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Advanced Quadcopter with Battery Safety Mechanism

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ABSTRACT*:*A quad-copter is an Unmanned Aerial Vehicle (UAV), with four motors which are driving counter rotating propellers mounted in cross pattern, through Electronic Speed Controllers (ESC).
In this paper, we have developed a cost efficient hover control mechanism and deployed on a low-cost microcontroller to control motors for aircraft design known as Quad-copter. The successful deployment of designed system on the microcontroller, resulted in simplicity of control mechanism and increase of manoeuvrability. Usage of Quad-copter by the military and other law enforcement agencies has increased manifolds, due to its advantage of highly reducing the exposure risks of the vehicle operator.

KEYWORDS: Unmanned Aerial Vehicles (UAV), Electronic Speed Controller(ESC).

I.INTRODUCTION

The stability of Quad-copter is most important aspect in applications like security surveillance and on board image shooting. It allows easy to control and prevention from crashing due to external factors [1]. Quad-copter has six degrees of freedom with three rotational and three translational movements. Quad-copter can be controlled using four degrees of freedom Yaw, Roll, Pitch and Thrust. In fig 1 quad-copter can be moved along x and y axis in translational movement and about z axis for rotational movement.

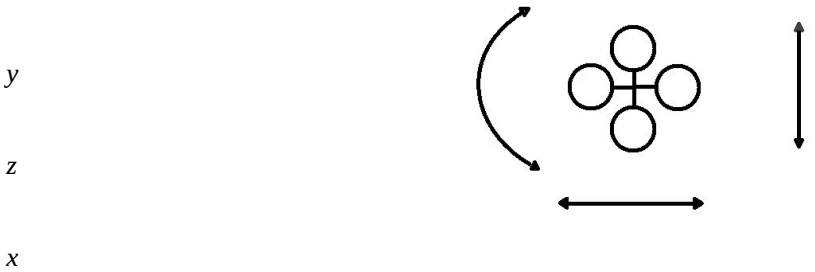

Figure 1: Quadcopter's Degree of Freedoms

A gyro sensor is interfaced with microcontroller to measure values and provide feedback values of Yaw, Roll and Pitch. This helps quad-copter maintain its stability and ease of control from the base station. The purpose of this study and its contribution to the unmanned aerial vehicle is simplified control mechanism.

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II.RELATED WORK

To get the generalised idea about flight mechanism of quadcopter and the necessary components required for building, online article 'Arduino Quadcopter: what you need to build one' by Jack Brown proved to be very helpful. As Arduino Uno is the flight controller of this research project we have used many libraries of Aero quad libraries for interfacing of MPU6050 sensor. To understand the working principles of brushless dc motors we referred some of the topics from book ' Permanent Magnet Synchronous and Brushless Dc Motor Drives' by R. Krishnan. Apart from text books we referred some scholarly articles under Quadcopter design topic which are listed as below:

Kenneth D. Sebesta and Nicolas Boizot, "A Real-Time Adaptive High-Gain EKF, Applied to aQuadcopter Inertial Navigation System," in IEEE Transactions on industrial electronics, vol. 61, no. 1, January 2014.

Jinay S. Gadda, Rajaram D. Patil., "Quadcopter (UAVS) for border security with GUI system,"IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308."

Also tutorials on how to make a Quadropter uploaded on youtube were also very helpful in getting insight of building frame and completing assembling of the electronics parts. Below is the link of the tutorial series available on youtube on Quadropters:

https://www.youtube.com/watch?v=on0h7sPV-YU

https://www.youtube.com/watch?v=6btEFJJD4_o

III.BLOCK DIAGRAM & HARDWARE DESIGN

Quad-copter Subsystem

The quad-copter subsystem used in this research consists of Transmitter-Receiver module (TX -Rx), a gyroscope unit, electronic speed controller circuits (ESC), brushless DC motors and a Lithium Polymer battery (LiPo). Fig. 2 shows basic components of quad-copter subsystems. Receiver module interfaced with microcontroller receives basic command signal which is Pulse Width Modulation (PWM) [1]. This signal is modified by microcontroller and sent to each electronic speed controller which in turn controls brushless Dc motor.

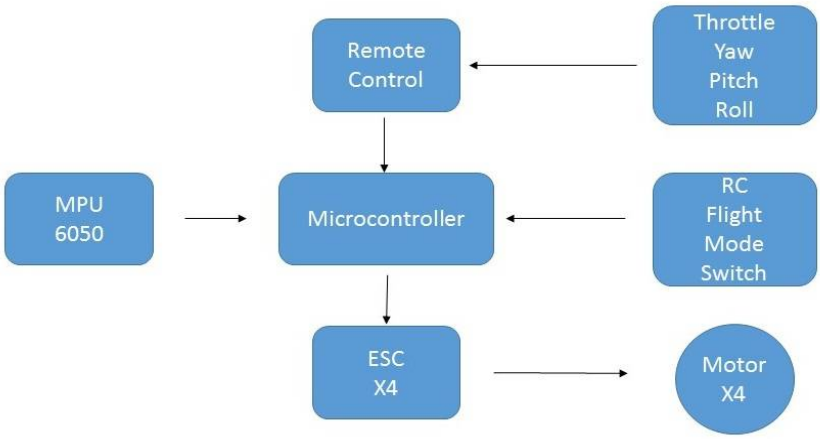

Figure 2: Block diagram

MCU

Arduino is open source hardware-software firmware used for building various embedded devices. In this research project Arduino Uno has been used as brain of the project for interfacing of receiver and sensor module. The main function of microcontroller unit is to implement designed program.

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Brushless Dc Motor:

Brushless Dc motors are commuted motors without brush. For enough thrust and torque brushless Dc motors are used as they can be operated at high RPM. Parameters of brushless DC motors are measured as Kv. Brushless Dc motors are often operated by AC electric signals. Brushless In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform and frequency.

Frame:

This frame was a good choice for our project, mainly because of the low price and the flexibility of installing components on the frame. Bumpers around the propellers protect those from damage in case of a collision. Figure 1 shows the frame including the wooden motor bases and the fiberglass rods.

Figure 3: Sample Quadcopter Frame

Motors:

The quadrotor's propellers are run by four brushless electromotor. These brushless motors have permanent magnets attached to the outer casing, while the stator is inside and contains several electromagnets.

CIRCUIT DIAGRAM

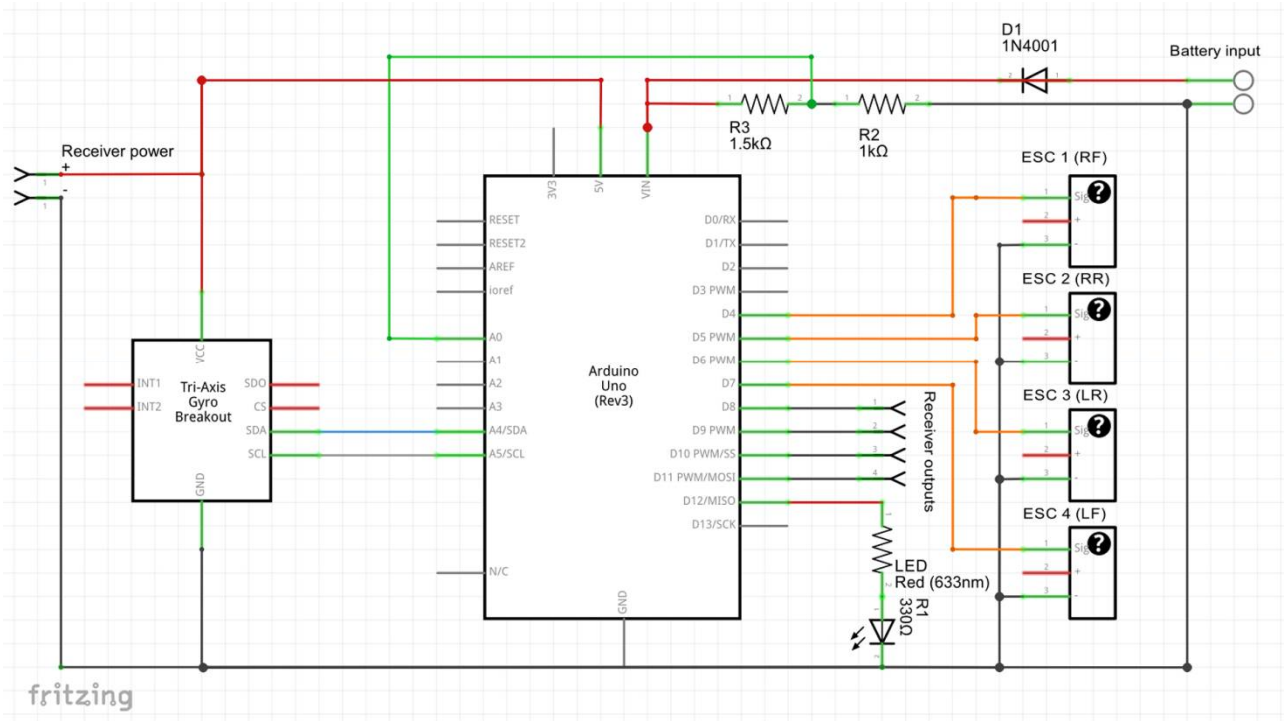

Figure 4: Circuit Diagram

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IV.DESIGN CALCULATIONS

1) Roll is the rotation about the x axis (between -180 and 180 deg);

2) Pitch is the rotations about the y axis (between -90 and 90 deg);
3) Yaw is the rotation about the z axis (between -180 and 180).

Battery Voltage:

Battery voltage variable can be added to programming part to avoid draining of battery below threshold voltage during the flight. A battery input can be added to analog ports of microcontroller to get feedback about voltage of battery. This can be explained through following formula:

Battery_Voltage=(analogRead(Port _Number) + Compensation Voltage for diode)*((Max_volt*100)/1023)

Gyroscope:

Gyroscope is the most common used sensor in quadcopter control board.It gives the angular rate around the 3 axes of space in deg/s, so, as for the accelerometer, by using following formula angle of accuracy can be calculated.

Angleaccurate= (GyroPercentage)*Anglegyro+ (1-GyroPercentage)*Angleaccel[5]

Yaw:

A yaw rotation is a movement of a rigid body about its vertical axis. The angular velocity of aircraft around vertical axis is the yaw rate of aircraft. It is commonly measured in degrees per second or radians per second.
Equation for YAW is:

Yawaccurate= (GyroPercentage)*Yawgyro+ (1-GyroPercentage)*Yawcompass[5]

Thrust

Thrust is the amount of force exerted by quadcopter to hover in space. Basically thrust is a force which moves aircraft through air.

For Thrust:

$$T=(\pi/4)*D2\rho\upsilon\Delta\upsilon$$

Where,
T=thrust
D=propeller diameter
υ=velocity of air at the propeller
$\Delta\upsilon$=velocity of air accelerated by propeller
ρ= density of air

V. RESULT AND DISCUSSION

Our needs analysis determined that we had to build a Quadcopter with simplified hover mechanism and battery that lasted for extended period of time. While designing this project, we maintained trade-off between time flight and overall power supply. To give the Quadcopter enough thrust for uplift, appropriate calculation ofsurge current according to Brushless Dc motors is needed. A closed loop feedback mechanism is used in this research project for safe landing before draining of the battery.Use of MPU6050 sensor with Arduino Uno has improved stability of Quadcopter in air. We controlled theQuadcopter successfullyfrom base station with Fm modulation of PWM signals. Use of FM transmitter and receivers extended control range of Quadcopter up to 2 Kms. Low battery detector algorithm is useful for safe landing of Quadcopter without draining below threshold voltage.

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Figure 4: Implemented Design of Quadcopter

VI. CONCLUSION

The project has been built perfectly and we have completed several tethered basic test flights.We have resolved several technical issues faced in this research project. As this project is developed on flexible platform, it could go in various directions ranging from military applications to basic law enforcement agencies. This project will clearly demonstrate the goals of proving that small scale UAVs are useful across a broad range of applications.

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