPES OF PCB:-

1) Single Sided PCB
2) Double Sided PCB

5.3 THE VARIOUS STEPS INVOLVED IN PCB

- Layout Planning
- Artwork Drawing
- Artwork Transferring
- Etching
- Drilling
- Component placement
- Soldering
- Testing Protection.

5.4 PCB DESIGN:

Layout basically means placing or arranging things in a specific order on the PCB. Layout means placing of components in an order. This placement is made such that the interconnection lengths are optimal .At the same time, it also aims at providing accessibility to the components for insertion testing and repair.

The PCB layout is the starting point for the final artwork preparation layout design should reflect the concept of final equipment.

There are several factors, which we must keep in mind for placing the layout.

1. Schematic Diagram:

The schematic diagram forms main input document for preparation of the layout for this purpose the software for PCB design, ORCAD was used.

2. Electrical and Thermal Requirement:

The PCB designer must be aware of the circuit performance in critical aspects of the same concerning electrical conditions and the environment to be used in.

3. Mechanical Requirement:

The designer should have the information about physical size of the board, type of installation of board (vertical/horizontal). The method of cooling adopted, front panel operated components etc.

4. Component Placing Requirement:

All components are to be placed first in a configuration that demands only the minimum length for critical conductors. These key components are placed first and the others are grouped around like satellites.

5. Components Mounting Requirements:

All components must be placed parallel to one another as far as possible .i.e. in the same direction and orientation mechanical over stressing of solder should be avoided.

5.5 LAYOUT METHODOLOGY:

For proper layout design minimal, steps to be followed a

1) Get the final circuit diagram and component list.
2) Choose the board types, single sided / double sided / multilayer
3) Identify the appropriate scale for layout.
4) Select suitable grid pattern.
5) Choose the correct board size keeping in view the constraints.
6) Select appropriate layout technique, manual / automated.
7) Document in the form of the layout scale.

5.6 ART WORK:

Art work is accurately scaled configuration of the printed circuit from which the master pattern is made photographically.

Art Work rules:

Rules followed while selecting artwork symbol are,

1) Minimum spacing between conductor and pad should be 0 / 35 mm in 1:1 scale.
2) Minimum spacing between parallel conductors should be 0.4 mm in 1:1 scale.
3) The area of non-PTH solder pad should not be less than (5 sq.mm.).
4) The width of current carrying conductors should be determined for maximum temperature, rise of 20 °C.

5.7 COMPONENT PLACEMENT:

- Preferably, place the component in X-Y direction subjected to mechanical construction.
- All components should be flat mounted i.e. flat placed to avoid of leads and for easy requirements. However in case of space
- Limitation the components such as resistors, diodes, etc. may be mounted vertically which doesn't affect the performance.
- In case separate analog and digital ground.
- Orientation of multi-lead components (e.g. switches, ICs) should be connected in between the analog and digital ground.
- Sufficient clearance is provided around component so that inversion or replacement and repair is easy.
- The design should such that minimum jumpers are allowed.
- It is preferable that, components like present, coils, and trim pots, etc. which alignment of calibration are placed in such that, they are accessible after the assembly of the PCB on cabinet also.

5.8 SOLDERING TECHNIQUE: -

- To active the moderate joints of the component with PCB the soldering are used. There are two methods of soldering.
- Iron soldering
- Mask soldering.

- Procedure of Soldering: -
- The parts to be joined must be cleaned be join and the solder metal are heated with the help of soldering iron. The angle made by soldering iron with the metal. Surface should be approximately equals to 45°c. As the melting point of the solder metal is less so it melt first. Then this melted putting of the solder material if forms permanent joints.
- The protection of PCB from atmospheric corrosion.
- Cu tracks of PCB can be protected by means of lacquer coating.
- Using enamel varnish or tin or gold platting done on cu tracks can also protect sometimes PCB.

CHAPTER 6

SOFTWARE DETAIL

We have programming in ‘C’ language that will convert in assembly using keil software .It is basically used for coding of controller.

6.1.INTRODUCTION TO KEIL MICRO VISION (IDE)

Keil an ARM Company makes C compilers, macro assemblers, real-time kernels, debuggers, simulators, integrated environments, evaluation boards, and emulators for ARM7/ARM9/Cortex-M3, XC16x/C16x/ST10, 251, and 8051 MCU families. Keil development tools for the 8051 Microcontroller Architecture support every level of software developer from the professional applications engineer to the student just learning about embedded software development. When starting a new project, simply select the microcontroller you use from the Device Database and the µVision IDE sets all compiler, assembler, linker, and memory options for you.

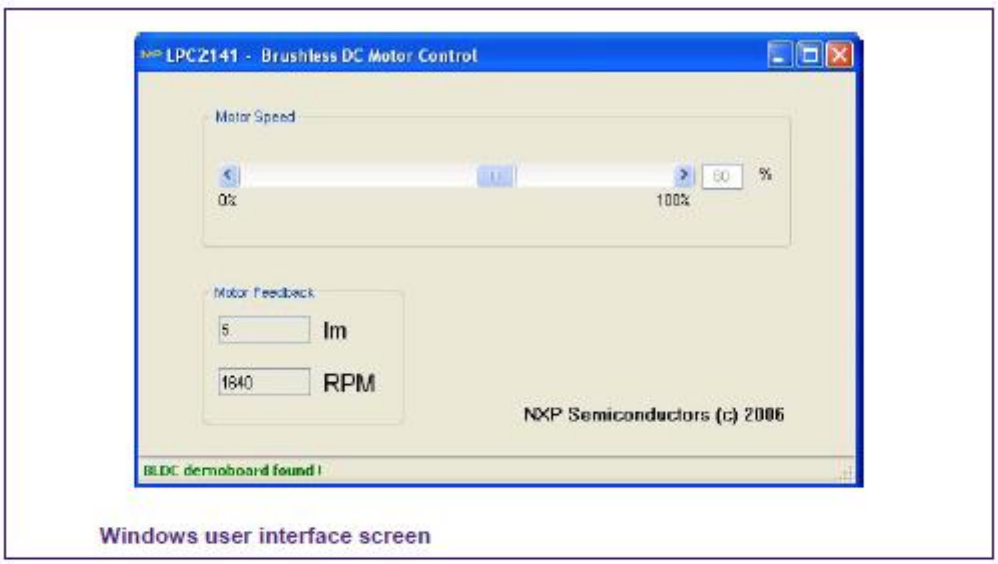


Figure 6.1 Windows user interface screen

Keil is a cross compiler. So first we have to understand the concept of compilers and cross compilers. After then we shall learn how to work with keil.

6.1.1 Concept of Compiler

Compilers are programs used to convert a High Level Language to object code. Desktop compilers produce an output object code for the underlying microprocessor, but not for other microprocessors. I.E the programs written in one of the HLL like 'C' will compile the code to run on the system for a particular processor like x86 (underlying microprocessor in the computer). For example compilers for Dos platform is different from the Compilers for Unix platform So if one wants to define a compiler then compiler is a program that translates source code into object code.

The compiler derives its name from the way it works, looking at the entire piece of source code and collecting and reorganizing the instruction. See there is a bit little difference between compiler and an interpreter. Interpreter just interprets whole program at a time while compiler analyses and execute each line of source code in succession, without looking at the entire program.

The advantage of interpreters is that they can execute a program immediately. Secondly programs produced by compilers run much faster than the same programs executed by an interpreter. However compilers require some time before an executable program emerges. Now as compilers translate source code into object code, which is unique for each type of computer, many compilers are available for the same language.

6.1.2 Concept of Cross Compiler

A cross compiler is similar to the compilers but we write a program for the target processor (like 8051 and its derivatives) on the host processors (like computer of x86). It means being in one environment you are writing a code for another environment is called cross development. And the compiler used for cross development is called cross compiler. So the definition of cross compiler is a compiler that runs on one computer but produces object code for a different type of computer.

6.1.3 Keil C Cross Compiler

Keil is a German based Software development company. It provides several development tools like

- IDE (Integrated Development environment)
- Project Manager
- Simulator
- Debugger
- C Cross Compiler, Cross Assembler, Locator/Linker

The Keil ARM tool kit includes three main tools, assembler, compiler and linker. An assembler is used to assemble the ARM assembly program. A compiler is used to compile the C source code into an object file. A linker is used to create an absolute object module suitable for our in-circuit emulator.

6.1.4 Building an Application In µ Vision2

To build (compile, assemble, and link) an application in µVision2, you must:

A. Select Project -(forexample,166\EXAMPLES\HELLO\HELLO.UV2).

B. Select Project - Rebuild all target files or Build target.µVision2 compiles, assembles, and links the files in your project.

6.1.5 CREATING YOUR OWN APPLICATION IN µvision2

To create a new project in µVision2, you must:

1. Select Project - New Project.
2. Select a directory and enter the name of the project file.
3. Select Project - Select Device and select an 8051, 251, or C16x/ST10 device from the Device Database™.
4. Create source files to add to the project.
5. Select Project - Targets, Groups, Files. Add/Files, select Source Group1, and add the source files to the project.
6. Select Project - Options and set the tool options. Note when you select the target device from the Device Database™ all special options are set automatically. You typically only need to configure the memory map of your

target hardware. Default memory model settings are optimal for most applications.

7. Select Project - Rebuild all target files or Build target.

6.1.6 Debugging an Application in µ Vision2

To debug an application created using µVision2, you must:

1. Select Debug - Start/Stop Debug Session.
2. Use the Step toolbar buttons to single-step through your program. You may enter G, main in the Output Window to execute to the main C function.
3. Open the Serial Window using the Serial #1 button on the toolbar.

Debug your program using standard options like Step, Go, Break, and so on.

6.1.7 Starting µ Vision2 and Creating A Project

µVision2 is a standard Windows application and started by clicking on the program icon. To create a new project file select from the µVision2 menu Project – New Project…. This opens a standard Windows dialog that asks you for the new project file name. We suggest that you use a separate folder for each project. You can simply use the icon Create New Folder in this dialog to get a new empty folder. Then select this folder and enter the file name for the new project, i.e. Project1. µVision2 creates a new project file with the name PROJECT1.UV2 which contains a default target and file group name. You can see these names in the Project.

6.1.8 Window Files

Now use from the menu Project – Select Device for Target and select a CPU for your project. The Select Device dialog box shows the µVision2 device data base. Just select the microcontroller you use. We are using for our examples the Philips 80C51RD+ CPU. This selection sets necessary tool Options for the 80C51RD+ device and simplifies in this way the tool Configuration.

6.1.9 Building Projects and Creating A Hex Files

Typical, the tool settings under Options – Target are all you need to start a new application. You may translate all source files and line the application with a click on the Build Target toolbar icon. When you build an application with syntax errors, µVision2 will display errors and warning messages in the Output Window – Build page. A double click on a message line opens the source file on the correct location in a µVision2 editor window. Once you have successfully generated your application you can start debugging.

After you have tested your application, it is required to create an Intel HEX file to download the software into an EPROM programmer or simulator. µVision2 creates HEX files with each build process when Create HEX files under Options for Target – Output is enabled. You may start your PROM programming utility after the make process when you specify the program under the option Run User Program #1.

6.2 CPU SIMULATION

µVision2 simulates up to 16 Mbytes of memory from which areas can be mapped for read, write, or code execution access. The µVision2 simulator traps and reports illegal memory accesses. In addition to memory mapping, the simulator also provides support for the integrated peripherals of the various 8051 derivatives. The on-chip peripherals of the CPU you have selected are configured from the Device.

6.2.1 Database Selection

You have made when you create your project target. Refer to page 58 for more Information about selecting a device. You may select and display the on-chip peripheral components using the Debug menu. You can also change the aspects of each peripheral using the controls in the dialog boxes.

6.2.2 Start Debugging

You start the debug mode of µVision2 with the Debug – Start/Stop Debug Session Command. Depending on the Options for Target – Debug Configuration, µVision2 will load the application program and run the startup code µVision2 saves the editor screen layout and restores the screen layout of the last debug session. If the program execution stops, µVision2 opens an editor window with the source text or shows

CPU instructions in the disassembly window. The next executable statement is marked with a yellow arrow. During debugging, most editor features are still available.

For example, you can use the find command or correct program errors. Program source text of your application is shown in the same windows. The µVision2 debug mode differs from the edit mode in the following aspects:

- The "Debug Menu and Debug Commands" described on page 28 are available. The additional debug windows are discussed in the following.
- The project structure or tool parameters cannot be modified. All build commands are disabled.

6.2.3 Disassembly Window

The Disassembly window shows your target program as mixed source and assembly program or just assembly code. A trace history of previously executed instructions may be displayed with Debug – View Trace Records. To enable the trace history, set Debug – Enable/Disable Trace Recording.

If you select the Disassembly Window as the active window all program step commands work on CPU instruction level rather than program source lines. You can select a text line and set or modify code breakpoints using toolbar buttons or the context menu commands.

You may use the dialog Debug – Inline Assembly… to modify the CPU instructions. That allows you to correct mistakes or to make temporary changes to the target program you are debugging. Numerous example programs are included to help you get started with the most popular embedded 8051 devices.

The Keil µVision Debugger accurately simulates on-chip peripherals (I^2C, CAN, UART, SPI, Interrupts, I/O Ports, A/D Converter, D/A Converter, and PWM Modules) of your 8051 device. Simulation helps you understand hardware configurations and avoids time wasted on setup problems. Additionally, with simulation, you can write and test applications before target hardware is available.

6.3 EMBEDDED C

Use of embedded processors in passenger cars, mobile phones, medical equipment, aerospace systems and defense systems is widespread, and even everyday domestic appliances such as dish washers, televisions, washing machines and video recorders now include at least one such device.

Because most embedded projects have severe cost constraints, they tend to use low-cost processors like the 8051 family of devices considered in this book. These popular chips have very limited resources available most such devices have around 256 bytes (not megabytes!) of RAM, and the available processor power is around 1000 times less than that of a desktop processor. As a result, developing embedded software presents significant new challenges, even for experienced desktop programmers. If you have some programming experience - in C, C++ or Java - then this book and its accompanying CD will help make your move to the embedded world as Quick and painless as possible.

CHAPTER 7

TESTING

Controlling system have been tested all the motors are functioning properly.

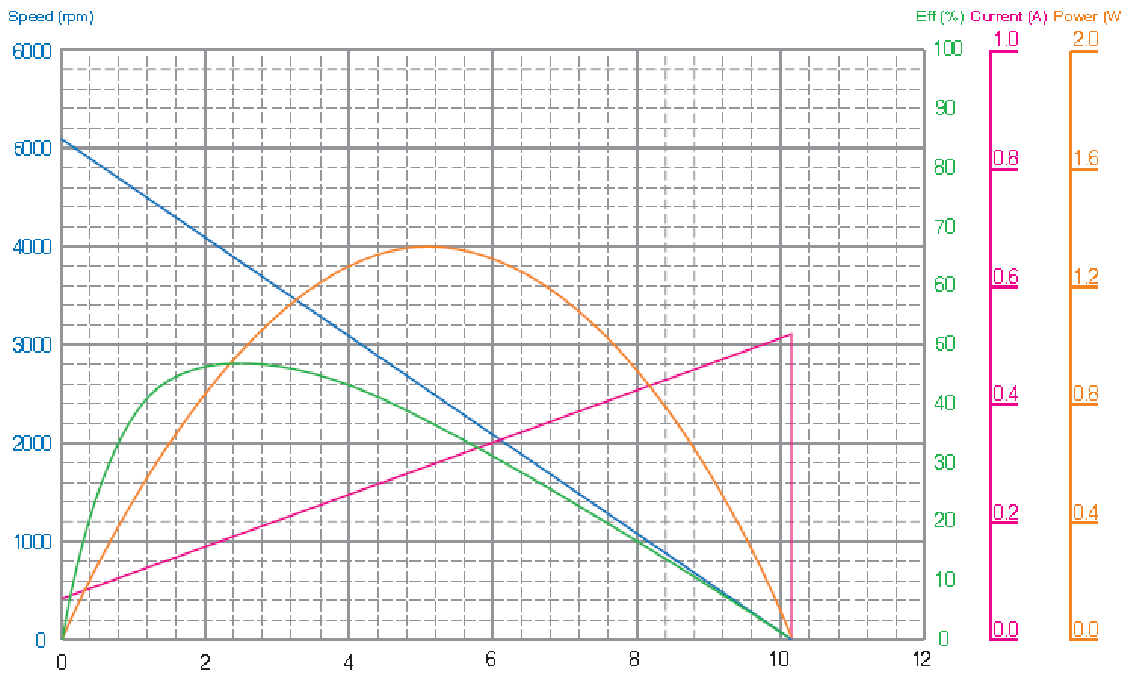
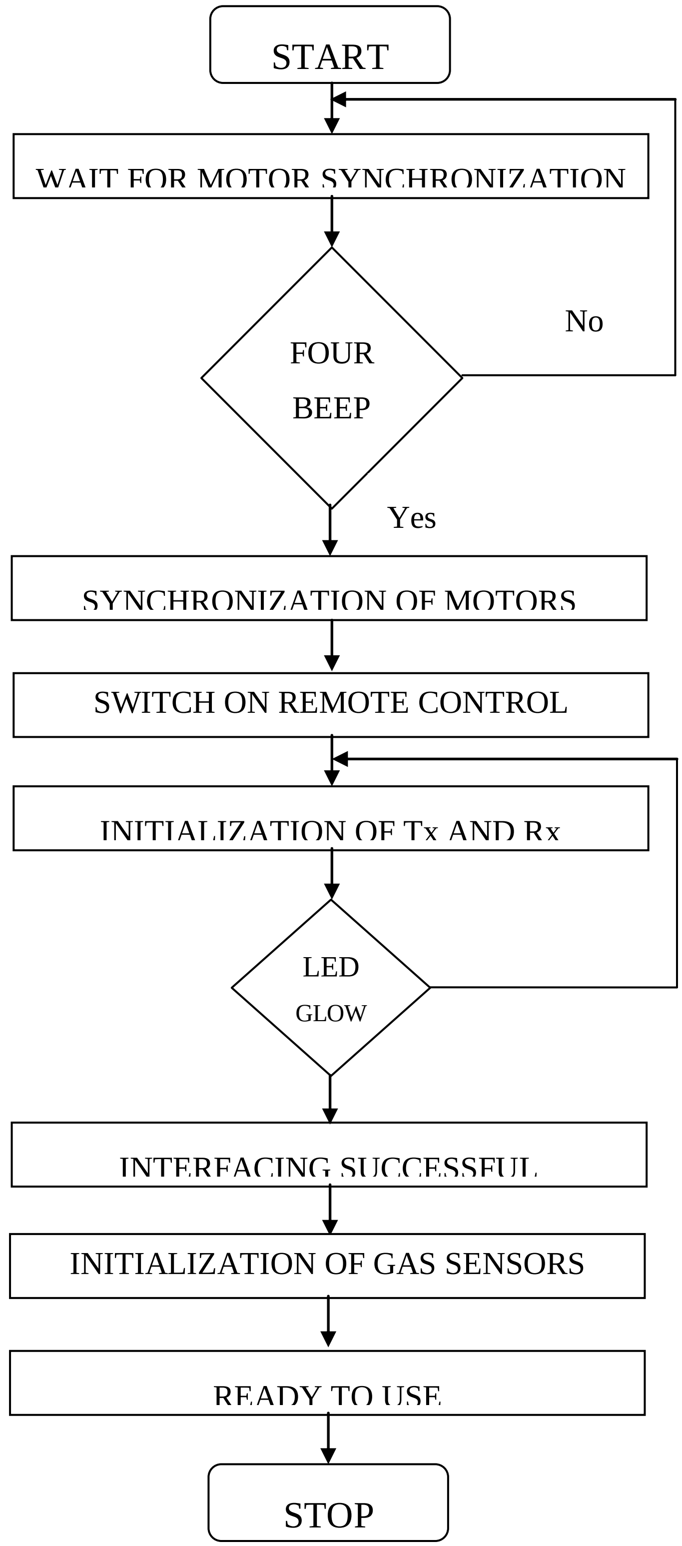


Figure 7.1 Motor characteristics

Vision system is tested; videos are clear on screen, which is beneficial for video capturing of location and surveillance.

CHAPTER 8

FLOW CHART



CHAPTER 9

RESULT

Results achieved

1. We found Effective control positioning system and display system achieved while flyingBy using high pixel camera it was possible to capture Video of locations and surveillances.
2. We have overcame with the great challenges of stability as well as balancing of quadrotor while takeoff and flying.
3. Accuracy.

CHAPTER 10

APPLICATIONS

10.1 REMOTE SENSING

Remote sensing makes it possible to collect data on dangerous or inaccessible areas. Remote sensing applications include monitoring deforestation in areas such as the Amazon Basin, glacial features in Arctic and Antarctic regions, and depth sounding of coastal and ocean depths. Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed.By helicopter images, data is created to analyze and compare things like vegetation rates, erosion, pollution, forestry, weather, and land use. These things can be mapped, imaged, tracked and observed. The process of remote sensing is also helpful for city planning, archaeological investigations, military observation and geomorphologic surveying.

10.2 SURVEILLANCE

Aerial surveillance is the gathering of information, usually in forms of visual images or video. Surveillance is the monitoring of the behavior, activities, or other changing information, usually of people and often in a surreptitious manner. It most usually refers to observation of individuals or groups by government organizations, but disease surveillance, for example, is monitoring the progress of a disease in a community.

10.3 OTHER APPLICATIONS

- In Hazardous Environments like Nuclear Power Plants.
- Defence.
- Security & Surveillance.
- Inspection and Surveillance Tasks in Nuclear Power Plants and Waste Storage Facilities.
- Spy work & Anti terrorism application.
- Visual photography.
- Space Exploration.

- Remote Sensing Applications.
- Disaster Rescue.
- Military Applications.
- Mapping Applications.
- Applications in the Domain of Disaster Monitoring, namely Forest Fires.
- Harmful gas sensing where human cannot go.

CHAPTER 11

ADVANTAGES & DISADVANTAGES

11.1 ADVANTAGES

- It has High Stability.
- Our flying robot shows High Reliability.
- Flying robot can do Vertical lift off thus no need of runway.
- It is also Suitable for indoor applications.

11.2 DISADVANTAGES

- Our project has Less Flight Time (around 15 min max).
- It has Payload Limit.
- Its Components are difficult to find in India for example BLDC motor of 11000RPM.
- Our project Budget goes high because motors have to be imported.
- Correction of detected gas is not fully efficient because of challenges faced due to budget.

CHAPTER 12

FUTURE SCOPE

A future project that NASA wants to become reality is a free flying robot capable of performing inspection and viewing missions in support of International Space Station (ISS) operations.

Figure 12.1 Autonomous Extravehicular Robotic Camera (AERCam)

NASA will introduce a new improved project of this robot, which is a part of Autonomous Extravehicular Robotic Camera (AERCam) program.

As a free flying camera platform, AERCam could provide additional external views unavailable from ISS or Space Shuttle cameras. It could even be flown to areas around ISS unreachable by suited crewmembers.

CHAPTER 13

CONCLUSIONS

The aim of our project was to have a fully functional quad-rotor helicopter capable of hover and directional motion based on operator inputs. We barely achieved our first goal of hover. During our test runs we achieved lift of the craft, and some level of autonomous hover, with visible corrections from the control system. However, noise provided enough uncertainty that we were not willing to attempt flight without a cable to secure the craft from flipping over and losing altitude. Despite not achieving untethered flight, we are pleased with the results we did obtain.

We feel that our design and construction of the physical structure was a success both in terms of stiffness and strength of the craft, and in terms of weight reduction. We also succeeded in writing fully functional software for the control of the four motors.

We remained comfortably below the Rs.30000/-budget of the project.

However, we feel the progress that we have outlined above was significant along the way to our goal of autonomous flight.

CHAPTER 14

REFRENCE

14.1 BOOKS

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4. Johnson, W., 1980, "Helicopter Theory" Princeton, N.J. : Princeton University Press.

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2. P. Pounds, R. Maloy, P. Hynes and J. Roberts, Design of a Four-Rotor Aerial Robot, Australian Conference on Robotics and Automation, 2002
3. P. Pounds, R. Mahony, J. Gresham, P. Corke, and J. Roberts, Towards Dynamically Favorable Quad-Rotor Aerial Robots, Australian Conference on Robotics and Automation, 2004
4. G. Hoffmann, D. G. Rajnarayan, S. L. Waslander, D. Dostal, J. S. Jang, C. J. Tomlin, The Stanford Testbed of Autonomous Rotorcraft for Multi Agent Control (STARMAC), DASC 2003

14.3 WEBSITES

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- www.flyingrobot.com 12th January 2012
- www.unitedhobbies.com 12th January 2012
- www.nex-robotics com 12th January 2012

COMPONENT LIST

COMPONENT LIST & APPROXIMATE COST OF MATERIAL

MODULE	QUANTITY	PRICE
1. Lithium batteries	4	3500
2. Propeller (puller)	2	400
3. ATMEGA-8 Microcontroller	1	200
4. Aluminium / balsa wood base	4	1000
5. Propellers(pusher)	2	400
6. RF Transmitter	1	3000
7. RF Receiver	1	2000
8. Brushless motors	4	8000
9. ESC(Electronic speed controller)	4	5000
10. Resistors	4	20
11. Capacitors	5	20
12. Diodes	4	20
13. Transistors	3	20
14. LEDS	4	30
15. Crystals oscillator	2	50
16. Regulator IC(7805)	1	10
17. ARM PROCESSOR	1	550
18. PC(programming and vision)	1	-
19. Wireless camera	1	1500
20. Camera Receiver	1	500
21. Gas sensor	1	200
22. LI-PO Battery charger	1	1000
TOTAL		**27,420**

ABSTRACT

The goal of this project is to create a semi-autonomous hovering platform, capable of vertical lift-off and landing without a launcher, and capable of stationary hovering at one location. However, the aerial robot proposed here, called the HoverBot , has two distinguishing features: The HoverBot uses four rotor heads and four electric motors, making it whisper-quiet, easy-to-deploy, and even suitable for indoor application . It also has an advance feature of sensing of the gases exist in atmosphere along with wireless camera for continuous transmission of video to remote location.

We have used in this project frequency of 2.4 GHZ. Four brushless DC motors of low weight and high rpm is being used along with four Propeller . High control frequency precludes the use of commercially available brushless motor controllers, such as those found in model aircrafts, as they only allow motor speed update rates of 2.4GHz. This controller has very low dead times and supports very dynamic movements. Intensive manual acrobatic flights with loops, flips, spins, sharp turns and combined maneuvers proofed the stability of the controller in extreme situations.

It has many advantages such as High Stability and suitable for Suitable for indoor applications and also it does not need any runway for vertical lift off .The best part of our project is that it can go at remote location where human cant go because of this advantage NASA is going to use flying robot as their future project.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES