HARDWARE IMPLEMENTATION

Introduction

To build an Unmanned Aerial Vehicle (drone) we need some hardware parts and embedded system. To make this autonomy we need sensors, modules, telemetry kit, flight controller and software. In some embedded system consists of build in sensors and communication module which helps to make autonomous any system. In this section we discuss briefly implementation and working of this system.

This system has two parts-

1. Structural Hardware Part
2. Electronic Hardware Part

Structural Hardware Part:

- **Parts for body construction:**

1. Aluminum square shape bar (hollow type)
2. Acrylic Sheet
3. Drawing box
4. Art paper
5. Set square
6. Cutter machine
7. Drill machine and bit
8. Nut bolts
9. Screw driver

Short description:

- **Aluminum bar:** We made two cross arm which length is 60cm. We choose aluminum square shape hollow bar. Because this bar is light weight, rigid, easy to drill and cut. It has a special quality to absorb heat easily like heat sink. When motor heated then heat can easily transfer to bar.
- **Acrylic Sheet:** This is light weight sheet like plastic and looks pretty good. We use this sheet as a base which holds cross arm tightly. Our landing skid also made of acrylic sheet.

- **Drawing box:** In this box consist all drawing instruments. We use this box to draw our hand design.
- **Art paper:** We used 2 A4 size paper to draw our body design. We need two sheets because we draw a real size body design without any scaling. So, we combine these two papers by tape.
- **Set square:** needs to make perfect angular measurement. Also need to verify our real design.
- **Cutter machine:** This one type of tool which helps to cut. We use this tool to cut aluminum bar and acrylic sheet.
- **Drill machine and bit:** this is an electromechanical machine needs to drill any objects. Its need drill bit which types depend on objects. We use these to drill aluminum bar and acrylic sheet.
- **Nut Bolts:** Needs to screw up all body components like arm, base, skid, motor etc.
- **Screw driver:** This tool needs to tight or lose the screw.

Photos of body construction:

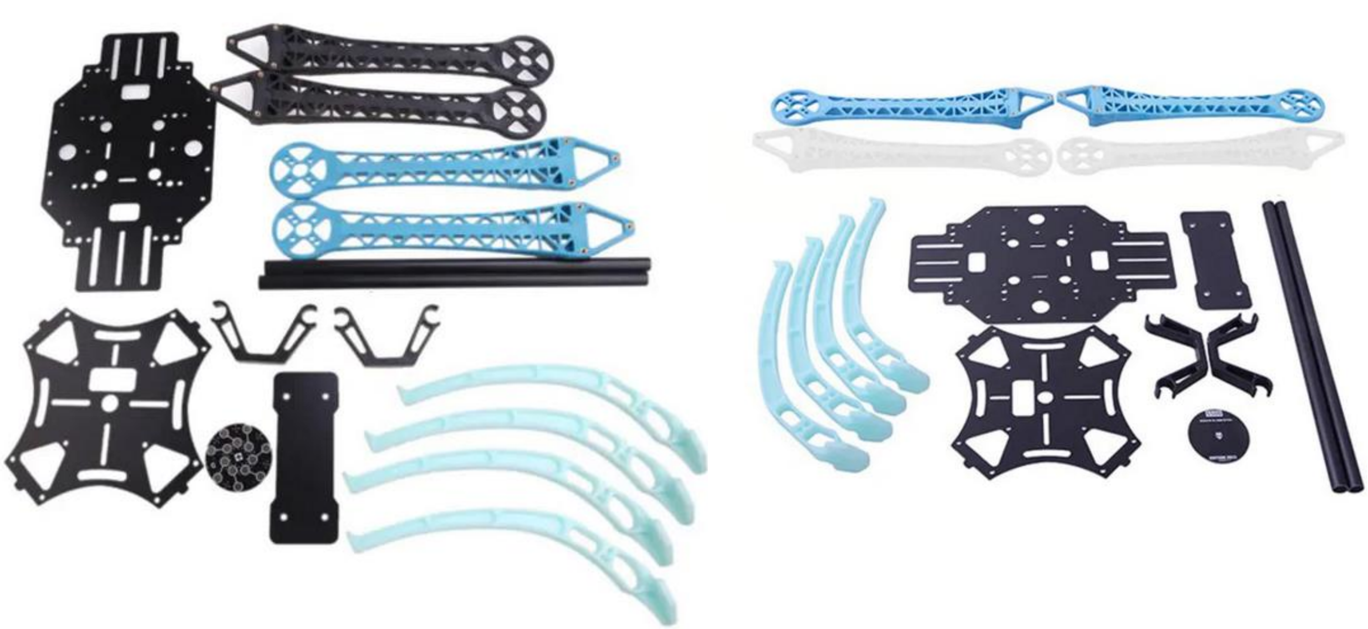

Figure 1: Instruments before Assumable

Fig 2: After Frame making

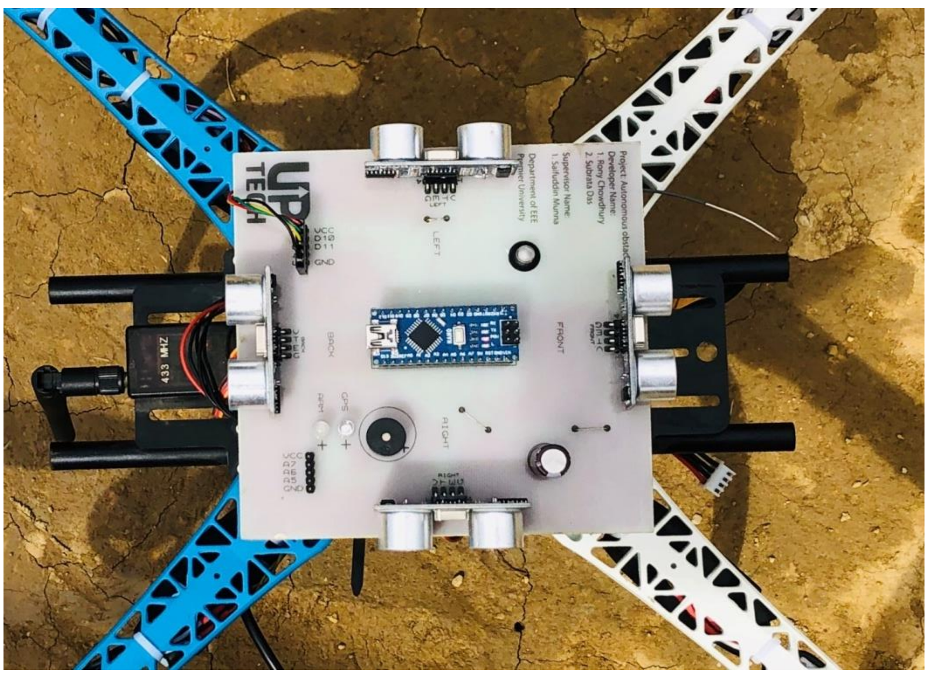

Fig 3: Top View of the drone

Figure 4: Rotor View

Figure 5: GPS Compass

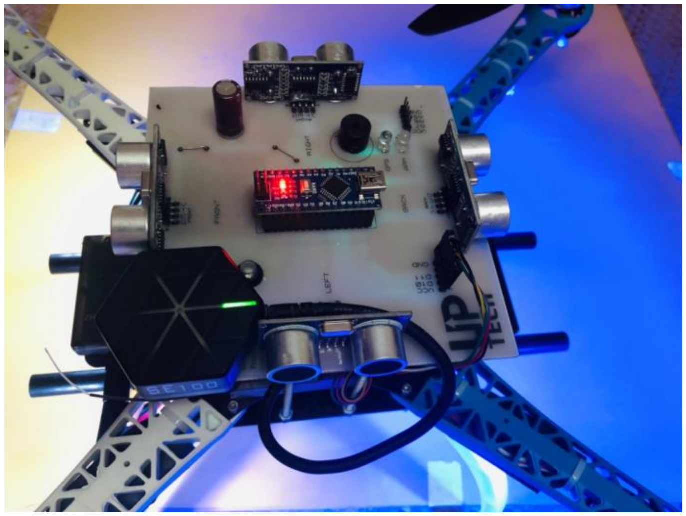

Fig 6: Drone after Power Up

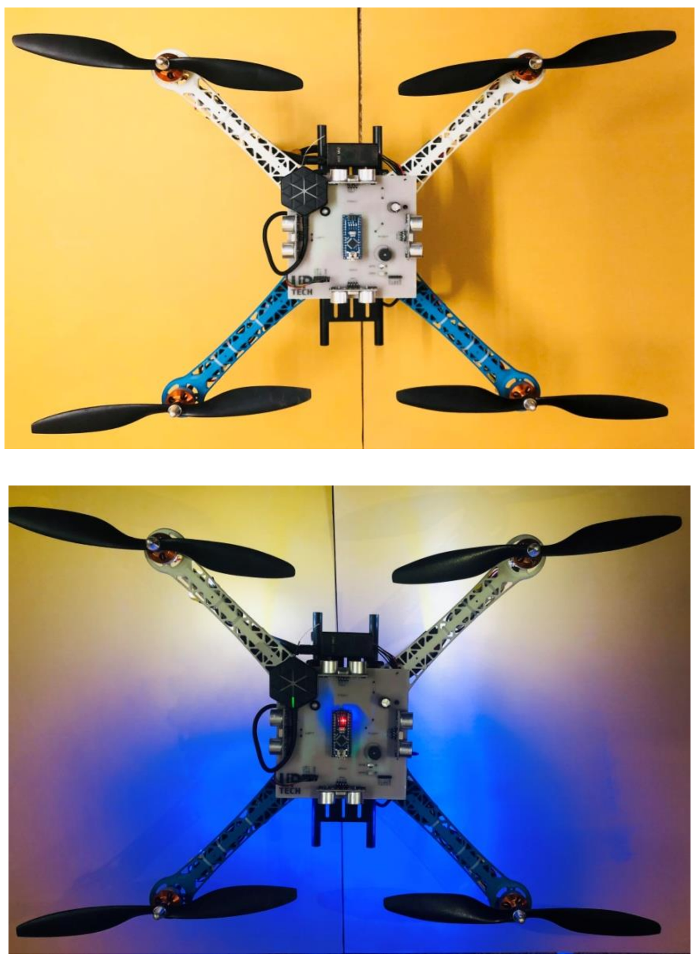

Figure 7: Final Ready Body

Electronics Hardware Part:

- **Component needed:**

1. Pixhawk PX4 pilot board
2. ESC (Electronic Speed Controller)
3. Brushless DC motor
4. Propeller
5. GPS module with external compass
6. 9 Channel Radio (Transmitter and Receiver)
7. 3cell Lipo battery
8. Soldering iron
9. USB cable and jumper wire
10. Electrical tape
11. Arduino Nano
12. Ultrasonic sensor

Short Description:

- **Pixhawk PX4 pilot board:** This is the main board or pilot board of our system. It has high speed microcontroller, flash memory and EEPROM. It has many I/O digital and analog ports. It also consists of built in accelerometer & gyroscope, barometric pressure sensor, GPS port, Telemetry port etc.
- **ESC (Electronic Speed Controller):** This is a controller board which control the speed of motor by using PWM from main board instruction. We used an ESC which has built in BEC (battery elimination circuit). BEC helps to provide power in pilot board.
- **Brushless DC motor:** This is one type of out runner dc motor which has high rpm and low power consumption characteristics. We used four motors to lift our total system. **Propeller:** A carbon fiber blade. Its size and pitch depend on total system design. We used 10*4.5inch propeller for lifting 1.5kg weight.
- **GPS module with external compass:** this is global positioning system module. It has built in compass sensor. This module helps to make it autonomy like coordinate tracing, holding and change its direction.
- **Radio telemetry kit:** This is one pair of transmitter and receiver. It helps to monitor flight data from ground station wirelessly. Also helps to upload a mission and change any instruction wirelessly.

- **6 Channel Radio:** it's a pair of transmitter and receiver. It needs for sending manual instruction, controlling in manual mode and changing mode. It also helps to calibrate PID's.
- **Lipo battery:** it is rechargeable battery made of lithium polymer substance. This is the main power source or fuel of our drone. It provides power in all sections.
- Soldering iron: it needs to solder any electronics component if required.
- **USB cable & jumper wire:** USB cable needs to programmed main board or interfacing to computer. Jumper wire needs to connect module with main board.
- **Electrical tape:** it helps to avoid short circuit of any connection and also provide safety handling with lipo battery.
- **Arduino Nano:** The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P (Arduino Nano 3.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.
- **Ultrasonic sensor:** An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves. This is because some objects are shaped or positioned in such a way that the sound wave bounces off the object, but are deflected away from the Ultrasonic sensor.

Wiring connection of electronic parts:

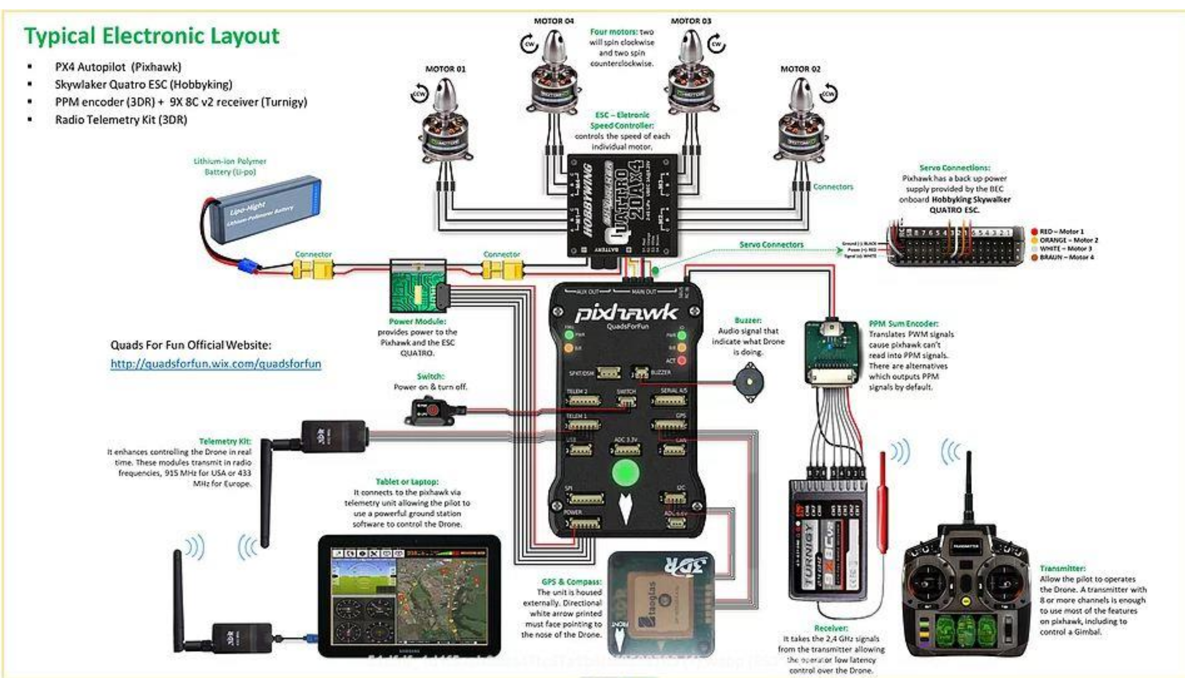

Figure 8: wiring connection of all parts with flight controller

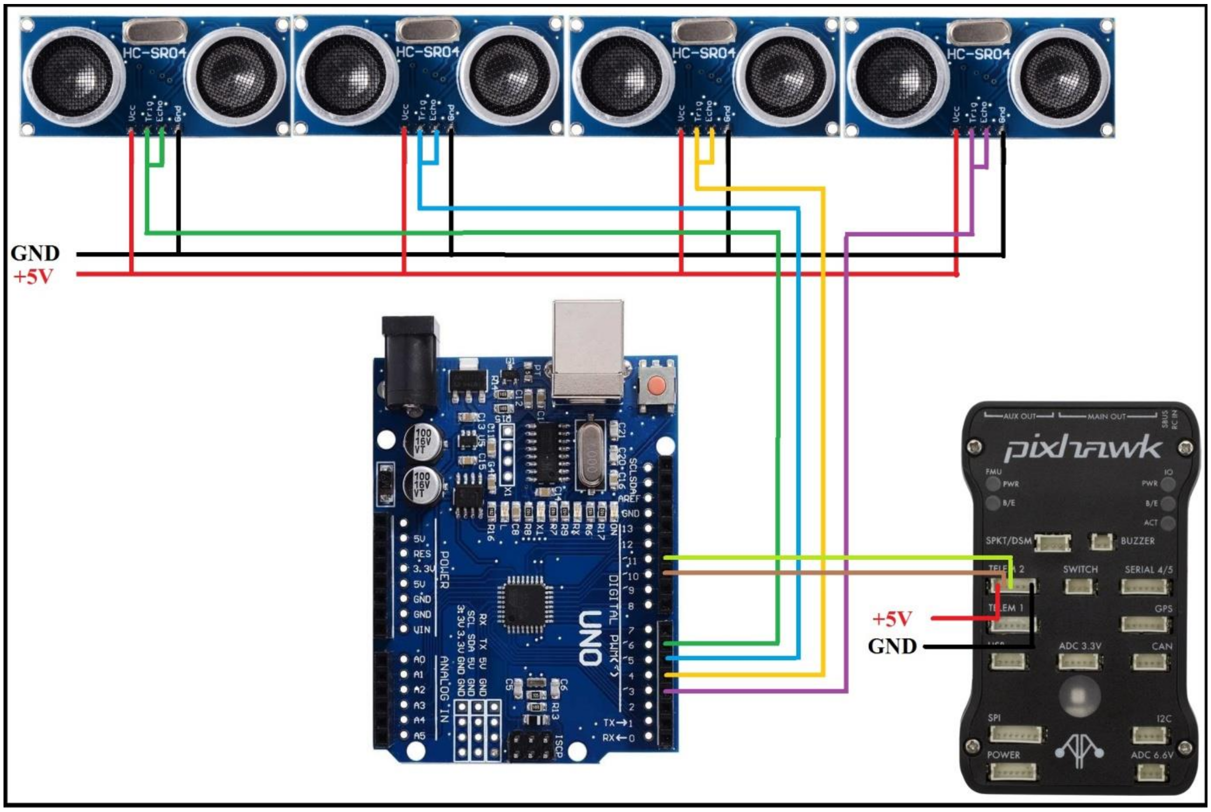

Figure 9: wiring connection Arduino and Ultrasonic sensors with flight controller

RESULT AND DATA ANALYSIS

Introduction:

Software is important part for any embedded system. Software used in embedded system for coding, configuring hardware, calibration and data logging purposes. In our system we also used some software for coding, calibrating, data analysis and configuring hardware. Implementation of this part is given below-

Configure and calibration

- **Coding and Log Data Collecting:** we used Arduino platform to code this system. This platform is similar to C, C++. Another open-source software used for simulation and log data download from flash memory of pilot board. But we have to write some code for interfacing with this software.

Figure 1: Data collecting form flash memory

- **Configuring Hardware and Tuning PID:** we use software to configure hardware part. Basically, need for mandatory hardware setup. We calibrate accelerometer & gyroscope, compass, radio transmitter by using mission planner software. Another important works is PID tuning for different parameter or mode performance.

Figure 2: Mandatory hardware configuration

Figure 3: PID tuning

- **Flight Data and Mission Setup:** it’s an important part to see real time flight data, position, and orientation and hawk eye view etc. Mission planning and uploading is essential part of an autonomous drone system. To perform this operation, we used Planner software. it has extra feature to see flight data, simulation log data and pre-loaded mission uploading facility. We perform these operations using this software.

Figure 4: Mission setup

Target data:

Our target is to make a stable autonomous drone. So, we have to concentrate on IMU (inertial measurement unit) which maintain its movement, position holding, graceful motion and orientation. In this case vibration controlling, throttle performance, response time, real time flight characteristics, temperature, air surveillance, Obstacles Avoiding and power continuity performance is important issue. In our system we have been maintained this factor in desirable condition and other factors also monitored.

All of data discussed based on 2.30min successful stable flight. All data include several modes including autonomous flight.

Output Data Analysis:

- **Accelerometer performance:**

The figure below shows the x-axis vibration level of 3-axis accelerometer. The desire vibration magnitude is 4 to -4. Our curve shows the average magnitude is 3.5 to -3.5. So the results is pretty good and works very well. For y-axis the desire magnitude also 4 to -4. we get average value tends to 4 to -4. this is also good.

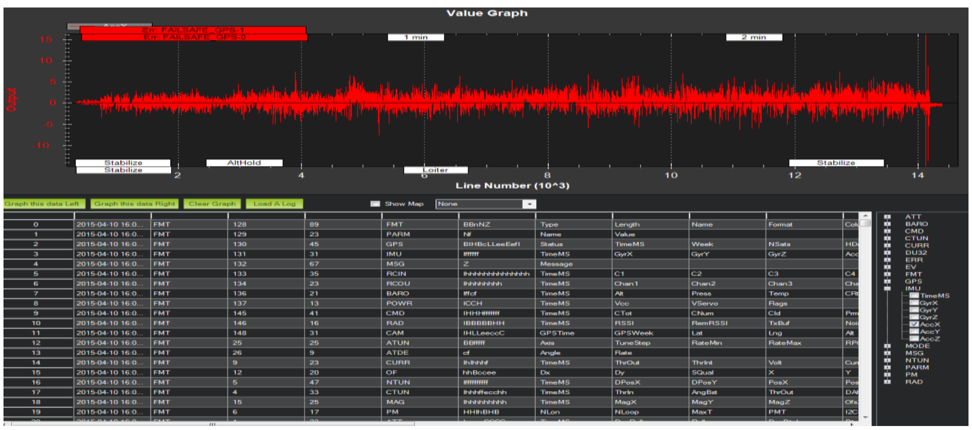

Figure 5: Vibration level of accelerometer x-axis

Figure 6: Vibration level of accelerometer y-axis

For z-axis desire value is -5 to -15. But we get little bit greater than desire value. In this case drone also flies very well.

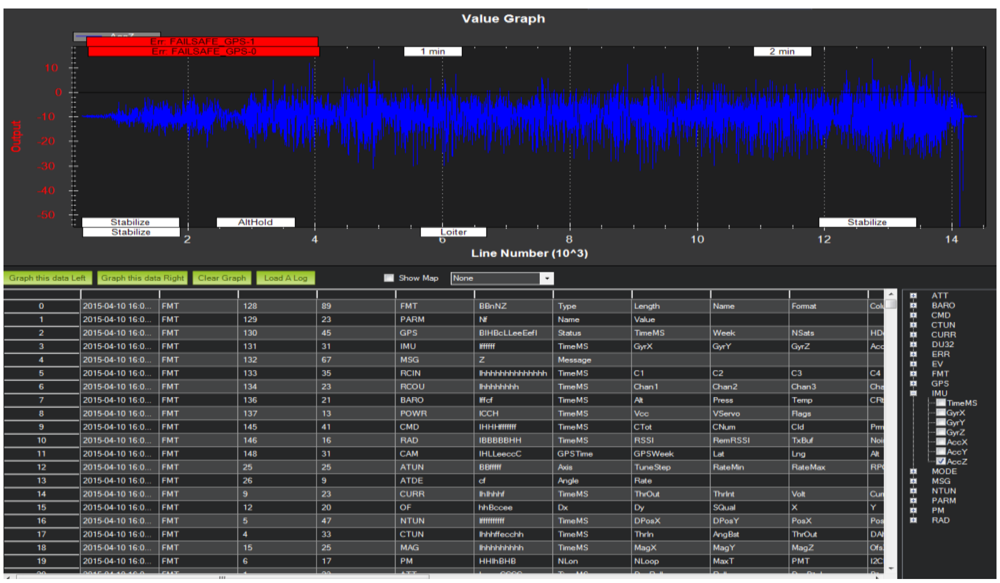

Figure 7: Vibration level of acceleration z-axis

Gyro performance:

Figure below shows the 3-axis gyro performance curve.

For x-axis we see in stabilize mode and altitude hold mode we get some spike which indicate gyro action. Though stabilize mode is manual mode so we change pitch & roll manually. So it makes balance after human action. In loiter mode that means in GPS lock mode- all parameters controlled automatically without human interface. So in loiter mode spike is less which indicate it makes balance automatically.

Figure 8: Gyro x-axis performance

In y-axis gyro performance curve shows that in both mode drone balance very well.

Figure 9: Gyro y-axis performance

In z-axis we see that curve is clam. So, yaw movement is very smooth and its hold stable direction in all flight mode.

Figure 10: Gyro z-axis performance

5.4.3 Throttle and hold performance:

This is one of the important curves which indicate the overall performance, stability and behavior of our drone. Red marked line, green marked line and blue marked line indicate desire altitude, altitude and barometer altitude respectively. When we shift flight mode to hover mode or GPS lock mode then DAlt curve generate and then altitude calculated from IMU unit and also generate the barometer altitude curve. These last two curves try to follow DAlt value. When these all curves in overlapped close enough that means its performance very well. We find this curve after long time PID tuning and using proper vibration damping system. So, this curve shows the performance so good.

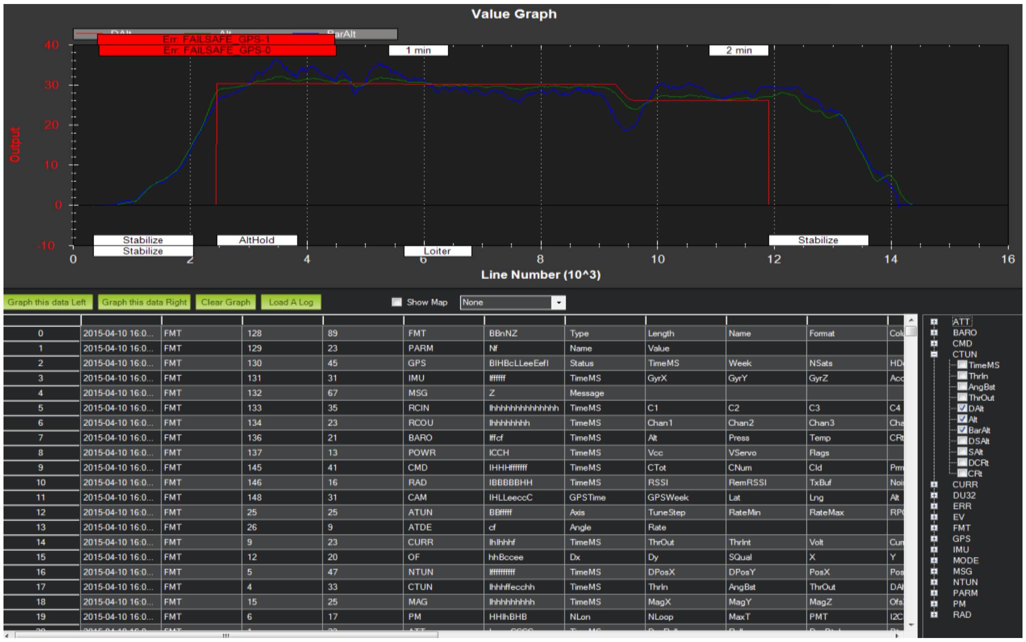

Figure 11: Throttle hold performance

Throttle performance in auto mode:

This curve shows the throttle response in autonomous mode. In auto mode throttle mode fluctuate slightly but the average value is not very bad.

Figure 12: Throttle performance

Temperature and Communication analysis:

in this curve red line, green line and blue line indicates transmitter buffer, receiver error and temperature respectively. We see that tx buffer is 100ms which is not bad. Board temperature is not increasing remarkably that means condition not bad. Also see that receiver communication error is zero, that means communication system works very well.

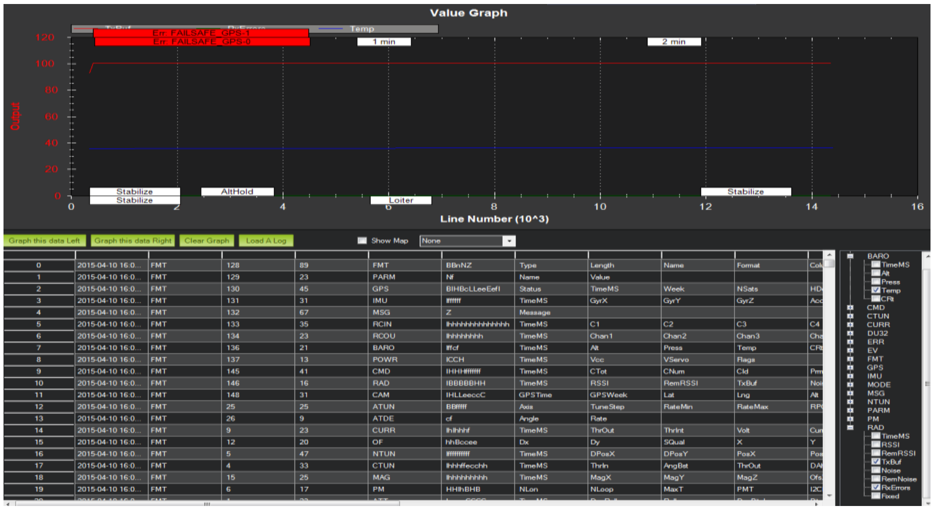

Figure 13: Temperature and Communication

Roll & Pitch performance:

Red line and green line indicate roll and pitch respectively. We see in stabilize mode and altitude hold mode we get some spike which indicate pitch & roll action. Though stabilize mode is manual mode so we change pitch manually. In altitude hold mode- altitude maintain automatically but pitch & roll is also manual control. In loiter mode that means in GPS lock mode- all parameters controlled automatically without human interface. So in loiter mode spike is less which indicate it holds a constant coordinate.

Figure 14 Roll & Pitch performance

Supply voltage analysis:

Maintain a sufficient power is important issue in pilot board. Our pilot boarded is capable safe operation between 4.6v to 6v. if power supply falls below this range, then system failure occurred. In this curve we see that average power is 4.65v. we can provide constant 5v by using power module. In our case we provide power to main board using BEC of ESC.

Figure 5.15: Supply voltage curve

Result:

From all of curve analysis we can conclude that overall performance of our system is good. This system is capable to fly in different without major complexity. It’s performance, movement, orientation, motion, stability also good.