International Journal of Engineering and Manufacturing Science. ISSN 2249-3115 Vol. 7, No. 1 (2017)

Design and Development of Arduino Uno based Quadcopter

Vibha Kishor[1], Ms. Swati Singh[2]

[1]UG Student, Department of Electronics and Communication, Meerut Institute of Technology, Meerut
[2]Assistant Professor, Department of Electronics and Communication, Meerut Institute of Technology, Meerut

Abstract- In the modern world with increase in the technology there is equal growth in automobiles which creates traffic leading to sound pollution, traffic jam and air pollution. So it take more than required time to reach from one place to another, thus we must look forward to some airways. Quadcopter is one of flying unit used to lift the object from one place to another in lesser time or can be used for surveillance purpose. At industry level applications, quadcopter are made using KK board module which comes with pre programmed KK board and balanced gyroscope module which is not economical for smaller applications. It's not a cost effective method. To make the quadcopter economical and efficient for small level applications this work is proposed, which design and develop a quadcopter using Arduino Uno board instead of pre programmed KK flight Controller board. It has wide application like quadcopter mounted with camera and GPS tracker could be used for surveillance of wide areas such as forest and coast guard applications etc.

Keywords—Accelerometer, Arduino Uno Atmega328 micro controller, BLDC Motor, Flight controller Board, ESCs (Electronic speed controller), Propellers, Transmitter and Receiver.

1. Introduction

Quadcopter is an assistive device which has a high demand in the industrial & surveillance sector. As the technology has matured and become more mainstream, a number of practical and very interesting uses of Quadcopter technology have emerged [1]. The present work includes the design and development of the Quadcopter using ATMEGA328. This system will either use a GPS system or it will use a camera for identification of path being traveled by it [2]. This system will be controlled by a remote system or a transmitter by sitting inside our home, office, or any place within its transmitter range. This concept will thus facilitate the surveillance activities [4]. The quadcopter is useful for in many situations. From the scope of the quadcopter, it's used for aerial photography, security and rescue, industrial inspection and much more. The result of this project will help people in natural calamities by reaching the dense areas where humans cannot reach immediately. Practically, quadcopter is being used for object detection through image processing in border security of the nation [6-7].

2. Hardware description

The quadcopter use an arduino microcontroller Atmel328 as the core controller and is designed and developed to achieve the real time operating system. This system uses one receiver attached on a controller board and a transmitter that controls the motion of a quadcopter. The hardware consists of simple Arduino board with an Atmega 328, propellers, ESCs & flight controller board (FCB), transmitter & receiver and gyroscope for a balanced flight as shown in fig.1.

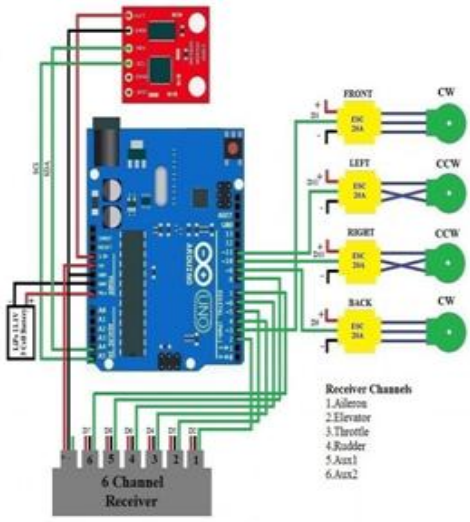

Fig.1 Hardware description of Quadcopter

Hardware is programmed in C language. The controller board and ESC's work together. FCB gives the command to ESCs which is further connected to BLDC motors for the rotation.

3. Working principle

Quadcopter system works on the principle of air lifting phenomena with high pressure. The propellers force the air in downward with high pressure due to which an uplift force is created and as a result action reaction law is applied on the whole system. When this uplift force dominates the earth's gravitational force, the whole system start flying in the air. But there is a problem with the rotation of propellers. If we rotate the propellers in clock wise direction then due to this rotation, a torque will be applied over the whole system in one direction .And similarly if we rotate the propellers in anti-clock wise direction then also a torque will be produced over the whole system and the whole system will start rotating anticlockwise. To overcome this problem we rotate two propellers in clockwise direction and remaining two propellers in anticlockwise direction. This phenomena produces torque in opposite direction and they get balanced and the system remains stable while flying.

Two basic phenomena are used for movement of quadcopter, thrust and torque. Quadcopter uses its four propellers attached to motors which creates thrust and help quadcopter to elevate high. Motion of quadcopter are defined based on the input values (x, y, z, θ, ϕ, ψ) given to it. Out of four motor attached with propellers, two motors rotate in clockwise (CW) direction while other two in counter clockwise (CCW) direction. Motion of quadcopter is thus controlled mainly by three movements. These movements are classified as

3.1 Yaw Rotation (ψ)

Yaw is defined as movement of quadcopter either to left or right and it is controlled by throttle stick of transmitter. Yaw decides the direction of quadcopter.

3.2 Pitch Rotation (θ)

Pitch is defined as the whole movement of quadcopter either in forward direction or in backward direction. It's also controlled by throttle of receiver. Moving the throttle in forward direction moves quadcopter in forward direction while moving throttle backward moves quadcopter in backward direction [2].

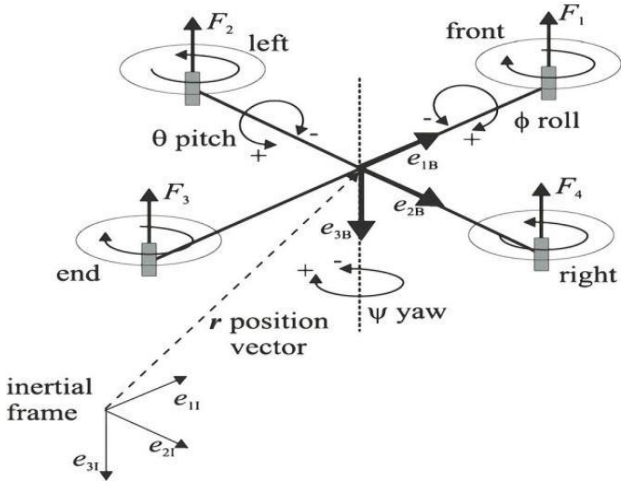

Fig.2 Yaw, Pitch & Roll rotation

3.3 Roll Rotation (ϕ)

The movement about the longitudinal axis of quadcopter is known as roll motion. Left or right motion of throttle stick is followed by quadcopter, it moves in towards right when throttle move to right and moves to left when throttle stick moves in left direction. This parameter thus makes quadcopter to fly in left or right direction. [2].

4. Design and Methodology

The methodology adopted in designing arduino based quadcopter is shown in fig.3.

4.1 Hardware Components Used

4.1.1 Arduino Uno

Arduino Uno is an open source physical computing platform used for building digital devices and interactive objects that can sense and control objects in physical world. It's a micro controller, based on AT mega 328P which consist of 14 digital input/output pins (out of which 6 pin are used as PWM output), 6 analog inputs, a USB connector,16 MHz quartz crystal, power jack, an ICSP header and a reset button. Arduino board consist of everything needed to work with microcontroller. Arduino IDE (Integrated Development Environment) is use to upload programs to the arduino boards and further these programmed boards can be used to perform intended tasks.

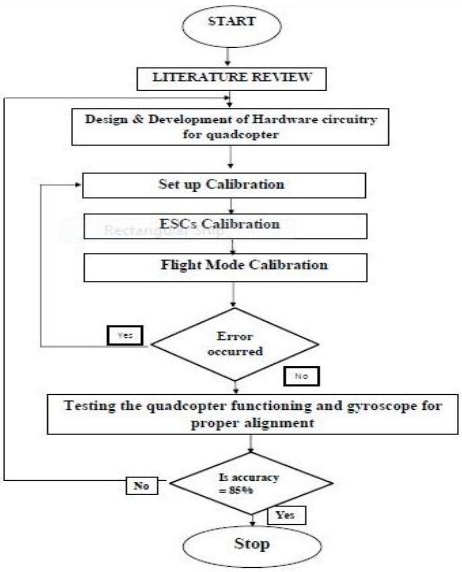

Fig.3 Flow chart for Quadcopter Designing

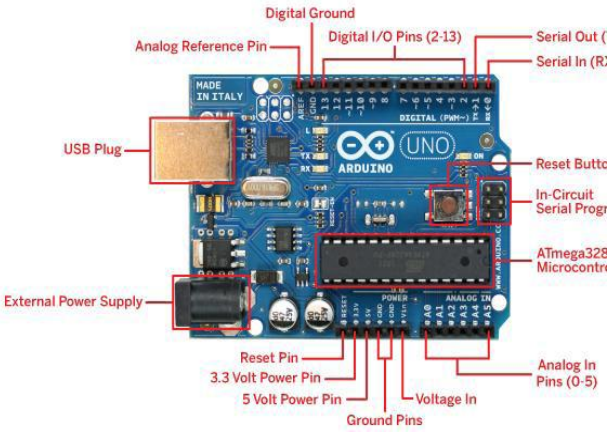

Fig.4 Arduino Development Board

4.1.2 BLDC (Brushless DC Motors)

Also known as electronically commuted motors (i.e. ECMs motors). BLDC motor are synchronous motor powered by DC electricity. Rated in KV, where it rotates 1000rpm per 1 volt supplied to it (if its rating is 1 KV). It offers several advantages over brushed DC motors like more reliability, low noise, reduction in EM Interference (EMI), high torque per watt etc.

Fig.5 BLDC Motor

4.1.3 ESC's (Electronic speed controller)

Four 30A ESCs (electronic speed controllers) are used in proposed Quadcopter. It convert the PWM signal received from flight controller or radio receiver and then drives the brush less motor by providing required electrical power. Thus ESC is an electric circuit that control the speed and direction of electric motor by varying the magnetic forces created by the windings and magnets within the motor.

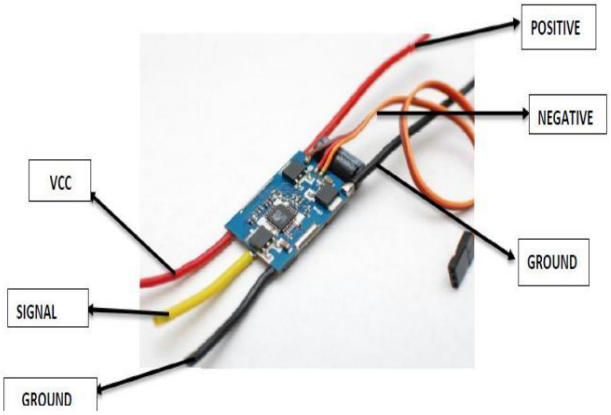

Fig.6 ESC's (Electronic speed controller)

4.1.4 Flight Controller Board

Flight controller used in quadcopter is the main functioning body of our aircraft. It's a circuit board that that are equipped with sensors which senses any change in orientation. It can receive different commands sent by user to control speed of motors so that quadcopter could be stable in fly mode. Here we have used arduino uno as our flight controller board. ESCs and Flight Controller board work together in following ways:

- ESCs receive command from micro controller circuit board and further give command to the motors for rotation.
- FCB generates various commands for ESC and motors according to the need of user.

The whole system is controlled by this controller board.

4.1.5 Transmitter and Receiver

Radio transmitter uses radio signal to remotely control quadcopter in wireless way, the commands given by transmitter are received by a radio receiver connected to flight controller. The no of channels in transmitter determine how many actions of aircraft can be controlled by pilot. Minimum of four channels are needed to control a quadcopter (which includes pitch. Roll, throttle, yaw).The stick control on radios transmitter is known as gimbal. RC receiver used operates on 2.4GHz of radio frequency (unless you do not have any specific need for a different frequency).

Fig.7 Transmitter and Receiver

4.1.6 Li-Po Battery

Li-Po (Lithium Polymer battery) is a rechargeable battery of lithium ion technology. They provide higher specific energy and are being used where weight is a critical factor. It also provide high voltage and long run time as they hold huge power in small package and have high discharge rates required to meet the need of powering quadcopters.

Fig.8 Li Po (Lithium Polymer) Battery

4.1.7 Frame

The F-450 quadcopter frame is used as it is best suited for the propellers and payloads which has to be lifted along quadcopter. Quadcopter requires a light as well as rigid frame to host a LIPO battery, 4 BLDC motors, 4 ESCs & a controller.Arms are made up of 5/8 hollow square aluminum bars and uses common nuts and bolts to hold the frame together. .

Fig.9 Quadcopter four arm Frame

4.1.8 Propellers

Used 10 x 4. CW and CCW 4 pieces of black propellers as per the requirements. Size of propellers varies with its applications like smaller propellers (under 8 inch) are used for racing. .While large sized propellers (over 8 inches) along with motors are used for carrying some weighted object like camera.

Fig.10 Propellers

4.1.9 Gyroscope

Quadcopter requires a flight stability sensors that stabilizes quadcopter during its flight mode. L3G4200DH gyroscope is low power sensor with a sensing element and an IC interface (able to provide the measured angular rate to users through digital interface 12C/SPI)

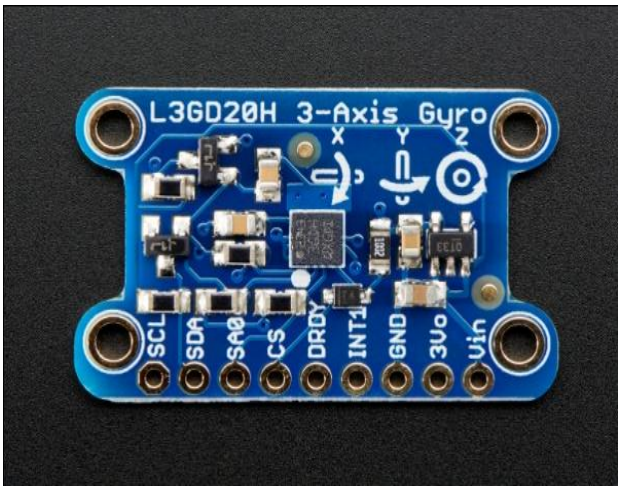

Fig.11 Gyroscope

5. Software Implementation

The micro controller ATMEGA328 is programmed using C language with arduino IDE software. It's a development environment that simply uses an user interface for adding and editing in the arduino coding language.These program are utilized in various calibration steps which includes

5.1 Set up Calibration

Set up calibration illustrates the interconnections of various hardware components used in quadcopter. Firstly program is uploaded on arduino board using IDE Software and then some motor arming routine is followed as illustrated in flow diagram shown in fig.12

.

5.2 ESC's Calibration

ESC calibration varies with the brand of ESCs used in quadcopter. The calibration of ESIC is done on priority basis with the help of a radio system for each rotor and corresponding ESC. It includes the following steps as follows:

- First upload the program on controller board, then turn ON the transmitter and put the throttle stick to its maximum.
- Now connect the battery.The auto pilot's red, blue and yellow LED will light up in cyclic pattern that indicates ESCs are ready for calibration mode.
- By keeping transmitter throttle stick high, disconnect and then reconnect the battery.
- Regular no of beeps on transmitter indicates the battery cell count and additional two beeps specify that maximum throttle has been captured.
- Now set the transmitter throttle stick down to its minimum position.
- ESCs should now emit a long tone that indicates minimum throttle has been captured and calibration is complete.
- Fig. 13 shows that the values of roll, pitch & yaw on IDE software. For a balanced flight these parameters of gyroscope must be set to -0,-0 & 0 respectively.

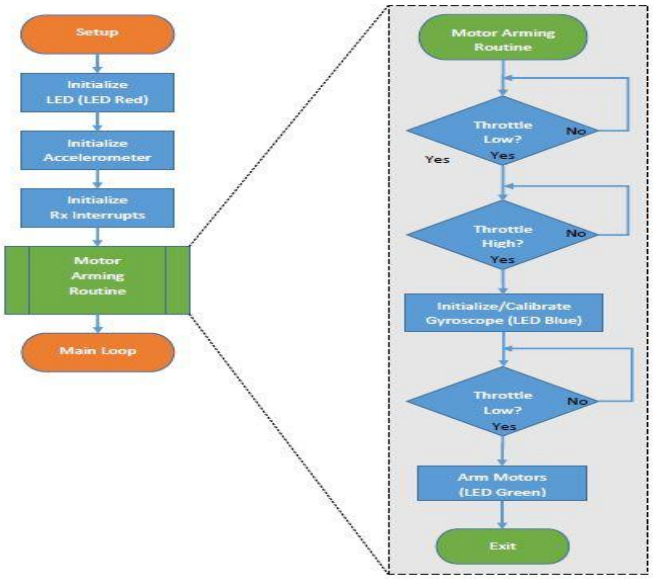

Fig.12 Set Up/Initialization workflow

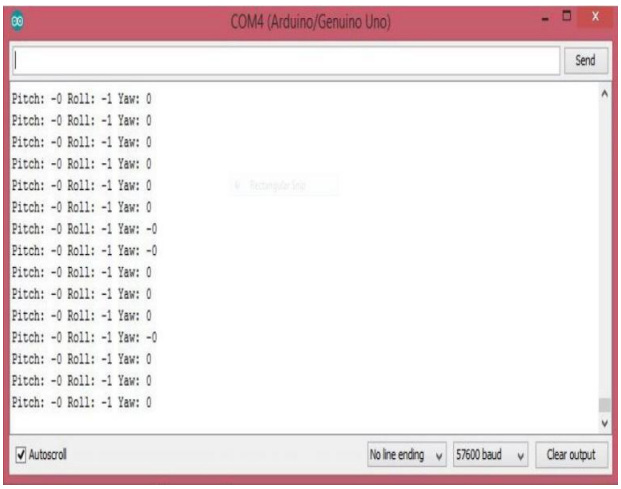

Fig.13 IDE serial monitor output while ESC's calibration

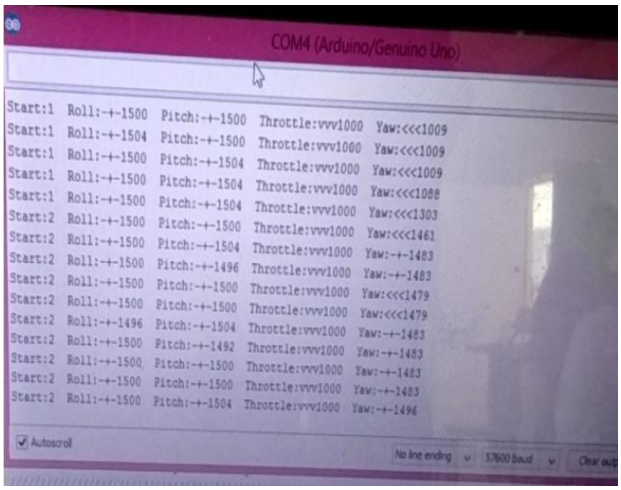

Fig.14 IDE serial monitor output for all sticks in center position

5.3 Flight Calibration Mode

Flight calibration mode is a field testing mode. Place quadcopter on flight mode and then test the quadcopter on field. After tuning the gyro parameters on the test stand, we began to test the quadcopter in free flight. These tests were performed outdoors in a large open area, while maintaining safe distance from the quadcopter.

We were confident after the single-axis tests that the quadcopter would be fairly stable in the roll and pitch axes, but it drifted significantly in the yaw direction. After stabilizing control on the yaw axis with proportional control only, the quad drifted much less in yaw and became much more controllable. We increased the proportional control term in the yaw PID until the quad was fairly responsive to yaw control inputs. We found that the quad made small, fast oscillations in the roll and pitch axes in flight. To fix this, we reduces the vibration on quadcopter by balancing the propellers, we

isolated the sensor board from the remaining vibration using vibration absorbing mount. Now quadcopter flight mode was much stable.

6. Motor Thrust Testing

To test the motor thrust and determine its relationship to ESC command signal, one of the motors was mounted to a load cell. The load cell had a 5 kg maximum load, more than adequate for the less than 1kg maximum that we expected from the motor. For each BLDC motor and the propellers of 10X4.5 we were able to generate a thrust of 0.902kg when supplied with 2000μs pulse. So, by using the four BLDC motors we can generate the maximum weight lifting capacity of 4X0.902=3.608kg for the Quadcopter provided the battery must be fully charged.

Fig.15 Final arduino based quadcopter design

7. Conclusion

Our research work yielded a successful development of Arduino Uno based Quadcopter at a cheaper and affordable amount. Quadcopter which can be easily made from shelf components. It can be used as a low cost alternative to various applications which includes pesticide sprinkling, end to end delivery within the transmitter's RF range, surveillance in defense and other sensitive places like nation border, mapping through remote sensing, etc. with very high level of precision.

7.1 Future Possible Upgradation

Our team goals were to design, test, and build a quadcopter kit. There are various possible up-gradation in future based on its application which includes:

- Adding a sonic sensor module to controller board for more accurate altitude determination.
- Implementing a GPS module on kit for tracking & spy based applications.
- This design can employ Motor Driver of high rating or Relay driver can be used for its commercial applications.
- Can be used for real estate photography by employing camera on it. Other applications includes inspection, surveillance and monitoring a wide area by camera equipped quadcopter.
- Pesticides sprinkling

Based on the weight lifting calculations we can use our single economical Quadcopter to lift these different modules satisfying the weight lifting criteria.

References

[1] Stafford, Jesse, "How a Quadcopter works Clay Allen". University of Alaska, Fairbanks. Retrieved 2015-01-20.

[2] Sandeeep Khajure, Vaibhav Surwade, Vivek Badak, "Quadcopter Design and Fabrication," International Advance Research Journal in Science, Engineering and Technology (IARJSET), Vol. 3, Issue 2, February 2016.

[3] Quadcopter Dynamics, Simulation, and Control, January 26, 2010.

[4] David Roberts, "Construction and Testing of a Quadcopter," California Polytechnic State University, San Luis Obispo, CA, 93407, June, 2013.

[5] S. Bouabdallah, P. Murrieri, R. Siegwart, "Design and Control of an Indoor Micro Quadrotor", Robotics and Automation 2004. Proceedings. ICRA '04. 2004 IEEE International Conference on, vol. 5, pp. 4393-4398, 2004.

[6] J. Engel, J. Sturm, D. Cremers, "Camera-based navigation of a low-cost quadrocopter", IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 2815-2821, Oct. 2012, ISBN 2153-0858.

[7]. J. Valvano, "Embedded Microcomputer Systems: Real Time Interfacing", Brooks-Cole, 2000, ISBN 0534366422.