Dragon Bee

University of Central Florida

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Senior Design I

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1. Executive Summary

After the idea of unmanned aerial vehicle (UAV) have emerged early 1900’s for military use, and the next big jump in transistor evolution came with the MOSFETs in 1960s, UAVs have invaded the commercial use. As public became interested in UAVs, the growth of UAV’s has been dramatically increasing last decade. UAVs have become known as drones which it comes in variety of shapes such as Quadcopter, Tricopter … etc. The ability of flying, drones been used in multiple applications that require height. One of the very many areas in which aerial platforms from drones can be deployed is aerial photography.

Getting involved in this revolution, this project objective is to build Dragon Bee with the aerial photography ability. The Dragon Bee project is, at the bottom line, take advantage of microcontrollers and provide to users opportunity to create fascinating photography with ease and without need to hire a helicopter or charter plane. Implementing multiple technologies such as GPS, compass, and proximity sensors will allow Dragon Bee to interact with a person who has the control over smart phone using Wi-Fi connectivity.

The idea of choosing Drone project over couple other project ideas came after the team members suggested to go for something challenging, fun and resourceful.

Dragon Bee is a project aimed to move Go Pro camera to the next level by giving every user an incentive control options. Without a camera pole and hands free, the user will be able to give the Dragon Bee orders at first and enjoy the fascinating snaps of pictures and videos. Multiple modes will be available at the user’s smart phone with easy-to-navigate menu.

At the brainstorming phase, team members have identified most of the challenges. At this phase, being entry level students was one of the hardest challenges in such team members had to go through an extra effort and more time searching about all the possible ways to implement quadcopter internal design. Wireless communication was another challenge since the project main goal is to control Dragon Bee using smart phones which eliminate the possibility of having radio frequency as smart phone main and reliable wireless communications are Bluetooth and Wi-Fi. As team members considering live streaming to a smart phone, Wi-Fi will be the right connectivity module for a reliable and fast steaming.

Another challenge was related to follow me mode that gives Dragon Bee an auto follow mode. GPS will be implemented in this project, in other words, GPS in strong signal area helps get user’s location.

Not to mention the user end software, the application at the user end will be design in was that provides control and stream video at the same time, and same device. At the control part, user will have the choice of multiple modes such as Autonomous mode, manual mode, and some other modes for more fascinating pictures and videos.

As of first senior design class was dedicated to research and design, some other unidentified challenges are related to testing and getting the prototype ready. For this matter, the second senior design is required for the last phases before presenting the successful final project.

Once the second semester starts, team members will be working on identifying the procedures needed to successfully build the PCB and test the execution. From there, team members will be able to work on the changes required. Also the challenging expectation to implement 3 points WIFI which the camera, the designed MCU and smartphone have to be all connected for successful streaming and control. Also the odds of WIFI connecting failures are expected.

2. Project Description

2.1 Project Motivation

A research conducted by OnePoll with a simple of 2000 women in April 2015 shows that average of 5 hours and 30 minutes a week spent on taking selfies and an average of 7 selfies taken before finding the perfect one. This research clarifies that taking pictures has become a part of daily basis activities. With the increasing integration of technology in our lives, Dragon Bee project gives the chance to reduce this amount of time in terms of time management. The project simply will save all the time spent on retaking pictures by allowing Dragon Bee to take multiple snaps with different angles in a short period with autonomous moves.

Moving from time management to sports, another motivation is to let Dragon Bee be involved in sports. A sport player or hobbyist will no more be in need of another person to take their pictures. Mostly the person taking pictures end up missing the right moment to snap a picture due to fast motion of the player. This project will allow everybody to enjoy favorite hobby or sport meanwhile getting aerial photographs that can be taken as fast as the person moving.

Not only this, but after Google updated YouTube platform this year to support videos in a 360 degree view with a captivating view. Now the viewers will no more be curious about what is behind the scene while taking picture. To put in another way, the 360 degree view videos will be the future of video taking. As such, team members have decided to adopt the idea of implementing 360 degree view capturing camera in the Dragon Bee.

Currently, implementing the 360 degree capturing camera requires more research regarding the stream of this kind of video format from the camera to the Smartphone application in with the same interface of control unit of the Dragon Bee.

One of the other concerns is the people with disabilities, this project target all people regardless their physical status. Anybody will have a chance to enjoy taking pictures in variety of different views. People who suffer from Parkinson's disease will no longer worry about holding a camera and take pictures.

After UVAs received civilians’ attention, a tremendous number of projects are proposed some in which succeed and some have experience some legal issues. Team members have decided to make something a little different that provides easiness at the user end and achieve their needs.

2.2 Goals and Objectives

One of this project's goals is the great experience of taking photographs in both modes aerial view and terrestrial view with possibility of stream videos live on users' smart phones. The stream will have two modes stream 360 degree video and a regular video. As of now, only Android platforms will be available due time constraints. Consequently, users will have full control to their favorite view.

Having an oblique view in the figure bellow will give the user a possibility to cover much more the ground area that is a big advantage of Dragon Bee, also with the ability of extreme drone low level flight, the Dragon Bee will be capable of taking terrestrial pictures and videos with both modes regular or spherical view.

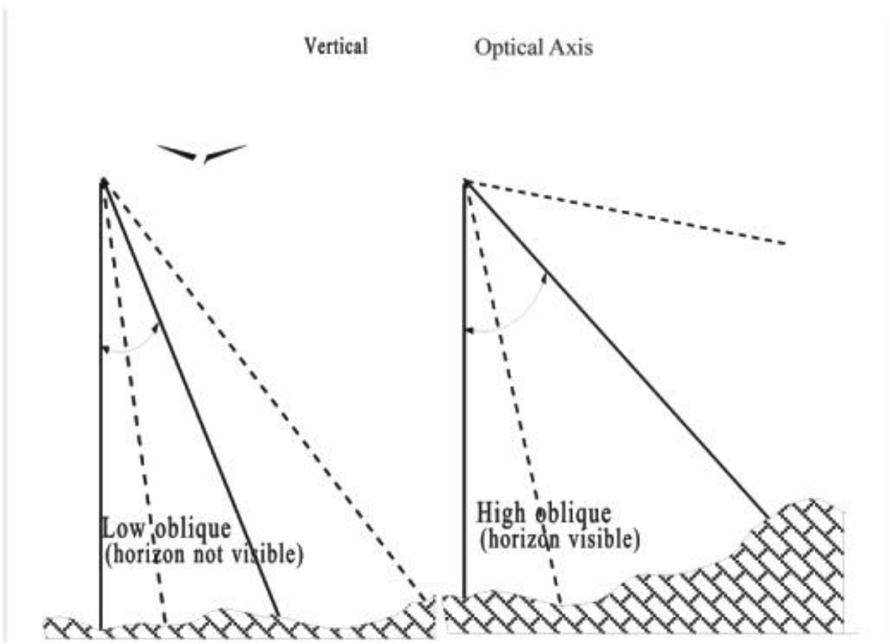


Fig. 1: Oblique View coverage example.

Implementing GPS module at the drone end is considered one of the project requirements. By doing so, the Dragon Bee side will be receiving GPS coordinates from the user's smart phone. From those coordinates Dragon Bee will be able to triangulate the position of a user's smart phone. This way, the follow me mode will achieved but it is subject to change due to GPS accuracy may not be enough for the accuracy of our project. Not to forget, the ability to include the coordinates in the metadata of each taken pictures or videos.

An easy and friendly user interface will be available to install on in any Android device. Including variety of options, Dragon Bee will provide multiple functions to achieve the goal Photographs for All.

For the stream sake, team members decided to have a 3 node's Wi-Fi connection using ad-hoc network mode, also known as peer to peer network. Those nodes are smart phone, Wi-Fi camera and MCU. Two TCP/IP connections will be initiated, one is for control and the other one is for video streaming as seen the figure 2.

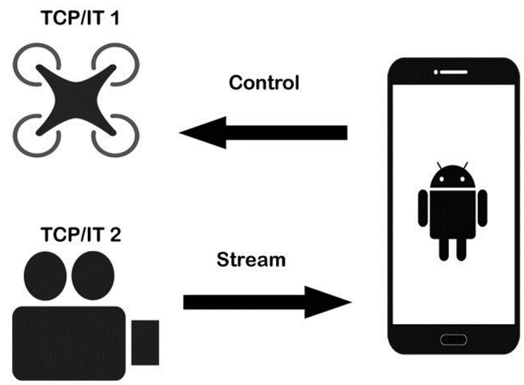


Fig. 2: Two TCP/IP connections.

When it comes to power supply, this project's goal is longer photograph missions. As a goal, many constraints have to be considered as weight, battery strength, low consumption PCB design, and light codes. As of brainstorming, battery charging will be done through pulling it out and plug it to socket charger.

Most of all, safety is one of the keys of a successful project. Dragon Bee will be carrying proximity sensors around the sides and on the top. Adding a piece of code, these sensors will prevent the drone from collision with any object around. For this reason, the Dragon Bee will find a way out by taking the appropriate action when collision detection happens. Those actions will be taken feedback of a user's behavior. Also the drone safety has been considered such as emergency landing and low battery situation. Due to first time team members experiencing this project, it will not be a waterproof drone.

This project is meant to serve as an accomplishment both electrical and engineering computer undergraduates. However, this project's main goal is to make ECE senior students experience "real world" while graduating, and it is an integral part of engineering undergraduate programs. Every ECE team has to successfully design and prototype a product such as an electronic device.

2.3 Specifications

This project has for main components, Quadcopter with ArduPilot, Wi-Fi enabled MCU, mobile platform, and Wi-Fi 360 degree camera. The specification of this project includes:

Quadcopter with ArduPilot:

- Carbon Fiber Body
- Integrated power distribution board for ESCs and FPV flight electronics
- A 2.5D CNC-ed G10 single body main frame board
- Easy Lipo Access
- Power Distribution Board
- Integrated and included Landing Gear reminiscent of the QAV500 CF Landing Gear
- Supports the Weight of about 540G
- Advanced ArduPilot with full mission scripting with point and click desktop utilities
- Support hundreds of 3D Waypoints
- Built in Barometer, Accelerometer and attached GPS module
- Built in hardware failsafe processor, can return to launch on Wi-Fi signal loss
- 15 different flight modes to choose from including Follow Me, and Circle Mode
- Ability to receive the data from MCU and send that data to the Quadcopter to Navigate accordingly

Wi-Fi Enabled MCU:

- Wireless communication to Android app
- 256K flash and 16k RAM with 4 timers and 4 UARTs
- Ability to Capture user input(non-flight related) which relays this data to APM 2.8 flight controller
- Able to receive data from Android app from about 100 meter

Mobile Platform:

- View the real time video from the camera
- Start and stop the recording and save the video/photo inside the phone
- 3 different mode operation controlling (Manual, Follow Me, Circle)
- Ability to test the Wi-Fi connection on start up

Wi-Fi 360Camera:

- Wireless communication between the app and the camera
- View the real time footage
- Save the video or picture inside the camera for up to 32GB
- 360fly gives you the power to capture the video in fully immersive, interactive 360° HD video

2.4 Design Constraints and Standards

UAVs are not allowed to fly anywhere. There are some safety guidelines and rules that must be followed. “Know Before You Fly” campaign is educating users and provides them with information and guideline on how to safely fly UAVs. This campaign is funded and operated by the Association for Unmanned Vehicle Systems International (AUCSI), the Academy of Model Aeronautics (AMA) and the Small UAV Coalition. The Federal Aviation Administration is have partnered with these organization with the goal to advertise the importance of safe and responsible flying.

Federal Aviation Administration (FAA) has established important standards on all Unmanned Arial Vehicles (UAVs). There are few safety rules that must be followed by all individuals flying for hobby or recreation. Individuals following these standards do not require obtaining permission to fly from FAA. These parameters are outlines in Section 336 of Public Law 112-95(the FAA Modernization and reform Act of 2012). Individuals using UAVs used for personal photography are ought to be recreational use. Oppositely, if you use the same devise for sale or compensation purpose will be considered non-recreational use. The table 1 below shows some safety guidelines and standards to be followed.

1	Fly below 400 feet and remain clear of surrounding obstacles
2	Keep the aircraft within visual line of sight at all times
3	Remain well clear of and do not interfere with manned aircraft operations
4	Don't fly within 5 miles of an airport unless you contact the airport and control tower before flying
5	Don't fly near people or stadiums
6	Don't fly an aircraft that weighs more than 55 lbs
7	Don't be careless or reckless with your unmanned aircraft – you could be fined for endangering people or other aircraft

Table 1: Safety Guidelines and Standards (Permission Pending)

There isn't fixed, national and global approach of the legal use of drones. The FAA can regulate and educate on a national level. Governmental departments like Homeland Security and the Bureau of Alcohol tobacco, Firearms and Explosive at the Department of Justice can also regulate the use of UAVs. The FAA modernization and reform Act passed in 2012 authorizes government public safety agencies to use UAVs 4.4lb with certain restriction. Few States and municipalities have passed regulation to limit the use of UAVs. By law, the FAA is the only organization charged with ensuring the safe and effective use of US airspace.

For this project, it was important to consider if there was any standard or regulation for video and photography because Dragon Bee is consists of a HD Camera. It will be taking photos and videos during the flight. There is no particular Federal law that forbids video surveillance in public or workplace. There are ten legal commandments that need to be considered while flying and filming. People are allowed to photograph in Public places like malls, parks, sidewalks, etc. Anyone can video graph and photograph in public property. People are allowed to take pictures of private property from a public place. You can take pictures of building statues and people walking in streets and any places that are open for public. If the drone is filming in the private property and are asked to not take pictures or have signed prohibiting any photography then we are obligated to honor the request. Government building like Military bases and nuclear facilities can prohibit photography or any filming that seems a threat to nation security.

Wi-Fi Standard: The 802.11 standard has several specifications of WLANs. This standard defines the air interface between two wireless devices, client and a base station or some cases between two wireless clients. For this project we will be using two wireless communications. One of them will be for wireless video streaming from Wi-Fi enabled camera to wireless enables smart phone. The second will be implemented on the custom MSP430 MCU and the smart phone. 802.11 families includes: 802.11, 802.11a, 802.11b, and 802.11g. The table 2 will compare the technical details of each of the three major Wi-Fi standards.

Feature	**WiFi (802.11b)**	**WiFi (802.11a/g)**
PrimaryApplication	Wireless LAN	Wireless LAN
Frequency Band	2.4 GHz ISM	2.4 GHz ISM (g) 5 GHz U-NII (a)
Channel Bandwidth	25 MHz	20 MHz
Half/Full Duplex	Half	Half
Radio Technology	Direct Sequence Spread Spectrum	OFDM (64-channels)
Bandwidth/ Efficiency	<=0.44 bps/Hz	≤=2.7 bps/Hz
Modulation	QPSK	BPSK, QPSK, 16-, 64-QAM
FEC	None	Convolutional Code
Encryption	Optional- RC4m (AES in 802.11i)	Optional- RC4(AES in 802.11i)
Mobility	In development	In development
Mesh	Vendor Proprietary	Vendor Proprietary
Access Protocol	CSMA/CA	CSMA/CA

Table 2: Wi-Fi Standard Comparison (Permission Pending)

MCU of this project will have the Wi-Fi(80211a/g) module attached to it for Wi-Fi connection. It will operate at 20MHz frequency that will give the range of around 100 Meter outdoor. This range is good enough for the project.

Battery Standards: We found many battery standards related to our project. The table 3 lists some of them. We have included some of them in the table below. The Zippo battery pack we are using is rechargeable and some of the standards include rules and guidelines on how to install, operate, maintain, and recharge the batteries.

484-2002 - Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications
485-2010 - Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
1184-2006 - Guide for Batteries for Uninterruptible Power Supply Systems
1188-2005 - Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications
1375-1998 - Guide for the Protection of Stationary Battery Systems
1491-2012 - Guide for Selection and Use of Battery Monitoring Equipment in Stationary Applications
1625-2008 - Rechargeable Batteries for Multi-Cell Mobile Computing Devices
1625-2004 - Rechargeable Batteries for Portable Computing
1660-2008 - Guide for Application and Management of Stationary Batteries Used in Cycling Service

Table 3: Battery Standards (Permission Pending)

Related Constraints

Economic: Along with many consumers, there are many states and regulators that believe the usage of UAV to be harmful and damaging. As of right now there are nine U.S. states that have passed a law restricting drones to be used for commercial, recreational and public use. The use of drones has increased privacy concerns amongst many citizens as it could be used to collect data. Amazon in particular has been under the radar as its drones use a camera and GPS to locate delivery destinations which many believe to be annoying and interfering.

Old-fashioned postal services take responsibility of damaged or stolen property while in delivery process, but delivery services offered by amazon drones unfortunately cannot promise the same and will face logistical problem. As there is no monitoring by a human, a drone cannot provide seamless deliveries. The issue will affect major cities the most as access to apartments within sky scrapers is a hard one to overcome for an unmanned aerial vehicle. Aside from humans, drones also put wildlife such as birds at high risk.

Environmental: One of the wide uses of UAVs is for farming. The cameras used in UAVs are very useful for plant overservation. It eliminates labor to use a person to do work. Some special UAVs are designed to lift heavy loads, which can be very handy in crop dusting. Japan has been using UAVs for pesticide control and other chemical dispensers on rice farms. They have been using RMAZ helicopter UAS. This particular craft can lift heavy loads up to 65lbs and can easily fertilize 5.5NM square field. Multispectral cameras are used to observe the chlorophyll level in plants. Pictures taken by the drone can be used to see the heat produced by the decomposing plants. The higher heat signature will inform the farmer to harvest the potatoes pile soon, or loose the batch to decomposition. The plant health and their stages can be easily indexed with Images taken by the drone. But this usage is not been authorized by the government of United States. So far the team has not come across any point where the drone will be any danger to crop or farming.

NASA used MQ-9 reaper to take multispectral images to watch the massive fire that happened in 2007 all across US but mainly in California. NASA described that the effective use of drones will not only finds hot spot but will be helpful to give constant vigilance in forests. UAS can also provide useful information on fire related weather. NASA has been using Global Hawk and Ikhana to view hurricanes from above, warning boats and weather forecast for possible hurricane's path. UAVs can been used to monitor the pressure difference even from Global Hawk's high altitude of 65,000 feet. This information can be used to accurately calculate the strength of the hurricane. The only drawback we can think of is the event of crash. If the drone were to crash due to power outage or possibly any other reason, it can cause a fire.

Social: Drones have been proven to be used for sheep herders, delivery boys, tour guides, filmmakers, and archaeologists. United States don't allow for commercial drone usage at all. Fast food restaurant like Dominos have used DomiCopter (drone) to test the possibility of delivering Pizza. Los Angeles sheriff department have been experimenting the SkySeer, as they call their drone, for search and rescue. Despite its usefulness, most of the public does not consider drones a good thing. UAVs have been used in USA for only military and hobby usage. It will long time before FAA comes up with decent regulation for drone usage. As of now, general public see them as potential threat machine. Youngsters have used them to play with as an expensive hobby but it has not entered in social aspect of life. Some of the states have passed legislation to prohibit any sort of usage of UAVs into public places. Drones usage has been a sensitive and controversial social issue through the country. The balance between protecting, ensuring public safety and civil rights are very hard to make while maintaining civilians' privacy.

Political: Drones have been deployed in many countries like Pakistan, Yemen and Somalia for military strikes. Addition to that, drones has been deployed in Libya, Afghanistan and in Iraq as United States military campaigns. The drones like Predator have high payload delivery that have effective casualty radius of about 200 feet. So far, there have been 347 strikes in Pakistan, 53 in Yemen and 2 in Somalia. The downfall to this is that more innocent people die every day in these strikes. If these strikes were to be done by military personal, it will differentiate the innocent people from enemies. We have killed four US citizens in these strikes. Anwar al-Awlaki and Samir Khan were two of them. The total civilian death in Pakistan an Yemen is 276 and 368 respectively. Of those, approximately 200 were children. These deadly strikes creates more terrorist than it kills.

Sen. Angus King has appealed to establish specialized court to approve drone strikes. However, justice department thinks its legal to use drones for striking the terrorist base and its use to demolish the domestic and international terrorism.

Ethical: As more people come to know about the drone, more ask the question if "Are drones ethical?" There is no doubt that drone weapons reduce risks to the U.S. forces but on the other hand they increase the urge to use force. Susan Brooks Thistle Thwaite with the Chicago Theological Seminary shows her concerns stating that drones create temptation to use force and destroy political and moral accountability. She also adds that anything that makes a war easier and cheaper is a rise for concerns.

Health and safety: The UAV has obvious limitations when it comes to safety. Drones are often causing of innocent lives lost. When it causes collateral damage it kills civilian and furthermore damages properties. Crash accidents could also happen where large drones could fall out of the sky causing serious injuries to people and property. Drones also have the potential of flying to into hazardous things such as power lines, to trees, windmills and other UAV. One of the latest example is the crash of a drone on the Whitehouse lawn.

Manufacturability: The Israel and United States are two of the top manufacturers of military drones. US budget is spending millions of dollars on drone manufacturing. These money can be used to reduce unemployment or for to pay national debt. The US Predator (military drone) costs taxpayers anywhere from $4.5 million to $11 million per unit. These are some very expensive drones. The pentagon has requested congress to spare around $5 billion dollars for drones in the 2012 budget. With this costly prices military drones are limited. In US, 36 states introduced legislation from drone usage that invades public privacy. Out of this 36 sates, 17 states have already some kind of legislation passed to restrict drone usage. This legislation has prevented manufacturers to build drones for public use.

Sustainability: It's no secret that wireless signals can be lost, hacked, or hijacked, in these cases the drone must be able to return home. Every drone will also have to deal with various weather conditions such as wind, rain, snow, hair and other extreme weather conditions. Both of the proximity sensors and IR sensor has to work consistently in order to avoid obstacles on the way. Users have to know the set distance into the setting of those sensors to effectively fly the drone. Users also have to maintain the specific distance from the drone in order to have the Wi-Fi connectivity for live video streaming.

2.4.1Battery/Power Consumption

Dragon Bee will be a mini quadcopter made out of carbon fiber. It is very light weighted. It is necessary to buy a battery that will last longer yet will have light weight so that our drone can lift it. The primary goal of the project was to maximize the flight time with useful features. Most of the quadcopters in market comes with the mid-range batteries that doesn't offer longer flight time. Therefore, teammates decide to upgrade a battery with a higher mAh. Also, it was really important to realize that increasing battery size is not also a wise thing. As the battery gets larger, the flight time becomes ineffective. It will reach to a point where it doesn't matter how large is the battery, the flight time will be constant. The main cause of this is the weight of the battery. This trade off makes it difficult to choose the right battery.

After a long research we have come accurse the Zippy Compact 5800mAh Lipo Pack. There are many other reason behind this choice. This battery offers great performance and have a compact size. This battery delivers full capacity and discharge. The table 4 shows the product specs.

Capacity (mAh)	5800
Config (s)	3
Discharge (c)	60
Weight (g)	448
Max Charge Rate (c)	5
Length-A(mm)	158
Height-B (mm)	45
Width-C(mm)	32
Voltage (v)	11.1

Table 4: Battery Specs (Permission Pending)

Usually there are two voltage range described in the flight controller spec sheet. The first one is the voltage input range of the flight controller, which operates at 5V nominal. The second is the voltage input range of the main microprocessor's logic. Flight controller, in the project is the ArduPilot, is a fairly integrated unit. The main attention should be the input range for the flight controller itself. In most cases multi-motor flight controllers operates at around 5V. This is due to the BEC because that is the voltage provided. So that being said, this project will not power the flight controller separately from the main battery. In the event of the main battery outage, back up battery will be considered to use if the time permits at the end of the semester. If so, we will use a battery backup and then the flight controller will be powered differently.

The main power consumption will be on the 4 motors. There will be many electronics attached to the power source. The list includes, Sensors, ArduPilot, MSP430, Wi-Fi Module, and perhaps more as we further do our research. We have talked about ArduPilot and motors power consumption. The next power consumer will be the MSP430. There are many configuration of MSP430 in sense of Supply voltage operating frequency, operating mode, and active peripherals. For this reason, only few of the combinations' current consumption are listed in the TI website. As of now we do not know the exact configuration we will be using for Dragon Bee.

To accurately calculate the current consumption of MSP430, the device datasheet lists numbers for each operating mode with certain operating voltage and frequencies. Depending on the sensors we will be placing the voltage and current is subject to change. The dragon will consist of the MSP430F5x/6x custom microcontroller. The exact model is not finalized yet but it will be from this F5x/6x family. This is Low-power microcontroller. The voltage supply will be around 1.8 to 3.6V during the operation. Since it is a lower power MCU, it will be consuming 195 micro Amps/MHz when active. Dragon bee consists of 2 proximity sensors for distance calculations and possibly one IR sensor. These are very low powered during operating. The detailed information and calculations of all power consumption will be shown later in the draft.

2.4.2Video Streaming

There are many ways to live video stream from the flying drone. For the dragon bee, teammates decided to use the WIFI FPV camera for live video streaming. There are many products available to choose from including some High Definition camera. After some research, we finally decided to go with GeekPro 2.0-inch WIFI camera. This is full high definition (1080P) with 12MP sport camera. It shoots full HD, 140 degree wide angle for clear image. It has the capacity to shoot 1080p with 30fps and 720p with 60fps. This camera is equipped with SD slot for saving the image and video. Another supporting feature is the loop recording. It will delete previous recordings to make space for more in case the SD card is full. The supported capacity of the SD card is up to 32GB which is far more than the flight time of Dragon Bee. This product is also waterproof that makes it more useful when flying over the water zone. The battery capacity is 3.7V (900mAh) just enough to last the complete flight time. It gives the recording time of about 70 minutes. The initial decision was to buy the GoPro camera but it was of a high price and therefore GeekPro was chosen. This is also subject to change as we further build our drone.

The most important feature and the prime reason behind this choice was the Wi-Fi capacity of the camera. It is as simple as downloading the free app which allows the users to take full control of the camera through Wi-Fi connection via phone, iPad or any mobile devise including some Apple products. The live video streaming was not our main objective therefore we decided to go with a product that has a built in Wi-Fi for sole purpose of convenience. The Wi-Fi built in this camera would reach up to 150 feet range for transmission.

The setup is very simple. The mobile application build by GeekPro Company is called iSmart DV and this app will be used to connect to camera and feed the live video from the flying drone. Camera will be mounted on the anti-vibration stand for quality video. Wi-Fi transmission give us more range to and more reliable. It's very convenient to use your phone to view the live feed rather than on a system which you have to carry with you. Other advantages are the quick uploading to cloud storage and easy sharing on social network. This app will give the user full control over the camera. It has dual mode, one for video shooting and one for simple HD photos. All this can be done with one finger tip. The price of this camera is much more affordable than any Go Pro products. It is still not known if the camera supports password protection for its Wi-Fi. We have a choice of going with either the 360Fly Camera or GeekPro.

2.4.3Budget Allocation

The main concern of this project was its expense mainly because all members are students. All members had to research in order to approximate the cost of the project. We then found out the project is in our budget. This project is not funded by any company or organization. The teammates have decided to pay for all the expenses equally trough out. At the start of the project, the Budget was thought to be somewhere around $500 to $1000 dollars. Some of the parts of the project have been ordered and turned out to be much less than what we thought. Table 5 shows the list of all parts and their prices.

Item	**Price**
Drone Kit	$ 100
Battery	$ 45
Sensors (3 to 4)	$125
WIFI Camera Kit	$73
ArduPilot Kit 2.8	$95
MSP430	$15
PCB	$75
Wi-Fi Module	$30
Wireless Charging Station (optional)	$100
360 degree Camera(if applicable)	$400

Table 5: Budget Allocation

Overall budget of this project will not exceed the $800. The budget goal is to stay under this amount so we can compete with the actual market price of our competitors. The price is subject to change as we further do the research and start building. There can be some of the parts be damaged before finalizing the project. Those additional will be considered later on the project. We have already bought the drone kit, MSP430, and the ArduPilot to actually have the hands on practice before we can start building the project.

Dragon Bee will be average cost project. Flight controller, motors, ESC's, batteries and frame of the drone are not cheap. It can be downgraded by using cheap and less effective materials but it will be inefficient. It was smart choice to buy the kit instead of separate materials for assembling. We carefully picked the kit that will be less costly yet feasible and compact in size. The kit included the motors, propellers, frame, Power Distributer, landing gears, and an anti-vibrate stand. This was only at a price of $100. The next big expense was the ArduPilot. This was also a smart choice due its performance and extraordinary features. Overall budget will increase if we get additional time to put features like solar charger.

3. Research

3.1 Quad-Copter

After a long research, the QAV250 Mini FPV Quadcopter Carbon Fiber Edition from Lumenier was chosen. The QAV250 Mini FPV Quadcopter is very small, lightweight and is made of 3K carbon fiber which gives excellent crash resistance. The symmetrical frame of the drone is 250mm in size and can allow up to 5 inch propellers. The QAV250 Carbon Fiber is designed to support a 3s LiPo battery. The components of the drone were selected due to the following reasons:

3.1.1 Quad Rotor Frame

When considering which type of frame to use for our drone, multiple ideas came to mind. The first thought to be considered is that the frame must be lightweight, robust, and most of all economical. Keeping in mind that the forces will act on the drone are primarily gravity, force of motors, air pressure and wind. Choosing a frame that is symmetrical will allow the center of gravity to be in the center. The force given by the motors will accommodate working against all the rest of forces. This is what is kept in mind when thinking about the base material for our drone. For the project, three materials are all possibilities due to their popularities: Aluminum, Steel, and carbon fiber.

Table 6 is a summary of the advantages and disadvantages of the three materials searched:

Type of material	*Advantages*	*Disadvantages*
Aluminum	• Light • Strong • Stiff • Moldable • Great for climbing and sprinting • Won't rust or corrode • Less expensive than carbon fiber	• Harsh on rough roads • Can fatigue over time (Leads to overbuilding which adds to weight) • Not easily repaired • Weak joints
Steel	• Inexpensive • Strong • Flexes enough for a soft ride • Most durable of all the materials • Lively feel • Easy to work with and repair	• Heavy • Rust/corrosion • Flexes too much for racing
Carbon Fiber	• Lightest material • Strongest material • Stiffest material • Best shock absorption • Infinitely moldable to any design • Flexible where it needs to be • Won't rust or corrode like steel	• A little expensive • Not all carbon is created equal • Can crack/fracture • Strength and stiffness depend on design

Table 6: Advantages and Disadvantages of different materials

After considering all the possibilities, carbon fiber material was found to be best option for the drone due to two of its strengths: it can handle stretching better than all other metals, and it is very lightweight compared to all its adversaries. Since the drone chosen is small, there is no doubt that the quadcopter on hand will have less long-term and maintenance issues. The next best option to choose will be Aluminum, since it works better when it's under pressure. Aluminum can handle external stretching on the structure and that makes it perfect for internal structure of a larger version of the drone. See figure 3.

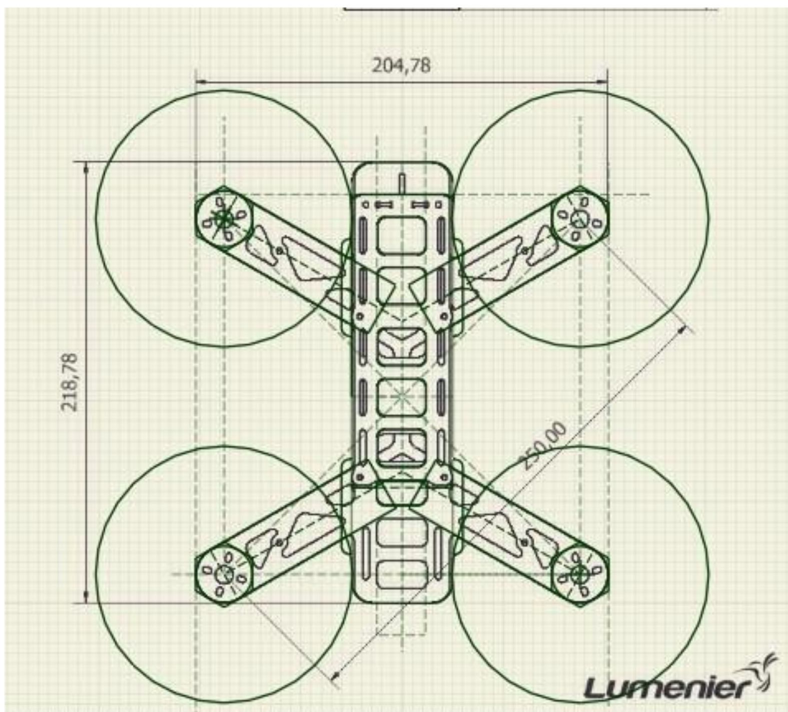


Figure 3: Carbon Fiber Quadcopter Frame Model 3K-QAV250. (Permission Pending)

3.1.2 Motors

This guideline is to help choose the right motor for the quad copter. To help with this decision, it would be desirable to have several test statistics at disposal which can be found in the thrust data tables. Most manufacturers will have carried out these necessary tests and these will be provided with the needed information. An example of one such thrust data table 7 for a EMAX MT2204 is given below:

The voltage (V)	Paddle size	current (A)	thrust (G)	power (W)	efficiency (G/W)	speed (RPM)
8	Carbon Fibre Prop 6x3	6.4	240	51.2	4.7	11910
12	Carbon Fibre Prop 5x3	7.5	310	90.0	3.4	20100
	Carbon Fibre Prop 6x3	11.5	440	138.0	3.2	16300

Table 7: Datasheet of MT2204 motor (reprinted permission pending)

Where to start? Knowing the weight of quad copter is the first thing to do. When building a drone, knowing the exact weight can be difficult, however starting somewhere and choosing and changing components can slowly refine the weight estimation.

Starting by first knowing what frame to use, as that gives some restrictions on the maximum motor or propeller size. Most of the frames come with instructions letting customers know what size of motors and propellers one should use. However there are any factors to be considered when choosing right motor and propeller for drone. Following are few considerations to check before choosing motors.

Thrust to weight ratio: With multi rotors it is important to make sure that the motors can produce around 50% more thrust than the total weight of a drone. Also it could be said that it should hover up at around half of the full throttle. If drone is flying smoothly, weight could be added so that it hovers at 70% throttle for less responsive drone. As an example if total weight of quad copter is 1000g, motors on a quad copter will need to produce 2Kg of thrust in total, or 500g max thrust per motor. This is an important rule to follow is it means that a motors will have enough extra thrust to control multi-rotor in wind and during aggressive flight maneuvers.

For quad copter racing, one would want a very agile quad copter, so having a much higher thrust to weight ratio is desirable, but for an aerial photography drone that will be flying gently, it could get away with lower power to weight ratios. In general it could be said that one should plan building a drone at around 2:1 power to weight ratio. As one can always use the extra remaining weight, features such as camera, gimbal control, or larger battery to fly for longer.

Worked Example - A rough weight estimation: Considering the mini quad that has features of capturing videos or pictures as described in ARRIS FPV 250 racing quad, first thing is to start with what frame to use, and in this case it's the ARRIS FPV 250 racing quad frame. The product description suggests we could use an 1800 kv - 2300kv size motor, so by searching on the internet, it could be found that some motors of this class weights an average around 100g (which is around an estimation). Similarly 3-4S Li-Po batteries that are around 2000-5800mah commonly used with mini quads. Adding extra weights of camera, flight controller, and gimbal controller. The summary of the weight estimation is shown below, which is very rough estimate that could be start with.

- Flight Controller - 15g
- R/C Receiver - 15g
- Silver Blade Frame - 150g
- 4x Motors and ESC - 100g
- 3S Li-Po Battery (2000-5800mah) - 250g
- FPV Camera and Transmitter - 100g
- Gimbal Control - 200g

So the weight of drone is around 830g, so need to have motors that can produce at least two times the amount of thrust in total (1.6Kg of thrust in total), however if they produce more, then drone will probably be able to fly faster. Therefore building a quad copter, each motor must produce at least 400g of thrust each.

The process of finding right motors that provide enough thrust is to look into different resources such as internet, manuals, or asking someone for help or advice.

Reading that data: Based on our weight estimation, it is important to find a motor capable of producing a maximum thrust of 400g each. By inspecting the thrust tables of each motor, one can find a few motors that have the required thrust performance. In this case, the MT2204 motor which looks promising.

If finding motor is hard decision, there is always websites which could have similar design therefore hints of what motors to use for a quad copter.

Checking the thrust: To investigate and extract useful information from a table such as the one above to find a use of quad copter motor. This manufacturer has tested this motor with two different voltages (2S (approx 8V) and 3S (approx 12V) battery), and a number of different propellers (called paddle size in the table). It also gives the amperage that the motor pulls, the thrust it produces, and the efficiency (thrust in grams/power in watts), as well as some other information. We can see from the table that with a 3S battery, these motors will produce enough thrust with 5x3, or 6x3 propellers which produce more than the required 400g each.

Comparing the efficiency: The first important investigation is to know will be the thrust. To further differentiate between motors, efficiency should next be considered. The efficiency is commonly expressed as the thrust divided by the power used in watts or g/W. The more efficient a motor is (or the bigger the g/W number is), the longer the copter will fly. A general rule of thumb would be anything over 7 for efficiency is good, and the higher the value the better it is.

Once knowing the thrust required for drone by motors, best thing to do is choose the one with higher efficiency. However, the downside of it is higher the efficiency, costlier the motors would be.

Best choice for the motor is with enough thrust that required having to loft total weight of drone efficiently and constant till battery dies. However, if wanted small agile copter for quick movements and turns in the air, motors have to have high RPMs. As shown in table 7, high rpm comes with price of low efficiency. For a mini quad, the type of motor needed like the EMAX MT2204, the table of which is shown above. This is why the efficiency of this motor is relatively poor.

Focusing on all these configurations such as speed, trust, power consumption, it has come to consideration that EMAX MT2204 motors are best for the “Dragon Bee” project. Figure-16 shows the dimension of EXAM MT2204 25g 23KV motor which shows how compact the motor is.

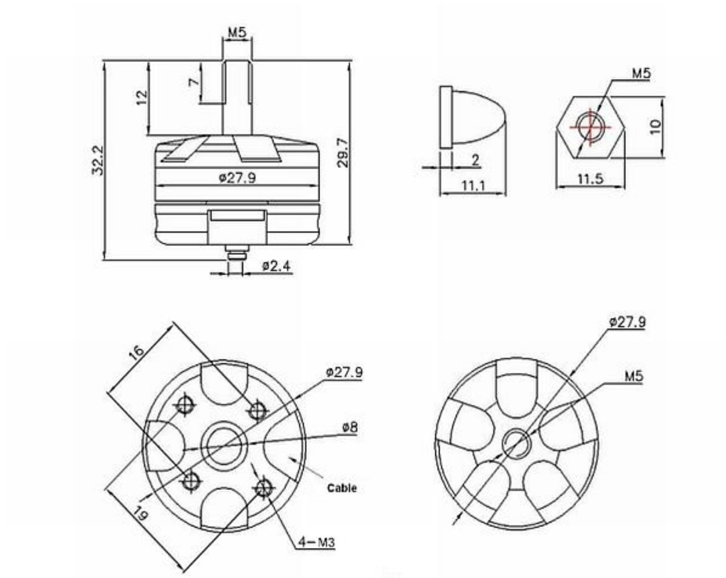


Figure 4: Dimensions of EMAX MT-2204 motor (permission pending)

EMAX MT2204-2300KV Features:

- The propeller and motor mount cover using integrated molding process to ensure concentricity mounted paddle
- Japan NMB bearings , low noise, long life
- The choice of Kawasaki, Japan 0.2mm spindle , more efficient, less heat
- The selection of high temperature NdFeB magnets
- The motor of the pros and cons thread configuration, eliminating the multi-axis shot after installing anti- paddle security risks
- Multi-axis multi- rotor brushless motor:
- Low center of gravity design
- Lightweight Design
- Long-endurance design
- KV: 2300
- Max Trust: 440g
- No. of cell: 2-3S
- Framework: 12N14P
- Propeller: 5" ~ 6"

- Length: 32.2mm
- Shaft: 3mm
- Diameter: 27.9mm
- Weight: 25g

3.1.3Propellers

Propellers are one the most important components for in a drone. Picking the right set of propellers is very essential for the drone to fly correctly. When researching the propellers, so many ideas came to mind. At the end, two choices were made. The first choice is to build the propellers from scratch with wood for example, and the second choice is to buy premade propellers. Considering the time and effort that will be consumed when making the propellers from scratch and the material that they would be made from, the decision was to simply buy premade propellers that would work with the size and shape of both the motors and also the frame of the drone chosen. Purchasing premade blades will allow the possibility of using tougher, light weight plastic. It is also an advantage to the group's time. Considering all these reasons, premade propeller blades will be purchased.

A quadcopter uses two clockwise (CW) and two counter-clockwise (CCW) propellers. Propellers are classified by length and pitch. For example, 9×4.7 propellers are 9 inch long and have a pitch of 4.7. In general, more current will required when the propeller's pitch and length are increased. Also the pitch can be defined as the travel distance of one single prop rotation. In a nutshell, higher pitch means slower rotation, but that will increase the drone's speed which also uses more power.

When deciding on length and pitch, a good balance is to be found. Generally a propeller with low pitch numbers can generate more torque. The motors don't need to work as hard so it pulls less current with this type of propellers. Lower pitch propellers will also improve stability. A higher pitch propeller moves greater amount of air, which could create turbulence and cause the drone to wobble during hovering. Since the drone that we are using is small, it was decided to choose 5 inch propellers with a 3 inch pitch and a weight of 1.7g. This will allow our drone to be light weight and energy efficient. See Figure 5:

Figure 5: Propellers used in the Drone on hand

3.1.4Electric Speed Controllers

Matching the right ESC: Teammates have confirmed that the motor is suitable for the application. The Amp draw for chosen motor, battery, and propeller could be estimated. For MT2204 motor, maximum of 7.5A for a 5x3 prop and 11.5A for a 6x3 prop is needed. Since choosing the 5x3 propellers, one needs to use an ESC that is rated over 7.5A.

Therefore, a 12A ESC from EMAX would be a good choice for these motors because it would be easier to hooked up with EMAX motors and it can provide continuous current of 12A which is more than enough to run motors that are running on 8A current.

EMAX Blheli12A ESC specifications:

- Use authentic electronic components to ensure high quality and enhance the current endurance ability of the ESC.
- Based on BLHeli firmware, optimized for high performance with great linearity and much quicker throttle response.
- Special designed for multi rotors, and compatible with great linearity and much quicker throttle response.
- Multiple protections featured including Low-voltage cut-off protection/ over-heat protection/ throttle signal loss protection.
- Throttle range can be configured and is fully compatible with all receivers, providing smooth with all receivers, providing smooth, linear and precise throttle response.
- All parameters can be programmed via using a program card or a transmitter, including default settings.
- product specification:
- Item: EMAX Blheli 12A

- Continuous Current:12A
- Burst current(10S):15A
- Li-xx battery(cell):2-4
- Dimension L*W*H(mm):40x20x8
- Weight(g) wires Included:11
- BEC Mode: Linear
- BEC Output:1A/5A
- Programmable: yes

Refine the weight estimate to choose a battery: Once knowing all components used for a quad copter, it is easy to decide what range of weight and capacity of battery to be used. Knowing the thrust by each EMAX MT2204 motors, which is about 400g, we know that the weight of quad copter should be around 800g. Therefore adding up weights of all the components excluding battery weight, quad copter should weight approximately around 550 gram including frame, motors, Ardupilot, camera, etc.

Now there is around 250g to 300g of capacity left in total weight of a drone. As a result the battery has to weight within that range. The voltage needed to drive these motors is 7.5A for a 5x3 propeller. With 5800mah Li-Po battery, which would make 800g drone fly for at least 15 minutes, four of those MT2204 motors could be run easily. The weight estimation of this battery is expected to be between 250g and 300g. That makes the total weight of the quad copter around 850g, which is acceptable.

3.1.5Flight Controller & ArduPilot

Once choosing Quad copter frame, motors, propellers, ESC's, and Battery, the next main focus would be choosing flight controller. A flight controller for a multi-rotor UAV is an integrated circuit normally made up of a microprocessor, sensors and input / output pins. Out of the box, a flight controller does not meet all the specifications a project required. Therefore, certain parameters in a software program is set, and once complete, that configuration is then uploaded to board. There are several flight controllers in the market are available; however, rather than simply comparing flight controllers the approach to choose the right one is to list specifications needed and select one that has most of that specifications.

As mentioned above some basic components a flight controller made up of are a microprocessor, sensors, and input/output pins. Following are some of the brief descriptions of each to help understand and to do more research in them.

Microcontroller: Microcontroller is the heart of a flight controller. Its job is to receive command from a controller, which could be through Wi-Fi, Bluetooth, or radio frequency, to a flight controller. It could be programmed with specific requirements as needed. Microcontroller received certain data from a controller, it reads it and then transfer those data to ECS connected to a flight controller, such that speed of motors could be controlled. It also sends back to controller information, such as battery life, distance and collision sensors data, and speed of motors. As a result, it could be said that the microcontroller is main bridge that connects controller and flight controller of a system.

Sensors: In terms of hardware, a flight controller is essentially a normal programmable microcontroller, but has specific sensors onboard. At a bare minimum, a flight controller will include a three axis gyroscope, but as such will not be able to auto-level. Not all flight controllers will include all of the sensors such as accelerometer, gyroscope, magnetometer, barometer, etc. If flight controller doesn't have onboard sensors there is always way to integrate it or better option is to get one with already built in one.

Input/Output pins: Flight controllers usually have GPS, compass, and Wi-Fi interface into it. Which all combined could have around 40 input/output pins in it. Some pins are used for power supply. Some ports are for MUX(UART0, UART2, mnnI2, and OSD). Compass is built in when plug in the jumper cap in the MAG pin header. Some pins could be used for external gps, sensors, or microcontroller connections.

Doing research on different flight controller and finding the one that meets specification requirement is time consuming. However, knowing the specification and use of it always narrows down the research.

Researching more on flight controller, it can be seen that Ardupilot APM 2.8 is best flight controller from the perspective of power, specification, and cost. It has DF13-4P I2C external compass interface, which is convenient for the connection of GPS and external compass. It's modified version added isolation resistor, when the OSD interface used with telemetry, the interfaces is effectively avoided. The new version adopts US LP2985-3.3, 16V withstand voltage, more reliable, and reducing the possibility of Bad Gyro health. Following are some of the features and data sheet of APM 2.8 flight controller that will be used in "Dragon Bee" project.

Features:

- Arduino Compatible
- Includes 3-axis gyro, accelerometer and magnetometer, along with a high-performance barometer
- Onboard 4 Megabyte Data flash chip for automatic data logging
- Optional off-board GPS, UBlOX Neo-6M module with Compass.
- One of the first open source autopilot systems to use Invensense's 6 DoF Accelerometer/Gyro MPU-6000.
- Barometric pressure sensor upgraded to MS5611-01BA03, from Measurement Specialties.
- Atmel's ATMEGA2560 and ATMEGA32U-2 chips for processing and usb functions respectively.

Data Sheet:

- 3-Axis Gyro
- 3-Axis Accelerometer
- High Resolution Altimeter
- 5Hz GPS Module
- Dimension: Approx 70.5x45x13.5mm
- Weight: 31g
- Weight: 43g (With Vibration Damping Plate)

Flight controller has many features from motor speed controlling to GPS controlling and from distance controlling to collision controlling. All of these controlling could be controlled by a controller connected with flight controller through radio frequency. However, as for this project, it would be newer and little more challenging to control quad copter with android phone. Therefore, it is better option to include microcontroller circuit, such that it can communicate with android device through Wi-Fi. Now the next part to choose is find compatible microcontroller such that it could be programmed to receive the commands from android or such device.

3.2 Microcontroller

As mentioned above microcontroller is the bridge that connects controller and flight controller. It could be programmed as needed to meet the requirements. It comes in different sizes in terms of bits, capacity, and power. The most current flight controller’s microcontroller families form the basis of AVR, PIC, or ARM. The primary manufacturer of PIC chips is Microchip. It is really hard to choose one over the other but it depends on what software can do in them. ARM uses 16/32-bit architecture, whereas AVR and PIC uses 8 / 16-bit. It is expected that a new generation of flight controllers can run full operating system as the launch pad of microcontrollers has become less and less expensive.

CPU: Normally these are in multiples of 8 (8-bit, 16-bit, 32-bit, 64-bit) and is a reference to the size of the primary registers in a CPU. Microprocessors can only process a certain set number of bits in memory at a time. The more bits a microcontroller can handle,More accurate and faster processing will be if a microcontroller can handle more bits. For an example, processing a 16-bit variable on an 8-bit processor is a bit slower and time taking, on the other hand a 32-bit processor is very fast. Also it has to be consider that the code also needs to work with the right number of bits,

Operating frequency: The frequency at which the main processor operates. Frequency is measured in “Hertz” (cycles per second). This is also commonly referred to as the “clock rate”. The higher the operating frequency, the faster it can process data.

Program / Flash Memory: The flash memory is where the main code is stored. If the program is complex it may take up quite a bit of space. It is fact that it could store more data if the memory size is large. Memory is also useful when storing in-flight data such as GPS coordinates, flight plans, automated camera movement etc. The code loaded to the flash memory remains on the chip even if the power cut down.

SRAM: SRAM stands for "Static Random-Access Memory", and is the space on the chip which is used when making calculations. The data stored in RAM is lost when power is cut. The higher the RAM, the more information will be "readily available" for calculations at any given time.

EEPROM: Electrically Erasable Programmable Read-Only Memory (EEPROM) is normally used to store information which does not change in flight, such as settings, unlike data stored in SRAM which can relate to sensor data etc.

Additional I/O Pins: Most microcontrollers have a lot of digital and analog input and output pins, and on a flight controller, some are used by the sensors, others for communication and some may remain for general input and output.. These additional pins can be connected to RC servos, gimbals system, buzzers and more.

A/D converter: Should the sensors used onboard output analog voltage (normally 0-3.3V or 0-5V), the analog to digital converter needs to translate these readings into digital data. Just like the CPU, the number of bits which can be processed by the A/D determines the maximum accuracy. Related to this is the frequency at which the microprocessor can read the data (number of times per second) to try to ensure no information is lost. It is nevertheless hard not to lose some data during this conversion, so the higher the A/D conversion, the more accurate the readings will be, but it is important that the processor can handle the rate at which the information is being sent.

There are many verities of microcontrollers with different features. Following are some of the features to look for when choosing the right microcontroller for the projects.

- Central processing unit ranging from simple 4-bit processors to complex 32-bit or 64-bit processors.
- RAM for data storage.
- ROM, EPROM, EEPROM or Flash memory for program and operating parameter.
- Storage Serial input/output such as serial ports (UARTs) or I2C
- Peripherals such as timers, event counters, PWM generators, etc.
- Converters such as analog-to-digital and digital-to-analog converters.
- In-circuit programming and debugging support.

Now know knowing the features, it would be an important to know which microcontroller to choose for a drone. The best one to choose would be the one with at least 16 bit such that it could transmit data faster if connected with a flight controller. It should have enough I/O pins for digital sensors, analog sensors, transmitting data, receiving data, any module connector, and more for any additional inputs. Some other features to look for should be the frequency, RAM, power consumption, voltage, and most importantly programmable with C language due to its simplicity.

Table 8 shows few microcontrollers with some of the important features. Those are from some of the microcontrollers used for purposes like receiving and transmitting commands from the controller, Wi-Fi module compatible, flight controller connectable, and sensors networking.

	PSOC	MSP430	PIC	Cirrus (ARM)
Frequency	90kHz-24MHz	4kHz-8MHz	32kHz-20MHz	Up to 200MHz
Voltage	3-5V	1.8-3.6V	2.5-5V	3.3V
Power (run)	96kHz:~6mW 24MHz:~35mW	4KHz:~5μW 8MHz:~7mW	1MHz:~0.2μW	200MHz: 750mW
Power (slp)	~15 μW	~0.2 μW	~0.2 μW	4 mW
A/D options	6-13 bits (configurable)	8-14 bits (various PNs)	4-14 bits (various PNs)	None
Price	$1.00-$8.00	$0.49 - $8.00	$2.00-$5.00	$13.00
I/O Pins	6-44	14-48	12-40+	Mem bus
RAM	256-1024B	128-2048B	128-256B	external
ROM	4-64KB (Flash)	1-60KB (Flash)	1-20KB (Flash)	Boot up OS only

Table 8: Microcontrollers used for UAV

From the table above, it would be better option to choose a microcontroller MSP 430F5529 from the TI. The main reason for its processor is 16 bits RICS architecture, which is compatible with flight controller of 8 bits processor. It has enough around 10 KB RAM, low supply voltage, ultra-low power consumption, low cost, and more than 80 pins for different uses. Most importantly it is easily programmed with C or Assembly languages.

3.3 Communication Technologies

When talking about communication technologies, it could be said the communication between quad copter and controller, or it could be between camera and phone for video streaming. Usually quad copters and controllers commute through radio control, which is commonly used due to its range, efficiency, and handheld controller. However there are other modes too for controlling drone, such as Bluetooth, Wi-Fi and radio frequency. Same scenario is applied to the camera on drone if video streaming in mobile devices, such as smart phone, laptop, or tablet. Before going to further discussion, it would be better to know about these communications.

As mentioned above, four types of communications Radio control (RC), Bluetooth, Wi-Fi, and radio frequency could be used to control drone. Below will be short description of each.

Radio Control: Radio Control (RC) communication normally involves a RC transmitter and RC receiver. For a quad copter generally four channels are needed for its basic movements. These channels are associated with following:

- Pitch (For forward and backward motion)
- Elevation (For height distance, closer to or farther away from the ground)
- Yaw (For rotation, clockwise or counterclockwise)
- Roll (to strafe left and right)

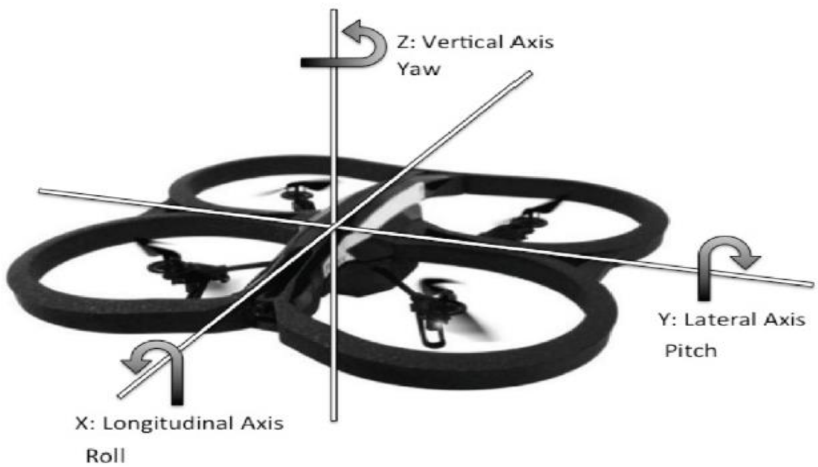


Figure 6: Dimensions of drone spines

Additional channels are added for more features. Adding these features makes drone more reliable and practical. These channels can be used for any of the following:

- Gimbal controls (pan up/down, rotate clockwise / counter-clockwise, zoom in/out)
- Changing flight modes (Controller mode, Follow me mode)
- Any number of other uses

The main reason for RC system quad copter is number one choice is because of its handheld controllable. On its own, the receiver relays the values input into the controller, and as such, cannot control a quad copter. The receiver must be connected to the flight controller, which needs to be programmed to receive RC signals. Most of the flight controllers on the market directly accept RC input from a receiver and even provide power to the receiver from one of the pins.

Further considerations could be used when choosing a remote control include:

- The max wireless range (feet or meters) of an RC system is most likely not provided by the manufacturers due to involvement of many factors such as obstructions, wind, temperature, humidity, battery power and more.
- Some RC system's receiver has a built-in transmitter for transmitting sensor data (GPS coordinates for example) which could be seen in RC transmitter's LCD display.

Bluetooth: Bluetooth products were originally intended to be used to transfer data between devices without the complexity of pairing or matching frequencies. Certain flight controllers on the market can send and receive data wirelessly via Bluetooth connection, making it easier to troubleshoot issues in the field. Some Bluetooth modules let connects autopilot of drone to Bluetooth compatible Android device using Droidplanner or Andropilot ground station app. The modules usually have range of around 30m, which is alright for flight controlling, mission planning, and follow me mode. All it requires is to plug it into telemetry device and pair it with Android or other devices.

Wi-Fi: Wi-Fi control is normally achieved using a Wi-Fi router, a computer or a smart phone. Wi-Fi is able to handle both data transmission as well as image transmission, however, it's difficult to set up and implement. As with all Wi-Fi devices, the range is limited by that of the Wi-Fi transmitter. Typical range of Wi-Fi signal is not measured due to it uses Wi-Fi connection of Wi-Fi devices such as phone or tablet. However this range could be extended using higher power Wi-Fi bridge where drone will be flying. Usually drone only has about 15db Wi-Fi magic in it, so anything more than that would be an improvement, such that more range of connection between drone and smart devices.

Radio Frequency (RF): Radio Frequency (RF) control in this context refers to sending data from a computer or microcontroller wirelessly to the drone using an RF transmitter / receiver (or two-way transceiver). Using a normal RF unit connected to a computer allows for long range two-way communication with a high "density" of data (normally in serial format).

3.3.1Wi-Fi Module for MSP430 Core

RF signal is good for long range and high density data transmitting. It's not good option for receiving data from a quad copter because its transmitter or a receiver is connected to a computer or a microcontroller. Also it cannot be connected to an Android device, so it's not compatible for live video streaming and controlling.

Bluetooth is another option for controlling flight controller and it can be controlled by a smart phone. However, as seen in research, the only and big issue with using it would be its minimal range. Additionally, if needed to do live video streaming and picture sharing, with Wi-Fi it could be done simultaneously.

Researching all these various communication technology, it could be seen that Wi-Fi communication fits best of need. Main reason for it is due to its range and android compatibility. As seen communication range between the drone and mobile device could be improved easily with high power Wi-Fi bridge. Further, Wi-Fi is better choice for the simultaneous use for a drone control and video streaming due to its low latency. Wi-Fi module could be used and it could be connected with a microcontroller, so it can send or receive data as it's programmed.

3.3.2Ardupilot/MSP430 Communication

To connect both the Ardupilot and the MSP430, a universal serial communication interface must be set. The Ardupilot and the MSP430 can both be connected through I2C, UART or PI etc.

UART: Universal Asynchronous Receiver Transmitter, is one of the most used serial protocols. The UART protocol has been around for a long time and it is known for its simplicity. Most controllers have hardware UART on board. It uses a single data line for transmitting and one for receiving data. Most often 8-bit data is transferred, as follows: 1 start bit (low level), 8 data bits and 1 stop bit (high level). The low level start bit and high level stop bit mean that there's always a high to low transition to start the communication. That's what describes UART.When the entire data word has been sent, the transmitter may add a Parity Bit that the transmitter generates. The Parity Bit may be used by the receiver to perform simple error checking. Then at least one Stop Bit is sent by the transmitter. No voltage level, so a 3.3 V or 5 V, whichever the microcontroller uses. Regardless of whether the data was received correctly or not, the UART automatically discards the start, parity and stop bits. If the sender and receiver are configured identically, these bits are not passed to the host. For UART the microcontrollers which want to communicate have to agree on the transmission speed, the bit-rate, as they only have the start bit's falling edge to synchronize. That's called asynchronous communication. Figure 7 describes the internal block diagram of the UART.

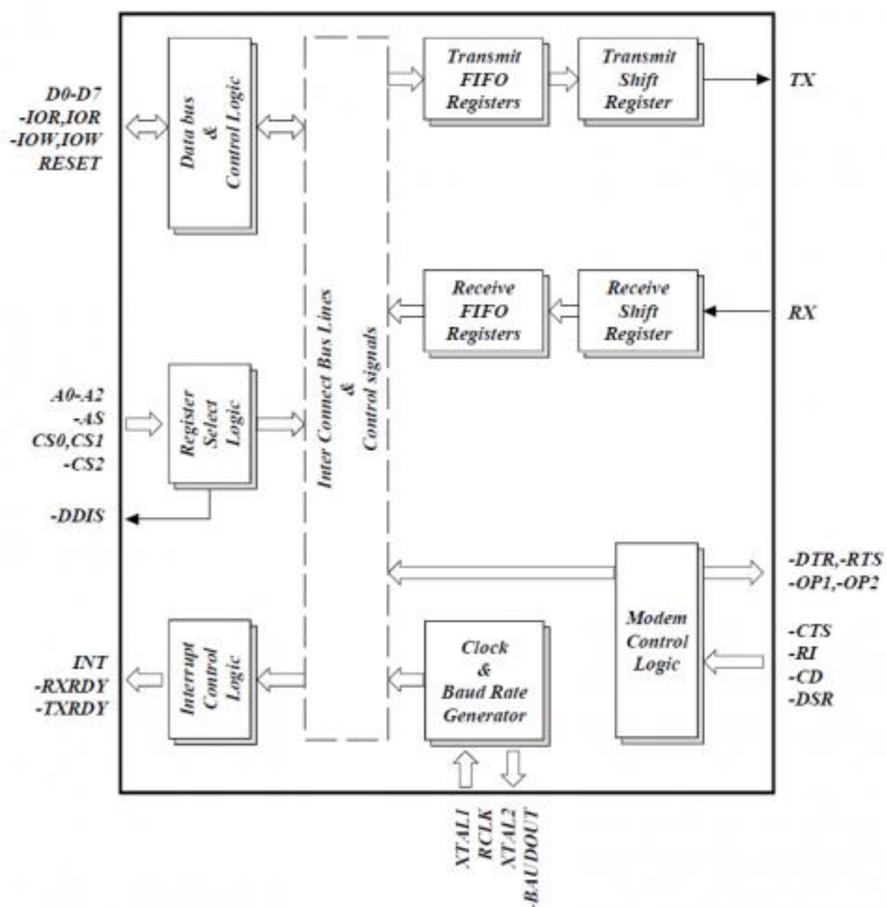


Figure 7: UART Internal Block Diagram. (Pending permission)

I2C: Inter-Integrated Circuit is also a synchronous protocol. The I2C communication is very popular and broadly used in many electronic devices because it can be easily implemented in different electronic designs which require communication between a master and multiple slave devices or even multiple master devices. I2C uses only 2 wires, one for the clock (SCL) and one for the data (SDA). That means that master and slave send data over the same wire, again controlled by the master who creates the clock signal.The clock signal is always generated by the current bus master; some slave devices may force the clock low at times to delay the master sending more data (or to require more time to prepare data before the master attempts to clock it out). This is called "clock stretching". Figure 8 shows how I2C communication is set up.

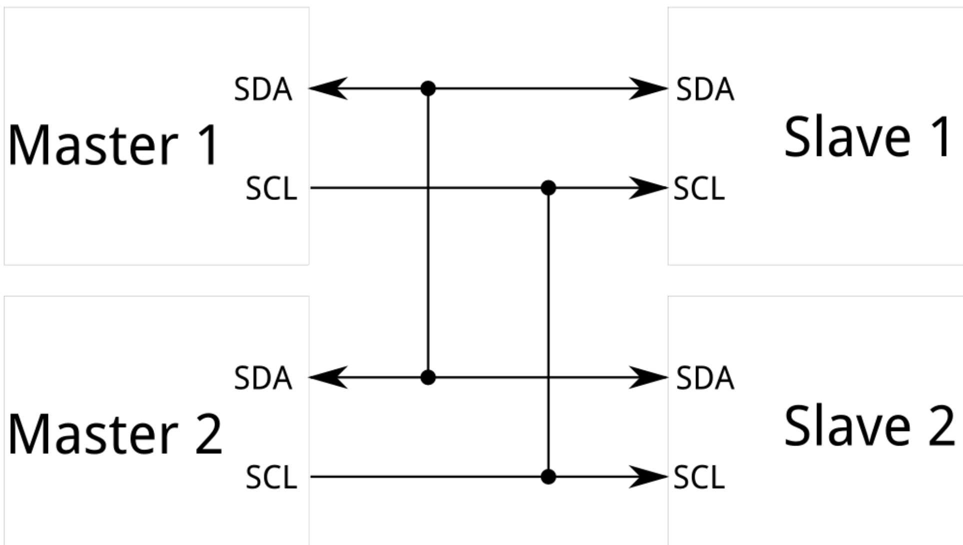


Figure 8: I2C Communication Regular Set Up. (Pending permission)

SPI: Serial Peripheral Interface is another very simple serial protocol. SPI devices communicate in full duplex mode using master-slave architecture with a single master. The master device originates the frame for reading and writing. Multiple slave devices are supported through selection with individual slave select (SS) lines. A master sends a clock signal, and upon each clock pulse it shifts one bit out to the slave. It also shifts one bit in coming from the slave. Signal names are therefore SCK for clock, MOSI for master out slave in, and MISO for master in slave out. By using SS (Slave Select) signals, the master can control more than 1 slave on the bus. There are two ways to connect multiple slave devices to one master. Figure 9 shows the SPI master/slave communication and they could be implemented.

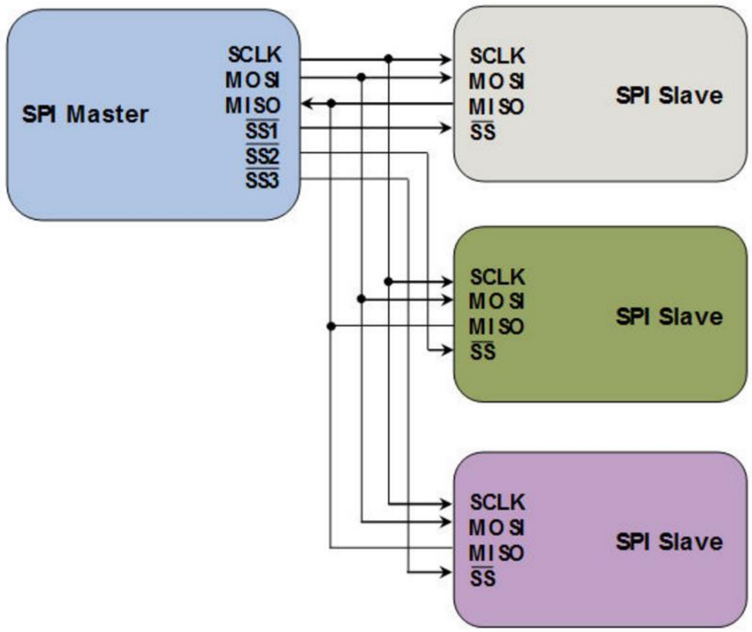


Figure 9: SPI Mater & Slave Connections

3.4 Position Detection Sensors

To keep the drone in position it is mandatory to implement some sensors into the design. Two major problems will be faced to have a steady position for the quadcopter on hand. The first major problem is to keep the drone at a certain level. The second problem is to make sure that the copter does not hit any obstacle while hovering in the open space. To overcome these two major problems, two types of sensors will be implemented in the design. The first sensor is an Ultrasonic sensor to keep the quadcopter at a certain height, and the second sensor is a 360 infrared sensor to make sure that quadcopter does not hit any around obstacles.

3.4.1Ultrasonic Sensors

The first thing that must be discussed is how does an Ultrasonic sensor work? An ultrasonic sensor has two parts. The first part is a transmitter that sends out a signal that humans cannot hear and the second part is a receiver that receives the signal after it has bounced off nearby objects. The sensor sends out its signal and determines how long the signal takes to come back. If the object is very close to the sensor, the signal comes back quickly and if the object is far away from the sensor, the signal takes longer to come back. Sometimes if the objects are too far away from the sensor, the signal takes so long to come back. In that case the receiver cannot detect the returned signal. The sensor sends a message back to the microcontroller used to control the quadcopter. The microcontroller then calculates how much time is taken for the signal to return. Then uses this info to compute how far away the object is.The speed of sound is normally known. The following formula is then used to compute the distance:

Distance = rate * time

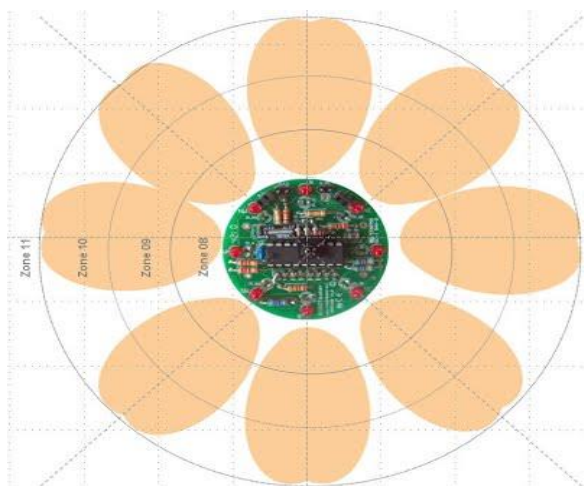
To make sure we get the right ultrasonic sensor for the drone on hand, few things must be taken into consideration. The ultrasonic sensor must be small, lightweight, energy efficient and effective. A comparison must be conducted between the most known sensors used in the drone world. The different models are essentially the same but differ slightly in the width of their detection areas, such that the EZ4 have a narrower beam than the EZ0. The EZ1 is a good balance of beam width and detection area, and costs a little less than the others sensors. This sensor was originally considered for the lateral proximity sensors of the quad-copter on hand. After a good consideration it turns out that a single forward oriented narrow beam would a sufficient for the design on hand. This type of sensor must be of a narrower beam and must have less noise interferences. The MaxBotix EZ sensor is pictured below in figure 10 below. The graphic gives an approximation of detection angle as a function of the type of object being detected. For example, a wall is detectable at a greater angle from center than a narrow rod. This angle of detection will be a factor in how the lateral sensor array is integrated into the design of the quad-copter.

Figure 10: The LV-MaxSonar EZ

Either one of the EZ0, EZ2, EZ3, or EZ4 sensor would work for the design on hand, with progressively narrower detection angles. Considering that the best sensor would be the one provides a good fit for both ground detection and a narrower beam (to have less noise, less ghost echoes, and thus a steadier signal). The EZ2, according to the MaxBotix website, offers a good combination between small object detection and narrow beam width. The MaxSonar EZ sensors utilize a frequency of 42kHz and have an effective range from 6 to 254 inches (6.45 meters), which is well suited to the specifications pertaining to distance sensors. The sensors operate between 2.5 and 5.5 volts at a ballpark 2 mA and offer an output choice of analog, serial, and PWM signals, analog being preferred. The MaxSonar EZ sensors have a satisfactory resolution of 1 inch increments, which should be more than adequate for their purpose.

3.4.2 360 Infrared Sensor

Infrared range finding sensors such asSharp GP2Y0A21YK were first considered as proximity sensors for the quadcopter on hand. Infrared proximity sensors work by emitting a beam of infrared light and then evaluating the returning light. Methods of evaluating the returning signals include triangulation, which considers the return angle. It also includes modulation, which focuses on a specific modulation of the signal. Infrared sensors are known for the shorter range they provide. The Sharp sensor listed at the beginning of this section has only an effective range of 15 to 150 cm. To keep the drone on hand from colliding to an obstacle, 360 infrared sensors is to be implemented in the design. Since the quadcopter on hand is small, the best choice of the 360 infrared sensors is the “IRCF 360 infrared sensor”. This sensor provides 360 degrees coverage for the drone. It is also energy efficient, lightweight, and effective. See figures 11 a) and b) below



a) IRCF360 Circuit

b) IRCF360 Zone Coverage

Figure 11: IRCF360 Infrared Sensor

3.5 Wi-Fi Camera

Nowadays, flying drone or UAV is common thing; therefore, people are finding best use of it attaching a camera on it. It is smart and ideal way to have picture or even a video from a distance. Since there is much more improvement in technology since the first time UAV devices introduce, there is always room for features in them. Camera attached to UAV for picture taking or video streaming is the most functional feature it has by now.

There are generally two reasons for using camera on a drone and they are for photo capturing and video streaming. Obviously none of them is possible by hand if it is hooked up to drone and it's at high level of height. Therefore, it has to be connected with a mobile device such as a smart phone or a computer (laptop, desktop, or tablet) through either Wi-Fi or Bluetooth. Nowadays, camera has microcontroller built-in it such that it could communicate directly with specific a Bluetooth or Wi-Fi signals. As far as controller for picture viewing and video streaming, there are apps that can be downloaded, which are compatible in mobile devices and camera. Usually information about specific app to download comes with a manual.

Now that connection between camera and mobile device is not an issue, it is time to talk about two different types of camera: Wi-Fi camera and Bluetooth camera

Wi-Fi Camera: Through the evolution of camera, new generation camera has become so advanced in technology that it don't ever require clicking of button on it. It could be operated through android or ios devices. Such cameras are very handy when to take a pictures or videos from far distance. These cameras are connected with smart phone through a Wi-Fi. As mentioned above these cameras are programmed with certain app that can be opened up either on Android or IOS devices, and videos or pictures could be taken from and seen into smart phone devices.

If need to control a camera with smart phone or a tablet and share pictures or videos on-the-go, Wi-Fi SD enable card would be a good option. These SD cards are similar to memory cards; however, they have Wi-Fi chip in them, which able to capture Wi-Fi signal from a mobile devices. This way, it could be connected to the net via camera the same way as it would be done with cellphone. All it needed to do is to create a hotspot using the internet-connected device, and then it's ready to go. These cards not only are Wi-Fi module, but they also have good storage capacity.

There are various cameras come with it nowadays, so there is no need to buy separately Wi-Fi cards. However, if camera doesn't come with it, there are few options such as Eye-Fi'smobiPro, Toshiba's FlashAir, Flaxcard from Trek2000, and ez Share's Wi-Fi card. They all can be connected to mobile devices, but some has more features than the others, such as sharing pictures or videos to more than one devices, indoor / outdoor range, and used in video games, DSLR, and cameras.

Bluetooth Camera: There are some differences between digital cameras that offer Bluetooth support and Bluetooth cameras that can be connected to your Android or iOS device. It's informative to know the main aspects of each category and few good choices one can have. There are always different types of cameras to look at even though the one type of camera to choose for.

Some Bluetooth camera offered by big companies like Samsung or Nikon are most likely Android-based cameras. The good thing about it is the pictures or videos can be sent to android smart phone directly with connectivity of Bluetooth. Other advantage of having it is Android as main platform is it gives advantage of downloading and installing apps from a Google Play Store. Photo Wizard or Video Editor can be installed into camera such that photos or videos could be edited directly in camera.

The disadvantages of having this camera on a quad copter are its limited access range. Since Bluetooth signal have strong connection but short range, it would not be a good option for UAVs. On top of that, it would be hard to control a camera like taking pictures or videos through a mobile devices, such as smart phone or tablet. As for those reasons, it would be good to use Wi-Fi cameras.

There are plenty of Wi-Fi camera options in the market; however, it’s good for reliable, durable, lightweight, and long lasting camera for the drone. Gopro is widely used camera for drone. However the downside of Gopro camera on a drone is it needs to rotate in order to take pictures or videos from different angles. As for that, there need to be gimbal controller need to be attached for such rotation, which would increase the weight of drone as a result more power consumption and bigger motors. To avoid all this problems, the company called 360fly came up with Wi-Fi camera that captures a view of 360 degrees with VR visual effects. Which eliminates the problem of rotation and gimbal controller? This 360fly app could be downloaded to the smart phone and live video streaming and photo capturing could be seen instantly. It comes with the price of just $399.00 plus Google Cardboard for $5.00 for VR Experience, which in compared to Gopro $399.00 plus Oculus Rift, $4000.00 for 360 degree VR experience.

In conclusion 360fly is better camera for drone due to following reasons:

- Low cost 360 degree VR experience.
- 360 degree video and panoramic capturing.
- Works with Bluetooth and Wi-Fi.
- Compatible in Android and iOS smart phones.
- Rechargeable internal lithium battery.
- Action camera adapter, tilt mount and flat base plates.
- Power cradle and USB cable
- 32 GB internal memory
- 3 axis sensor and accelerometer

3.6 GPS

GPS is the abbreviation of Global Positioning Sensor, which is space based navigation, provides position and time information in any weather conditions. It provides navigation anywhere on earth or near it where there is unobstructed line of sight to four or more satellites. This is the system a car GPS or phone GPS uses; however, in drone GPS has its own functionality with similar purpose but small scale signal receiving and transmitting method. The only difference in drone GPS is it uses ground base radio waves from the fixed antennae such as radio, Bluetooth, or even Wi-Fi signal. GPS module is usually connected to the flight controller of the drone system, which will be discussed in detail in below paragraphs.

In terms of hardware, a flight controller is essentially a programmable microcontroller for basic maneuver. However, for additional features like acrobatic flight, keeping drone at certain height, or make drone return to some set destination, specific sensors should be added. The least thing a flight controller will include is a three axis gyroscope for yaw, pitch, and roll. Extra sensors should be added for additional features such as barometer for hovering drone at certain flight at fixed position, accelerometer for stable flight, compass for it will try to keep its Yaw orientation, GPS for tracking specific location, etc. Further combination of some of these sensors does lot more than each sensors functions individually.

If using waypoint navigation and return to home features then GPS module and compass is needed to tell Ardupilot where it is. The GPS module not required if only plan to use the APM2.8 board as a flight stabilizer. There are variety of GPS module could be used and can be tested for simple functions such as tracking a point from distance above. However, since the technology has advanced and processor size has gone to micros, many more features could be added to the GPS module. There is one problem choosing the right GPS module for the drone is that there are so many GPS modules nowadays in the market, and it is hard to choose for the project with "follow me" mode. Therefore following are some of the factors to look for when choosing the GPS module for the project.

- **Size**

This is something to consider when the project is at very small scale such as drone project. GPS modules are getting smaller since the advancement of technology, smart phone GPS, but the antenna has to shrink to fit the module which will affect things like lock time and accuracy.

- **Update Rate**

The update rate of a GPS module tells how often it recalculates and reports its position. The standard for most devices is once per second (1Hz). If travelling an airplane or something, one is probably not going fast enough to have changed position significantly in the past second. However, UAVs, cars, or fast vehicles may require faster update rates to stay on track. As the advance in technology 5Hz and even 10Hz update rates are becoming more and more available for cheaper price. Though that a fast update rate means that there are more NMEA sentences flying out of the module. Some microprocessors will quickly be trying to parse that much data. On the plus side, if a module that runs at 5Hz or 10Hz, it can usually be run at an easier pace.

- **Power Requirements**

Since GPS is asked to do bunch of numbers that it has to get from satellites in orbit around the earth and use that information to figure out where exactly a device is located, it takes power. It's a lot of work, and tiny GPS units are doing it multiple times per second, so it consumes a lot of power. On average, generally a GPS module consumes around 30mA at 3.3V. The GPS antennas usually enlist the help of an amplifier that draws some more extra power. If a unit appears to have somehow little power consumption, it is better to check that an antenna attached.

- **Number of Channels**

Even though there are only so many GPS satellites in view at any given time, the number of channels that your module runs will affect your time to first fix. Since the module doesn't know *which* satellites are in view, the more frequencies that you can check at once, the faster you'll find a fix. After you get a lock, some modules will shut down the extra blocks of channels to save power. If you don't mind waiting a little longer for a lock, 12 or 14 channels will work just fine for tracking.

- **Antennas**

Many modules come with this chunk of something on top of it which is a precisely made chunk of ceramic. Each antenna is finely trimmed to pick up the GPS L1 frequency of 1.57542 GHz. It is an expensive, but they are made a lot of them. There are some other GPS antenna technologies such as chip and helical, but they are not as common, a bit more expensive, and require significantly more amplification and filtering.

Again thing to keep in mind, the satellites are in the sky around 12,552 miles above, so it has to be make sure that antennas with ceramic points towards the sky. GPS antennas are getting better and can certainly get GPS signal indoors, but it's hit-or-miss. There could be a reception problem in crowded places due to high number of frequency exchange. Therefore, if using antenna for a drone project, it would be better to test it in an open field.

- **Accuracy**

Final thing to consider is how accurate is GPS? Well it varies a bit, but it can usually find out the exact location of a device, anywhere in the world, within 30 seconds, down to +/- 10m. It is +/- because it can vary between modules, time of day, clarity of reception, etc. The less down, better it is Most modules can get it down to +/-3m, but if needed sub meter or centimeter accuracy, it gets really expensive. Therefore, for the drone project with low budget, height has to be compromised.

GPS modules could also be used for "follow me" mode which makes it more advanced. With few program changes or making it compatible with microcontrollers, it could be used to make it follow a smart phone device. Only thing a person would need is smart phone within the some range, but it could be extended with some modifications such as making drone Wi-Fi compatible. Following is an example of how GPS tracking system could be used to make it follow a person.

Figure 12: “Follow me” Mode

As seen on the figure 12, automated drone is following a biker taking a video and pictures from certain height above him. Its integrated microcontroller is programmed such way that it is connected with a phone or a device a biker is having with him. It seems like the drone communication is though Bluetooth due to its short range and outdoors; however it could be connected with the Wi-Fi module such that it could have longer range.

For the “Dragon Bee” project, UBLOX NEO-6M GPS module is used because it includes GPS and compass sensors in it. It comes with 4-pin port with box around it for damage protection, and it is easily compatible with APM 2.8 board. Following are some of the features for GPS power module from UBLOX NEO-6M. Typical accuracy for this GPS module is about down to 2.5 m with 15s, which is reasonably accurate for the normal drone tracking GPS module.

- 3V-5V power supply Universal
- Module with ceramic active antenna
- With data backup battery
- LED signal indicator
- Antenna size:25 x 25mm
- Module size:25 x 35mm
- Mounting Hole:3mm

- Baud rate: 9600
- Compatible with various flight controller module
- EEPROM save the configuration parameter data when power-down

3.7 Power Consumption Management

All electromechanical systems require batteries for engine start-up and signal management. Since most copters run off DC sources, the electric network may be required to convert the DC energy to AC by means of relays and inverters. To really analyze the power management in terms of batteries for the quadcopter on hand, both AC and DC analysis must take effect. Considering the two analysis, some other areas must be considered such as thermal effects that can result in component shutdown.

When looking for a reliable power source for the quadcopter on hand, there are few things to be considered along with the design. The priority of power comes to motors, the processor, the sensors, or the camera. After a long research the concern turns out to be the motors of the quadcopter because they consume a lot of power. The processor along with the main board will operate on a very low power. The sensors themselves are auxiliary systems and they will operate with the processor, and are not entirely necessary for flying the drone. However, it does give the user essential data regarding flight data and analysis for control.

Most of the components on the main board are low-power devices, and their operational current ratings are from nA to mA range. Which will make all power dissipation from the source minimal? However, the issue will be the initial start-up, and shut-down. The effect of current and voltage spikes due to an under-damped system. Which may affect the regulators and therefore the life of the components of the quadcopter? The good thing is that most of the components on the main board are digital components. Which means that they cannot suffer from the under-damped DC effects?

The components of the drone are of different voltages and power needs. As mentioned in the previous paragraph the processor will have an operating range from nW to mW, and a voltage of 3V to 5V. The sensors, however, will require more power (mA operating range) to give the required feedback signals to the processor and to the user. This will require the team to calculate the overall power dissipation of the board. The thermal effects from the parts must be calculated as well, taking into account that the drone will operate at 25.

The amount of power to be used for quadcopter is very essential. Considering the time of flight, power dissipation of each component, and the operational criteria, the type of battery to be selected is very critical. In the design on hand the battery must provide significant current to accommodate the proper functionality of all components of the drone, including the four motors. The specifications of the battery must be as follow:

- The battery must be of High power RC (between 10.5V to 12V)
- The battery must be light weight and efficient.
- The battery must sustain a flight of 15 minutes or more.

The next thing to be considered in our design is the current. The current is the key for calculating the approximate flight time. Most batteries are rated in terms of milliamp-hour. Which is basically the amount of current provided by a certain battery in an hour? For example, assuming that the flight time is linear, the time of the flight for the drone on hand could be calculated as follow:

Motor Operation equation:

$$\frac{Q_{charge}(in\ A \times hr)}{I_{mo}(in\ A)} \times 60 = t_{motor}\ (in\ min)$$

The formula above hold true for the maximum current output where:

- Q_{charge} is the charge provided by the battery
- I_{mo} is the motor's operational current
- The factor 60 is the conversion factor from hours to minutes
- t_{motor} is the maximum time for which the motor will remain on.

Since there are 4 motors operating, few options are being considered. One of the options is to have a battery for each motor. Another option is to have one single battery for multiple motors. After a long consideration, one battery for all motors turns out to be the best option. A research was conducted about batteries and the following information was found:

3.7.1 Batteries

There are five types of batteries to be considered for the design on hand

- Alkaline
- Nickel Metal-Hydride (NiMH)
- Nickel Cadmium (NiCad)
- Nickel Zinc (NiZn)
- Lithium Polymer(LiPo)

The following will give the recommended specifics for each battery and their applications to which they may be the best fit. Please note that all batteries related to the motors will use a C-cell configuration (with certain exception in the LiPo cell batteries). All of these batteries will have massive overlap in their applications. It is important to consider effects of each batteries weight, overall charge, and best application. Thus, the batteries themselves are considered in their life-longevity, feasibility, and reusability.

- **Alkaline Batteries**

Alkaline batteries are one of the most popular batteries on the globe. See figure below. These batteries are very famous for their basic usage and they sustain a reasonable amount of power. If alkaline batteries are to be used in the quadcopter on hand, few things must be considered. The first thing to keep in mind is that these types of batteries are not rechargeable. Thinking about lowering the cost, alkaline batteries are not of a good use. The good thing about these batteries is that they are very cheap and affordable. They can be acquired in almost any store in the US and in most first world stores. The biggest problem with alkaline batteries is their low charge. Most batteries carry about 1.5V with a current of 700mA or more. This is due to battery architecture and personal safety issues. Note: the minimum current required for stopping a human heart inside the human body is between 100-500mA. For designing a power source for the motors, the amount of batteries required to operate the motors would be considerable. To just have an idea of how many alkaline batteries would be necessary in our design, let’s assume that the motors of the drone consume most of the power. Each motor requires 12V at 8A. The design will need at least 8 batteries for each motor, assuming ideal conditions because:

$$\frac{12\,V}{1.5\,V/battery} = 8\ batteries$$

Using the formula from above, all 4 motors will need about 32 alkaline batteries, which is a lot considering cost and weight. Also with all the 32 batteries the motors can run for approximately 5 minutes under standard operating current. This may not seem an unreasonable flight time but the desired flight time is about 15 minutes minimum. This doesn’t mean the alkaline is not without use in this project. Because it doesn’t have much power to draw, the overall power supplied would be a perfect match for the main board. This would allow for a dedicated power supply to allow for the maximum flight time of the copter.

- **Nickel Metal-Hydride (NiMH) Batteries**

The next alternative, NiMH batteries, are famous for their use in most cordless phones. This was one of the first rechargeable battery sources discovered and is still considered as one of the most reliable sources for longevity and reliability. These batteries are still used in most models of RC. These batteries are a little bit expensive compared to alkaline batteries. The problem with this type of batteries is that they cannot hold a charge for a long time. What they lack in charge, they make up for in reusability. With these batteries, there are two issues regarding power. First, the highest you typically see these batteries rated for is at 9.6V. This voltage brings an issue with a voltage limited ESC and motor, since there may be a voltage drop of 2.5V due to back EMF. Also, the weight of the battery to power the drone on hand will exceed the expectations.

The NiMH batteries can be used for powering smaller devices with ease, same as alkaline batteries. These batteries can, for example, power wireless phones, which can be used constantly for up to 4 hours. Most NiMH batteries are rated higher than their alkaline counterparts, being ranked from 1200mAH to 2000mAH of capacitance for most C and D class batteries. This would be a good recommendation for a rechargeable source. Considering the necessary power to make our drone operational, the NiMH batteries won’t be used for the project on hand.

- **Nickel Cadmium (NiCad) Batteries**

Nickel Cadmium batteries are famous for being rechargeable and good batteries for RC Circuits. Nickel Cadmium batteries are slightly cheaper than NiMH, and they are known for their faster recharge time. This type of batteries had a potential use in the military especially because they charge real fast.

For the design on hand (the quad-copter), the NiCad batteries come in 6.0V (5 cell), 7.2V (6 cell), and 9.6V (8 cell) packs, usually rated at approximately 2200mAH per battery. Compared to their counterparts, NiMH batteries, the NiCad batteries usually have a voltage of 1.2V. The alkaline batteries have a voltage of approximately 1.5V. Therefore, 12/1.2 which is about 10 batteries will be needed for the project on hand. However, the problem will be in charging these batteries, because each battery will need to be charged alone. Also, considering the size of the drone on hand, 10 NiCad batteries are a bit too much of weight and size.

NiCad batteries have become less and less popular due to problems involving charging and lifetime performance. Also these batteries have memory issues in charging, dendrite formations, heavy metal poisoning, and reverse current.

- **Nickel Zink (NiZn) Batteries**

A type of batteries that has been around for more than a century is the Nickel Zink batteries. Nickel Zink (NiZn) batteries are more like alkaline batteries with only one difference. They provide a voltage of 1.6 volts, which is very close to the 1.5 volts of alkaline batteries. See figure. NiZnbatteriee tend to perform well on high-drain devices such as handheld games. However, the problem with NiZn batteries is that they have short life after about 30-50 recharges. NiZn batteries also require a special charger optimized for their chemistry. Overall, these batteries are good for high-drain devices that require a high voltage.

NiZn batteries have a capacitance that varies between 1800mAh minimum and 2000mAh maximum. These batteries require a charging time of about 2.5 hours. The problem with these batteries is that they have a chemical combination that might be hazardous when exposed to the outside. Since the NiZn batteries are very comparable to their alkaline adversaries, they are not going to be considered for the project on hand.

One major company has been producing such type of batteries and that company is Powergenix. This company has been developing Nickel Zink batteries for a long time. They provide a lot of information on their website for any developer who wants to make use of their batteries on their project. Most of the PowergenixNiZn batteries comes in 1.6 V AA batteries.

- **Lithium Polymer (LiPo) Batteries**

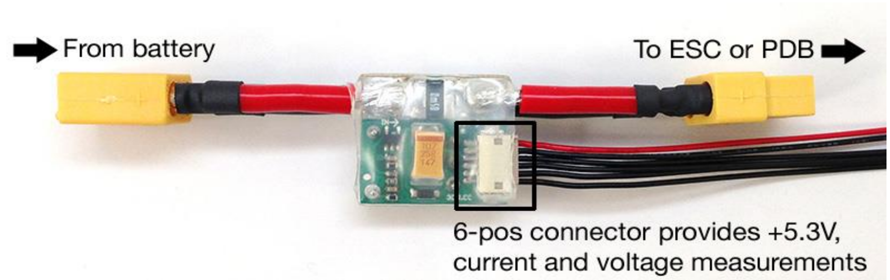
Lithium Polymer (LiPo) batteries have become the most popular batteries used nowadays in the RC world. LiPo batteries combine some real good attributes such as low weight, high energy density, and ever greater discharge rates. Lithium-Polymer (LiPo) batteries have transformed all facets of RC. These batteries have been improving since they came out to market and that has provided a significant performance boost for RC copters, boats, airplanes, cars, and helicopters, while also paving the way for new vehicles such as multi-rotors. The problem occurs when there is a false handling for these batteries. These batteries can die easily and even catch on fire if not utilized properly.

The good thing about LiPo batteries is that they have a much higher voltage rating in one cell than in its other adversaries. Also, the charge typically found in these batteries is between 3.6V to 4.7V per cell, which will be great for the project on hand since a light weight and efficient battery is necessary. This allows for the construction of a powerful battery with a minimum number of cells required to power all circuitry and motor for the quadcopter.

When it comes to the cost of these batteries, the price varies from brand to brand and also from capacity to capacity. For example, a price of $30 to $40 will be required to purchase 2300mAh LiPo battery at 11.1V. Also, a price of $100 to $150 will be required for a 5800 mAh at 11.1 V. After a good comparison between all the LiPo batteries on the market, it turn out that the ZIPPY Compact 5800mAh 3s 60c LiPo Pack will be the best for the project on hand. The specifications of this battery are as follow:

- Capacity: 5800mAh
- Voltage: 3S1P / 3 Cell / 11.1V
- Discharge: 60C Constant / 70C Burst
- Weight: 448g (including wire, plug & case)
- Dimensions: 158x45x32mm
- Balance Plug: JST-XH
- Discharge Plug: 5.5mm Bullet Connector

The capacity of this battery will allow the quadcopter to have a flight time of over 15 minutes. The weight and dimensions is perfect match for the quadcopter on hand. The price of this type of batteries is about $60 which meets the budget on hand. Overall, this battery will exceed the expectations as far as powering each and every element on the quadcopter. See figure 13 a) below:



a)Battery **b)Power Module**

Figure 13: Zippy 5800mAh LiPo Battery

3.7.2 Power Module

Powering this flight controller is one hard task since it could not be powered with any voltage and direct current. Therefore Power Module is used between battery and the flight controller, which works as a voltage regulator. The PM is a simple way of providing the flight controller with clean power from a Li-Po battery as well as current consumption and battery voltage measurements. Basic purpose of using the power module is to receive the high power voltages and drop down voltages but to provide a needed current. It is very essential to use power module for such reasons but which power module to use?

For flight controller APM 2.8, it is better to use 3DR Power Module. The main reason for it is because it's compatible with APM 2.8. It has 6-pos connector provides around +5.3 V power supply to APM board. APM 2.8 board has 6 pin PM port which can be connected directly from the 3DR power module 6-pin connector. APM PM can provide power to the APM 2.8 as well as current consumption and battery voltage measurements, all through a 6-pos cable. The on-board switching regulator outputs 5.3V and a maximum of 2.25A from up to a 4S Li-Po battery. The Power Module comes completely assembled with XT60 connectors, and wrapped in shrink tubing for protection.

PM could be connected to ESCs or PDB (Power Distribution Board). It also has power output port to supply power to the motors. However, power module doesn't have sufficient power for servos or high current devices such as FPV transmitters. Servos must be power by separate ESC. Therefore, since using PDB is better option for power distribution to ESCs, power module's output port will be connected to the Input of PDB. Following in figure 13 b) shown how PM will be connected to APM board and PDB.

3.7.3 Power Distribution Board

Power distribution board is a component of an electric supply system which divides an electric power feed into subsidiary circuit, in the project it's ESCs. It distributes power from the flight battery to ESCs to power the Quad's motors. It is safer and efficient way to supply power to the ESCs since it could have a breaker in it if used which eliminates damaging in ESCs or motors. Usually power distribution board is made by had with few connectors, headers, pins, and wires. However, nowadays drone manufacturing companies has started selling it separately. It could be purchased with very low price, and it includes all connections that are required to connect battery to ESC and more. It is possible to make own PDB on a PCB board with few pins and wires but its time consuming and result in failure. Therefore, to make the project smoother and error free, it is decided to use 3DR's PDB for the "Dragon Bee" project. A part, PM, which connects a battery to APM and power feeder to the motors, is used from 3DR company could be directly connected to this PDB through XT-60 connector. This PDB for the ESC system could be purchased from this company separately; therefore, it would be a good choice to use the PDB from 3DR. Further, since it is used for a quad copter motors, a quad PDB is being used.

3.7.4 Battery Charging

One of the main important components to search for when it comes to battery is its charger. There are a lot of battery chargers out in the market, but since a LiPo battery is to be used in the project, a safe and reliable charger must be chosen. After a great consideration it turns out that the Venom 2-4 AC/DC LiPO Battery Balance charger is the best choice for charging the Zippy compact LiPo battery. This charger has many great features including auto detection of current rate and capacity of individual cells. It also carries the functionality of identifying the cell count automatically. The automatic cut-off safety and the temperature protection function are also available as features of the Venom charger. These features will help us avoid any problems that might affect the safety such as overheating the battery.

The specifications of the charger are as follow:

- LiPo Cell Count: 2-4 Cell
- Charge Current: 0.1 - 3.0A
- Circuit Power: 40W
- Input: DC 10.0-18.0 Volts - AC 100v-240v
- Fuel Source: Electric
- Display Type: LCD
- Length: 5.1 in (130mm)
- Height: 1.9 in (48.25mm)
- Width/Diameter: 5.6 in (142.25mm)
- Weight: 10.8 oz (306g)

The battery on hand is only 3 cells which will work perfectly for the charger. The weight and dimensions of the charger won't affect the design on hand since the battery charger will be used to only charge the battery. See figure 14 below:

Figure* 14 *: Venom 2-4 AC/DC LiPo Battery Charger

3.8 Mobile Application

3.8.1 Mobile Application Overview

Mobility is the reality of today's generation. People use mobile for everything. With two of the group member being the computer engineering, it was a great decision to design a nice interactive mobile app to control and view the live footage from the drone. For all its importance, mobile is not worth a penny without its apps. The extraordinary features of the apps and its usage make it more interesting and productive for people to use the app in their daily life. There were many other ways to approach to control the drone. Students in the past and hobbyist have used many different technologies to fly the drone. Most of the projects came across were using Radio controlling technology. To make it more interesting and different, Dragon Bee connection was decide to be on Wi-Fi. The teammates are designing a special android app to view and to control the drone. The app screen is divided into two separate sections. One will be for live video streaming, and the other half will have the controlling buttons. There are 3 basic mode of the drone inside the app. They are Manual, Autonomous and 3D mode. For which user will select as their need. Each mode as it's on functionality and features that user will enjoy.

There are many reasons why mobile controlling was decided for this project. There some already built in technology in the smart phones like compass, Wi-Fi and GPS that will come in handy when controlling the drone. Main usage for compass is for compass control. For example, user wants to turn the drone left or right or move the drone front or back. Digital Compass is a very helpful in drone navigation. Digital compass in the phone measures the orientation of the drone compared to the earth magnetic field. User can use it to find the angular orientation of the robot at any given point in time. This feature is well implemented in the 3D mode.

Wi-Fi is one thing all smart phones are equipped with. For this project, Wi-Fi is a big tool that will be used for controlling and for live video streaming. The Dragon Bee will consist of HD Camera that will deliver exceptional video and photo straight to the smart phone app. GPS is one of the fundamental tool that is being used in this product. People use GPS in their daily life for directions. This is the same purpose why GPS is used in this project. Through Wi-Fi connectivity, Dragon Bee will detect the location of the Person that it has to follow. ArduPilot 2.8 has a very impressive mode call "Follow Me" mode. Using this mode Dragon Bee will follow the person currently connected to its Wi-Fi. This mode is used when user selects Autonomous button on the App.

The manual mode can be select if the user wants to manual control the drone. It will display left, right, up, down, front, back buttons and acceleration button to control the drone as a remote control. The last mode is to operate and view the 3D of the drone. When selected, user will enjoy the 3D view of the drone camera and will be able to control the drone using their motion of the head. For example, if the user wants to see left of the drone, he or she will just move their head left a little. This feature is motion controlled from the user's head as it displays wonderful 3D view from the camera. User can not only see the camera in 3D but will be able to move the drone according to the movement of his head.

3.8.2 Potential Mobile Application Tools

The dramatic growth of mobile applications has driven the smart phone revolution to support new wireless communications such as Wi-Fi, Bluetooth, 4G LTE …etc. For the ease of use, this project is planned to adopt all Wi-Fi supported smart phones for both platforms Android and iOS. Since, the time constraints may not be in this project favor. Only Android platforms will be support by the Dragon Bee for the testing purpose.

Choosing Android over iOS is a matter of testing easy where Android applications are easy to use, more open than iOS, and the most used mobile operating system. There are multiple IDEs that support building android Applications. Although the main language to build an Android application is Java, there are other languages used such as C/C++ in some cases. Other than Java, the framework requires other parts. Android also takes within its scope the XML language as well as basic Apache Ant scripting for build processes.

For an official support, team members decided to use Android Studio and SDK tools and platforms using the SDK Manager. The Android SDK Manager organizes the SDK tools, platforms, and other components into packages for easy access and management while building an app. Android studio provides a tremendous support to Android developers. It will be easier to build a mobile application for Dragon Bee using some of Android Studio features such as Gradle, shortcuts, multimedia, wireless P2P connections through Wi-Fi, user's current location, and variety of user interface options.

3.8.2.1 Android Studio

Android Studio is a specialized IDE designed only for Android development and its main goal is to shorten the development time and make it easier and simpler. After dedicating some time searching about Android Studio development kit, a lot of features are going to help meet the requirements of building an Android app that has both video stream and control the Dragon Bee.

- **Gradle:** Among those features, Gradle project structure is an automation tool which replaced Apache Ant. Gradle is a custom build tool used to build android packages known as APK files by managing dependencies and providing custom build logic. It allows developers to create multiple APKs with different features for the same android app; APK files gets signed and pushed to the device using Android Debug Bridge (ADB) at the execution time.
- **Shortcuts:** Another, Android studio uses Smart shortcuts that replaced references to resource files with their real values. This way, it will be easier to find out which color to use or the height of the layout directly from the code editor. The following is an example shortcut. To easy build a friendly user interface, Android studio favored among other IDEs for its improved graphical preview where all the changes observed in real time. Also it is considered the fastest when it comes to building release versions of more complicated projects.

```
<colorname="start_button_green">#1369a9</color>
```

- **Multimedia:** The Android platform includes libraries for streaming media files either local or over a network. There are two main classes VideoView and MediaPlayer and those two components will be the only needed components since only basic video player is required for live streaming through a remote address.
- **Wi-Fi Connection:** Wi-Fi is one of the appropriate wireless connections to use for streaming live videos because of the transfer speed that goes up to 250 megabits per second (Mbps). At the Android end, two TCP/IP connections will be running continuously. First one will be responsible for the video streaming which it will be issued between an Android device and Wi-Fi enabled camera. The other connection will be issued between the same Android device and MSP430 MCU which will be responsible for sending control commands to MSP430 MCUS.
- **Location service (GPS):** In some cases like auto follow mode, the quadcopter periodically requests the user's location through the smart phone and use it as "fly to here" commands every two seconds. Also GPS coordinates will be fed to the quadcopter each time start a new mission, and simply those coordinate are "Go Back Home" coordinates which will present an emergency landing point.
- **User Interface:** Even Android studio a newborn is an integrated development environment (IDE), it provides professional layout tools to build a friendly UI. A layout describes the UI's visual structure, such as an activity or app widget. This visual structure can be described in two ways:
  - Android provides a human readable and machine readable markup language called XML; this latter corresponds to the View classes and subclasses, such as those for widgets and layouts. XML layouts can be created either interactively by the designer tool or written by the appropriate XML language.
  - The Second way to create a layout is through the application code, then it instantiates at runtime creating View and ViewGroup objects programmatically.

The default Android Software Development Kit (SDK) comes with the following common layouts shown in the table 9 bellow.

Layout	**Description**
LinearLayout	It arranges its children in row either vertically or Horizontally
RelativeLayout	It arranges its contents by specifying location of each child related to each other or to the parent layout.
FrameLayout	It is used to reserve an area on the screen, and the area is shown as a single item
TableLayout	It arranges all its elements in a table view

Table 9: Android SDK Layouts

RelativeLayout is chosen as the appropriate layout for this project's app, in such, the parent is reserved for the video streaming and two children are reserved for control menu and modes menu. Modes menu will be build using List View for the available options. The following figure 15 gives an example of the layout (a) and List view (b).

(a) Common RelativeLayout

(b) List View

Fig. 15: Android Studio Layout

3.8.2.2 Justinmind interface Prototype

Designing and coding the same time gets sometimes frustrating especial when the time is one of the main constraints of this project. In other words, designing a friendly interface will require a comparatively long period of time; therefore Justinmind interface prototype designer software will help design UI prototype faster and better with default built-in widgets, then the final design can be converted to a real Android app interface which gives more time to worry about app core coding.

Justinmind Prototype allows the team to create interactive wireframes with interactions, animations, and even data with drag and drop tools. Also it comes with readymade widgets create highly interactive wireframes for any application in no time and across different screen sizes and devices. It is the perfect tool to visualize designs before moving on to coding.

3.8.3 Mobile Application Requirements

It is a challenge to gather proper mobile app project requirements. Poor requirements can lead to project failure. For this project, three main requirements are consider. Functional, nonfunctional and technical are the three requirements are taken into consideration. Technical requirements table below shows the minimum requirement for mobile application. All programing is done in Android Studio using JAVA. The GUI requires input from touchscreen based phones. Audio is one function that won't be included into this app. That functionality will be implemented if the time permits. The table 10 shows the technical requirement of the Mobile Application.

Technical Requirements		
Programming Language	C(core),C++, JAVA(UI)	
Platforms(os)	Android(6.0 or older)	
Minimum Space	90MB	
Processor	1.4GHz Quad Core Processor	
Screen resolution	960x640	
Video Code	H.263,H264(AVC),MPEG-4	
Video Format	MP4,M4V,WMV,AVI,FLV,MKV,WEBM	
Audio	MP3,M4A,WAV,WMA,MIDI,XMF	
Input	TouchScreen User Interface , Virtual Qwerty Keyboard	
Sensor	Accelerometer,Gyro,Proximity,Compass,Barometer	
Connectivity	Wi-Fi/3G Internet(1mbps)	
GPS	YES	(For Direction)

Table 10: Technical Requirements for Mobile App

User experience, Interruption handling, Performance, usability and Accessibility can be considered nonfunctional requirement for this app. A good user experience can be a plus to safely fly the drone. If the person has flew any UAVs can fly Dragon Bee much better. The interruption always happens when using any mobile app. This includes, phone calls, text messages, low battery any related warnings. This mobile app will be designed to be well operated in any interruption. The drone connectivity is through Wi-Fi so any interrupt in the system should not affect the drone what so ever. If there is system failure, then it will hold its last position and wait for set amount of time before it flies to its designated default location.

Performance is one factor that is taken into account while building this app. It is necessary to build an app that gives its best performance. Unlike any web application, the network performance is not guaranteed. The app delivers all its command to drone through Wi-Fi so it is a major factor in performance criteria. The user needs to maintain certain position to get best performance by the video camera.

For the purpose of this project, the teammates have only considered build an android app. Any android device can be used to download the app from Android Studio. This app is so simple to use that any person with disability can still use it without any trouble.

Functional requirement table 11 describes all the features and functionality of the Mobile Application. User can relate to this table in order to find what each function does.

Functional Requirement	
Description: Mobile App to Control Dragon Bee drone and view live Streaming	
Assumptions	No Interrupt in Wi-Fi connectivity No dead battery event on mobile device Drone battery charged over 10%
Persona	Any user interested in flying drone and videography
Impact	User must know how to fly drone User must be in Wi-Fi range of the drone User must have Wi-Fi capable phone Drone should not run out of battery Nice to have clear sky, should not be flying in rainy weather
Primary Actor	Hobbyists, Photographers, sports man Hobbyist will use the manual mode. Photographer will use either 3D or Follow me mode. Sports man will use Follow me mode for self-shooting.
Input	System will ask for modes to choose from, Example: Manual, Follow Me, and 3D <Manual> RIGHT, LEFT, UP, DOWN, FORWARD, BACKWARD <Follow ME> Buttons to set specific distance if needed. <3D>Input data is collected from digital compass from the phone. NO USER INPUT
Action	The system should recognize the selected mode and start display the video accordingly and show the button in manual mode and Follow Me mode.
Output	The system will start the video streaming from the camera. The system will display the controlling buttons if the manual mode is chosen. The drone will move according to the selection. For example, If left button is chosen then it will move left.
Exception	In the event of lost Wi-Fi connection, or phone running out of battery, the drone will fly to its default location set by the user after waiting for small period of time. Live video streaming will also be disconnected if the drone is out of range. If the drone battery gets lower than 10%, the drone will automatically fly to its default location.
Dependencies	No function depends on other function. The video streaming depends on the Wi-Fi connectivity. Less distance from the drone will deliver better video.

Table 11: Functional Requirement

3.8.4 Mobile Application Standards

There are many standards that can relate to this project. For the purpose of this project, only limited standards are listed in the table 12 below. These standards are for various API usages and for the mobile web app usage. These guidelines are kept in mind when building the android app.

2015-01-08	Indexed Database API This document defines APIs for a database of records holding simple values and hierarchical objects.
2014-03-13	Metadata API for Media Resources 1.0 This specification defines a client-side API to access metadata information related to media resources on the Web.
2013-10-24	Geolocation API Specification This specification defines an API that provides Web pages scripted access to geographical location information associated with the hosting device.
2010-12-14	Mobile Web Application Best Practices This document specifies best practices for the development and delivery of Web applications on mobile devices.
2015-07-14	Permissions for Device API Access This document identifies the permissions that are needed to use specific client-side APIs which grant access to sensitive data and operations.
2011-03-17	Device API Access Control Use Cases and Requirements This document defines requirements for controlling access to device APIs, illustrated by corresponding use cases.
2010-06-29	Device API Privacy Requirements This document provides definitions, use cases, and requirements for making device APIs more privacy-friendly.
2009-10-15	Device APIs Requirements These are the requirements intended to be met in the development of client-side APIs that enable the creation of Web Applications and Web Widgets that interact with devices services such as Calendar, Contacts, Camera, etc.

Table 12: Mobile Application Standards

4. Design

Now knowing all the parts and components to use for building a “Dragon Bee” drone, it is time to design it.Two main parts of Dragon Bee drone design includes Hardware design and Software design. Hardware design includes the design part of a drone structure and connections, and the Software part of design includes mostly Android app designing.

Designing include some schematics, which gives general scope and conceptual design of the project. Additionally it includes the design of connection between two communication systems. It gives the basic ideas how two systems will commute and connected to each other.

It also include the wiring for components such as sensors, battery, microcontrollers, flight controller, power module, ESCs, motors, etc.

Following are some of the block diagrams illustrating both of these design parts. I will describe the overall system design of drone and its communications.

4.1 Block Diagram

The “Dragon Bee” project can be divided into two main categories: “follow me” mode and distance control from the ground. Both of them have to be controlled though the android phone.

Following are brief description of both of those categories with a basic block diagram. “Follow me” mode: The main purpose of this drone design is “follow me” mode through the Wi-Fi module. It has to connect with Wi-Fi of the smart phone a person is carrying and follow that device wherever a person with that device goes. Choosing Wi-Fi module as a communication between a drone and phone has its own advantage, which is long distance range that Bluetooth doesn’t have. However, it could be used as communication protocol.

Figure 16 is the block diagram of the “follow me” mode which includes some parts and protocols.

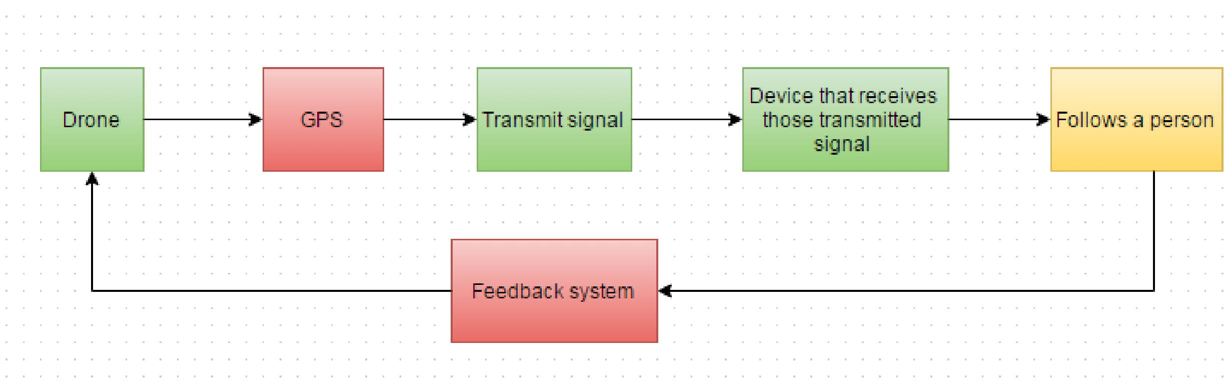


Figure 16 : Follow me mode diagram

As seen from the block diagram there are few steps how drone can be commuted to smart phone device and how it can be made follow a person.

- The drone with its own built-in GPS system will send Wi-Fi transmitting signals to the smart phone.
- Smart phone receives those signals and transmit back to the Wi-Fi module telling the location of it.
- GPS device or a microcontroller reads those signals, calculates some arithmetic, and tracks a smart phone device.
- Once a device is tracked, it is programmed built-in it which allows a drone to stay within a certain range and distance from the smart phone device.
- It also give a feedback to the smart phone of how high is the drone flying, the speed of it, and the exact position of it from the smart phone device.

Distance control: The next main category is the distance control in "Dragon Bee" project. This part is little subpart of the first main category of "follow me" mode, which includes kind of how high the drone is from the ground. The difference in this category that differentiate it from the first one is the distance could be set, controlled, and changed before the flight, which means the drones height could be pre-determined. Transmitter and receiver are same parts as "follow me" mode; however, functionality and mode is little different. Figure 17 is the clock diagram of the distance control mode of the drone.

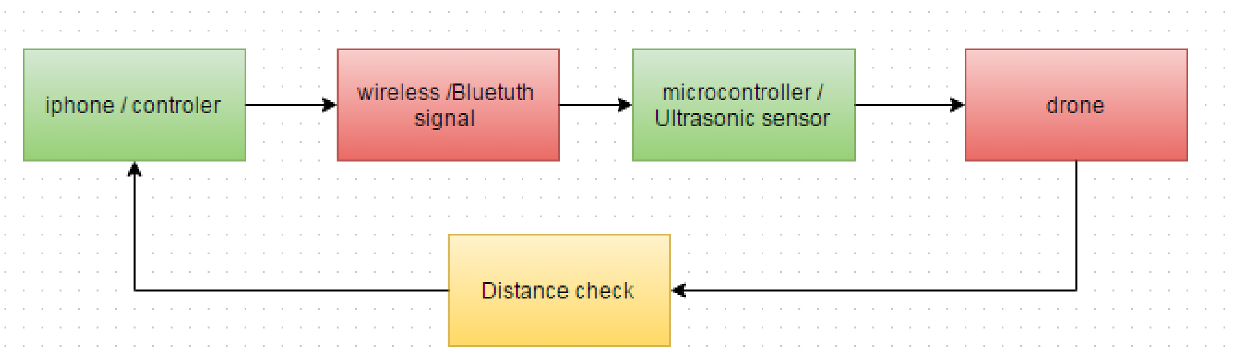


Figure 17: Pre-Distance control block diagram

As seen from the block diagram in Figure 17, most of the parts being used for this mode are same as the previous one with little changes. Following are few steps which show how this mode will function.

- The smart phone device such as i-phone or android phone is used to set the flight distance, height, for the drone.
- Once the distance and height are set, it transmits the data to the microprocessor built-in the drone via Wi-Fi.

- Microcontroller in the processor reads the data, does arithmetic, and sends adjustment signals to the flight controller, which controls the motors.
- Once the flight controller receives signal from the microprocessor, it adjusts the current supplied to the motors and based on the currents on the motor the rpm of the motors could be adjusted and height can be controlled.

4.2 Hardware Design

The hardware part of the design includes some schematics and connections within the hardware parts. It also gives hint how parts will be connected at what pins or terminals. It will give batter understanding how components will be wired with each other for power input/output and data receiving/transmitting.

Below is the overall picture of how battery, motors, power module, ESCs, flight controller, microcontroller's integrated circuit, GPS module, camera, and receiver are connected.

4.2.1 Flight Controller (Ardupilot 2.8)

The major change from turning RC airplane to a drone is connecting an autopilot between RC receiver and planes servos. Autopilots can take over controlling such as movements of aircraft; however, it adds additional features to it. Features such as adding modes that makes the drone fly at certain height, distance, speed, and directions. Autopilot makes a simple flying aircraft to the smart aircraft which could travel without control with designed rout. Its height and distance could be pre adjusted so it could capture pictures and videos if camera hooked up to it.

The question is how to hook up connections between this autopilot to the motors such that motors can function as directed by the controller.

Since making the smart and Wi-Fi compatible drone, an integrated circuit with programmable and Wi-Fi signal transmitted microcontrollers are used for this project. Therefore, instead of RC receiver and Bluetooth receiver, it will be an integrated PCB outputs will be connected to the APM2's input. The way to connect is to though UART from the integrated microcontroller PCB output to APM2's input. If using an RC receiver, it would be easily plugged in with female-female cable from RC receiver into APM2's input. In output side of the APM2's, plug in output of servos and motor controller for drone, which in this project MSP430. Below is brief description of some channels and pins usage in APM for drone controlling.

Pins and ports in APM2 are used for:

- At least a 5-channel MSP 430 unit. 7 channels or more is highly recommended.
- For APM20, a power source will be needed. For electric aircraft, this is usually the ESC. For gas/nitro powered planes, its own battery or BEC is needed.
- For APM2.5, the supplied APM Power Module for the power source could be used.
- Pins for 360 Infrared and Ultrasonic sensors.
- Ports for GPS module and power module.
- Other pins and ports could be used for additional features if added.

Below in Figure 18 is the schematic diagram for APM2's connection, which is not so accurate but the pins could be changed as requirements following the manual of APM2.5/2.6/2.8.

Analog input pins:

Pin 0 to 8: The APM2 has a row of analog input pins, labeled A0 to A8 on the underside of the APM 2.8 board. These are available as pin numbers 0 to 8 inclusive in PIN variables. These pins are used for analog inputs such as ultrasonic or infrared sensors.

All these pins can take up to 5V and may be used for any general analog input. They are also commonly used for airspeed and sonar inputs.

Power module input pins:

Pin 12: power management connector current pin, accepts up to 5V, usually attached to the power module with 17:1 scaling. These pins are used to supply power to the APM 2.8.

Pin 13: power management connector voltage pin, accepts up to 5V, usually attached to power module with 10.1:1 scaling

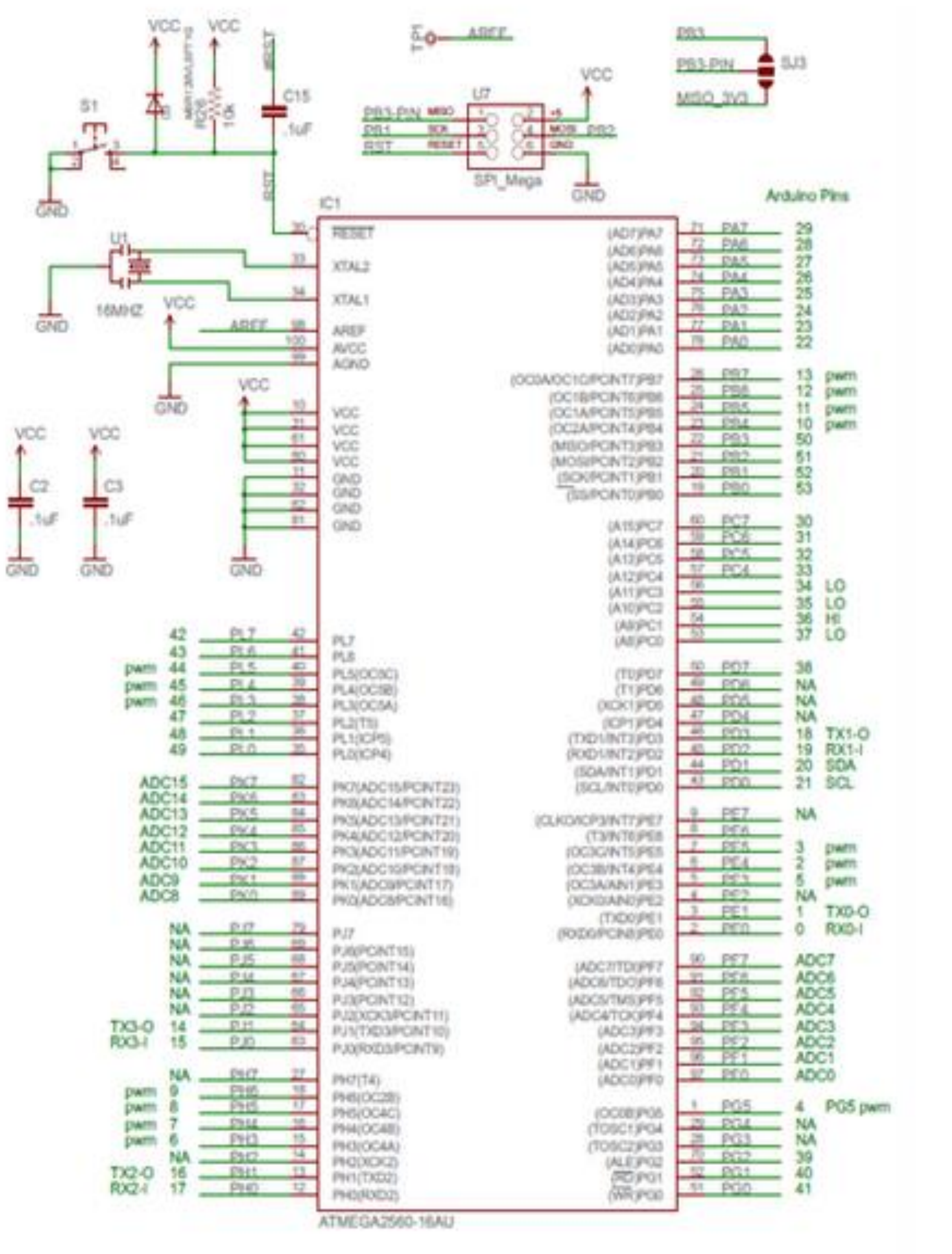


Figure 18: APM design diagram

Digital input pins:

Digital input pins are used for signal receiver. It could be RC receiver, Bluetooth receiver, or in the case of this project its Wi-Fi receiver. In APM 2.8, pin 45 and 46 are used for Signal receiving and transmitting to Wi-Fi module, in the project MSP 430F5529. Pin 45 is used for receiving transmitted data from the microcontroller and pin 46 is used for transmitting data to microcontroller.

Along with this pins are pins for voltage supply to microcontroller connected with APM 2.8. It supplies power up to 5V to microcontroller need to function. There need to have pin for ground for microcontroller. Therefore some pins in this region are used for ground coming from the microcontroller.

Digital output pins:

The APM2.8 uses the same set of 9 analog input pins as digital output pins. They are configured as digital output pins automatically when starting to use them as digital outputs.

Pin 54 to 62: pin 54 to 62 is needed to add to the pin number to convert from an analog pin number to a digital pin number. So pin 54 is digital output pin on the A0 connector. Pin 55 is A1; pin 56 is A2, etc.

These pins are usually used with the RELAY_PIN to RELAY_PIN4 parameters, allowing controlling things like camera shutter, bottling drop etc. They are also used as sonar “stop” pins allowing it to have multiples sonar and not have them interfere with each other.

Output pins:

These pins are used for two purposes. First, it is used for servo controls such as elevation, aileron, rudder, and flap. These servos are mainly used for plan. The second purpose to use some of these pins is for ESC, which is connected between servos. ESC is used to receiver commands from the APM 2.x and to drive the motors as directed.

Powering APM:

There are two “sides” to the positive circuit in the board. Each side has positive-rails available for inputting the power and distributing it to peripheral devices. The center row of pins in the three groups of pins (Outputs, Inputs, and Analog) labeled “+” is referred to as a “positive-rail”. This means that the base of all the “+” pins are connected so they represent a single electrical path. The positive-rails of the Input and Analog group are connected together. So that means there are two separate positive circuits, one for the Outputs and the other one for Input/Analog.

All of the components on the board take power from various points on these rails, so it is necessary for both “sides” to be receiving +5V power supply (within the specs below) for the board to function. These positive-rails can be joined together by placing JP1 in the middle position of these two positive rail sides on the board. This connects all the positive-rails and provides power to both sides of the board. Therefore, low-level power can be distributed to peripheral sensors and devices such as microcontrollers, GPS module, sensors, Rx, etc. via the power-rails.

Powering APM is easy task since the company provides the PM pins with it. What if PM is not used to provide power to the circuit? Then the other option is to deliver power through ESC's. Therefore, there are two scenarios to talk about when considering the APM power supply: by power module (PM) and by ESC.

Powering with Power Module:

From the power module connection the negative wire is connected to a negative-rail shared by the entire board regardless of JP1. Positive voltage comes in to a T-junction. To the left of this junction is a path through the JP1 to the positive-rail of the Outputs. To the right it is path to the positive side of Analog/Input, which flows through an over-voltage, over-current, reverse-polarity protection (500mA fuse and 6V Zener diode). A side effect of passing through the Zener diode is a .37V loss; therefore, input voltage should be bumped up by .37V to account for this lost. From here the positive voltage runs to the positive-rails of the Inputs and Analog. Inputs should not be used to power anything except Wi-Fi receiver MSP430. Following in figure 19 could be seen the T-junction and two sides for the positive-rail.

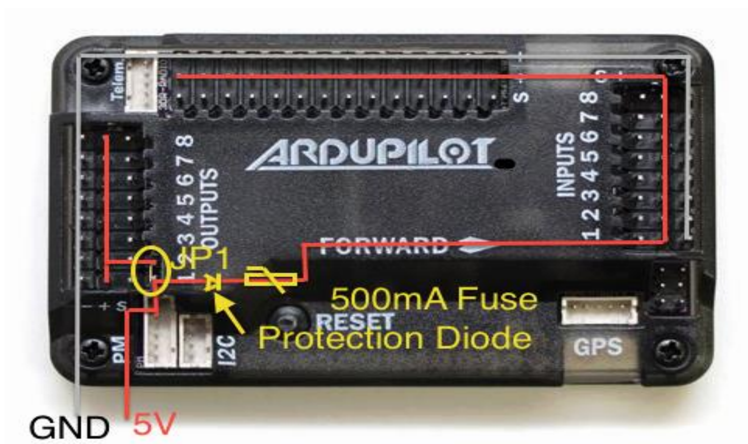


Figure 19: Two sides of junction (Output and Input/Analog)

Higher current loads such as servos should be powered from the power-rails (positive-negative) of the Output side. There has to be an adequate voltage-regulator to provide power directly to the Output power-rails, all servo power leads will attach to these same rails. The signal wires can be connected to the Analog "S" pins in the case of a camera gimbals. Since JP1 is removed in this scenario, the other "side" of the board will need power provided to its power-rails directly.

Alternative ways to power the board are following:

- The APM 2.5/2.6 board has two separate power circuits separated by jumper JP1, which make it very easy to power by a variety of methods.
    - A fused power circuit, generally Input and Analog, provides primary board and general I/O power. However, it cannot provide power for servos.
    - The other power circuit is for the OUTPUT connector power rail, which can provide power for servos.
- The jumper JP 1 determines whether the two power circuits are connected or separate.
    - If JP1 is removed, the power rail on the OUTPUT connector “Floats” and may be used to distribute power.
    - Although if JP1 is removed the OUTPUT connector cannot be used to supply power to the APM board. However, Output connecter could be used as a power supplier to the APM board when one of the voltage supply pin from the Output is connected to the power supply AUX pin in Input. It is connected though BEC for manual control purpose such Flap by manual.
- Therefore, It is possible to power the APM board from the Power Module connector or the OUTPUT or INPUT connectors.
- Normally the APM 2.5/2.6 “Power Module” is used to provide primary APM 2.5 board and general I/O power.
- Alternatively primary board power can be supplied by a BEC either from one of the ESCs or from an external BEC.
- If servos are used, supplementary power is required.
    - Generally one power supply is provided for the board and one or more additional power supplies for the servos.
    - But if a sufficiently large external ESC is used it can supply power for both via the OUTPUT connector.
- Only the OUTPUT connector can provide power for servos as the other circuit is fused.
    - The address connector is sometimes used provide servo signals, but the servos power must come from elsewhere.
    - Analog pins A9, A10, and A11 I/O connecter could be used to operate servos; however, as mentioned above Analog pins do not provide sufficient power to servos. An external power supply must be used.
    - A9-A11 I/O connector come pre-wired to correct digital out for servo control lines use.
- The type of use will determine which options are available.
    - Copter can power the APM from a power module or a UBEC or a BEC from one of the ESCs and can power servos from a UBEC or from the other ESC’s BECs.
    - Wise options considered from having appropriate wires and devices.

In the “Dragon Bee” project, we have power module and ESC comes with APM kit; therefore, it should be considered to provide power to APM board with power module and provide power to servos from ESC.

Following in the table 13 is a short description of power delivery in APM 2.8 through either Output connecter or Input connecter with power module and jumper JP1 connected to them.

Power Options	Nominal	Abs MAX	JP1Status
Power on Output PWM connector	5.37V +-0.5	6V	JP1 connected
Power on Input PWM connector	5.00V +-0.25	5.5V	JP1 connected

Table 13: Power delivery description in APM

As seen from the Table-13 that abs max are the numbers means the power supply to AMP board should not be exceeded that those values. Otherwise it could damage the circuit board of AMP. Further, connecting USB at high range (abs max) voltage could damage the board as well; therefore, it is important to disconnect a battery before using USB or voltage supply should be within the rage.

Now we know the design and power supply to the flight controller, APM 2.8. The next task should be to knowing the design and functionality of Power Module, ESC, PDB, and battery, which will be discussed in section 4.2.3.

4.2.1.1 GPS Module

UBLOX 3DR GPS plus compass module or Neo 6M GPS module plus compass is generally used with ArduPilot APM 2. Since Neo 6M GPS module comes with APM 2.8 kit, it should be used as GPS module. This GPS module comes with the compass ic in it.

ArduPilot APM 2.8 has GPS module port in it along with 12C external compass port, which provides up to 5V power supply to it. However the power supply required for this module is between 2.7V – 3.6V depends on compass is used or not. Following in figure 20 is the schematic of Neo 6M GPS module.

As seen in the schematic pin 21(RX) and 20(TX) are used for the GPS data receiver and transmitter. Pin 23 is used for power input, usually around 3.3V, which will be supplied by APM board. Fourth pin from GPA port should be for ground, which usually is used to reduce electromagnetic interference and improve the high frequency performance of the circuit. Same pins configuration applies to compass input and there is 4 pins serial port located at very bottom to GPS port on APM 2.8. UBLOX Neo 6M module has its separate port output for compass use.

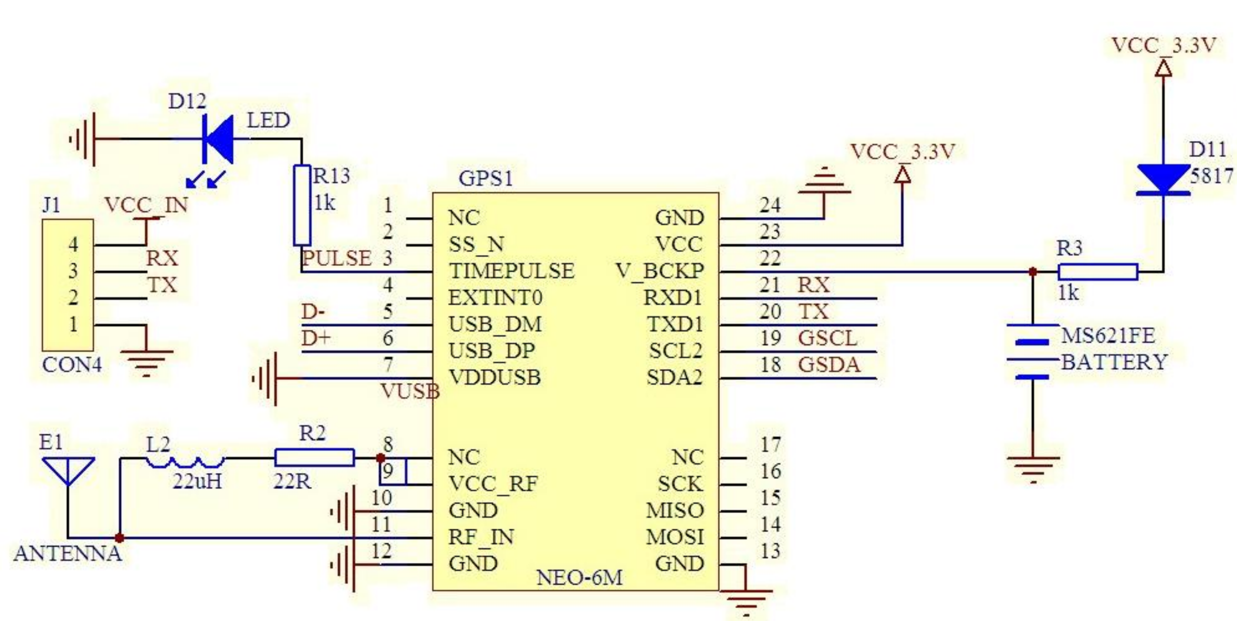


Figure 20: Neo 6M GPS schematic

4.2.2 MSP430 Processor

The microcontroller that will be implemented in the project on hand will be the MSP430F5529. The package used will be 80 pins. The pinout diagram is listed in Figure 21 which is found on page 8 of the data sheet for the MSP430F552x line of microcontrollers:

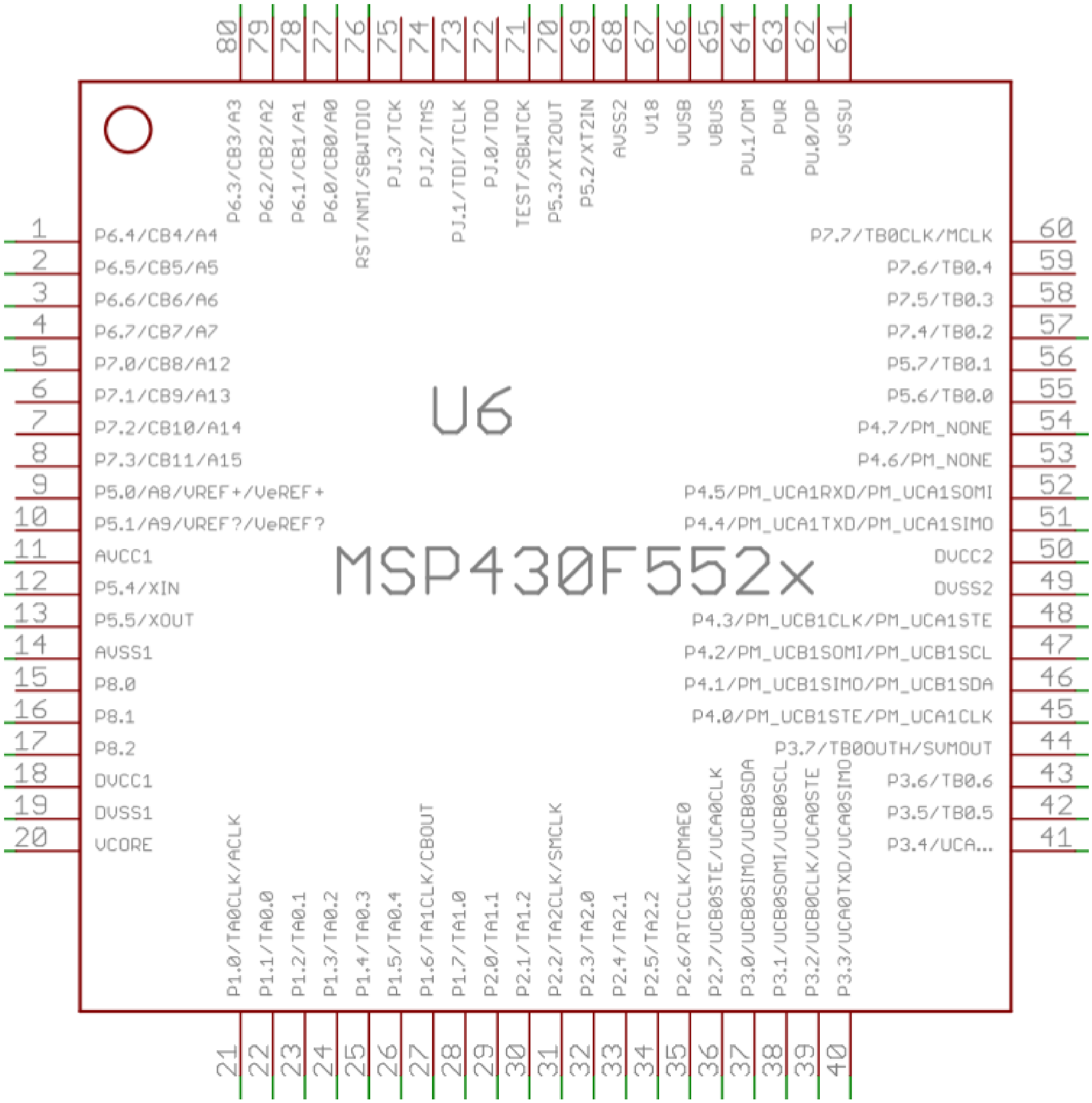


Figure 21: MSP430F5529 Pinout Eagle Cad Layout

The MSP430F5529 will be prototyped on the Launchpad which has onboard emulator support. The debugging and programing will be done through the Launchpad at the beginning. Then, once the device is built onto a PCB board, the onboard emulator will be used to program and debug. This debugging and programing will be done via JTAG interface. The JTAG interface will be used to program the MSP430. Four connections will be required to link the MSP430 to the JTAG. This full speed 4-wire JTAG communication is only possible with a MSP-FET430UIF connected to the JTAG header. This connection will also power the device while it is connected. See Figure 22 below:

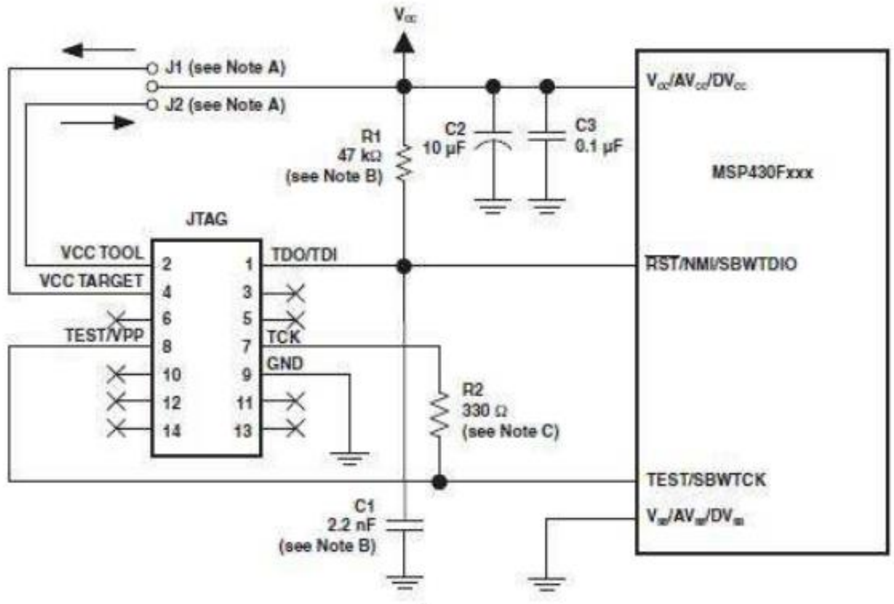


Figure 22: JTAG connection schematic, T.I. Wiki

The use of a 100 nF capacitor in series with power supply for the MSP430 is necessary. This construction will be used to decouple the device from the power supply. The MSP430 will be powered using DVCC = 3.3V. The figure 23 below shows the connection.

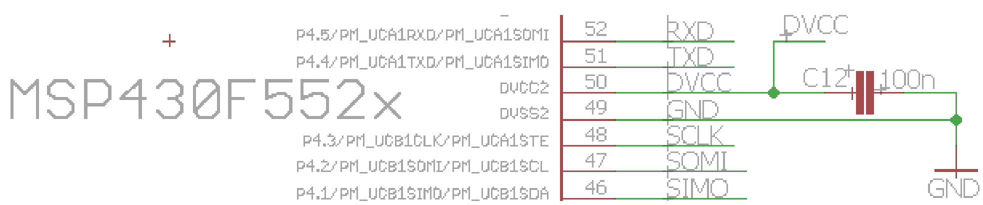


Figure 23: MSP430 Power Diagram

4.2.3 Power hub

Since MSP 430 is connected with flight controller APM 2.8 and it's powered by it, it is important to know how APM 2.8 will be powered. Therefore, the design of power module will be discussed in this section. Additionally, power supply to motors could be discussed along with powering flight controller because they both will have common power supply battery. Due to different voltages and more than one device, it should be safer to power module (PM). For supplying power to multi motors for quad copter, it is better choice to use power distribution board (PDB). To control motors manually with functionality like voltage regulator, electric speed controller (ESC) should be used between PDB and motors.

Designs and schematics of some of these parts will be discussed in following subsections. These parts include: Li-Po battery, PM, PDB, ESC, and motors.

4.2.3.1 Electronic speed control (ESC)

When connecting the ESCs directly to autopilot board, connect the power (+), ground (-), and signal (s) wires for each ESC to the controller main output pins by motor number. Find the frame type below to determine the assigned order of the motors.

Removing the jumper JP1 allows using the APM's servo output rail to distribute power from your ESC's BEC or an external BEC. If using the servos, plug an ESC's BEC power wire and ground wire into two of the power and ground pins on the APM's servo output rail to provide a common power and ground bus for servo power.

Leave the jumper JP1 present if using ESCs that have no BECs or if all the ESC's BEC power wires are cut and not powering any servos from the servo out rail. Following is the figure of ESC's 12 A continuous with BEC schematic.

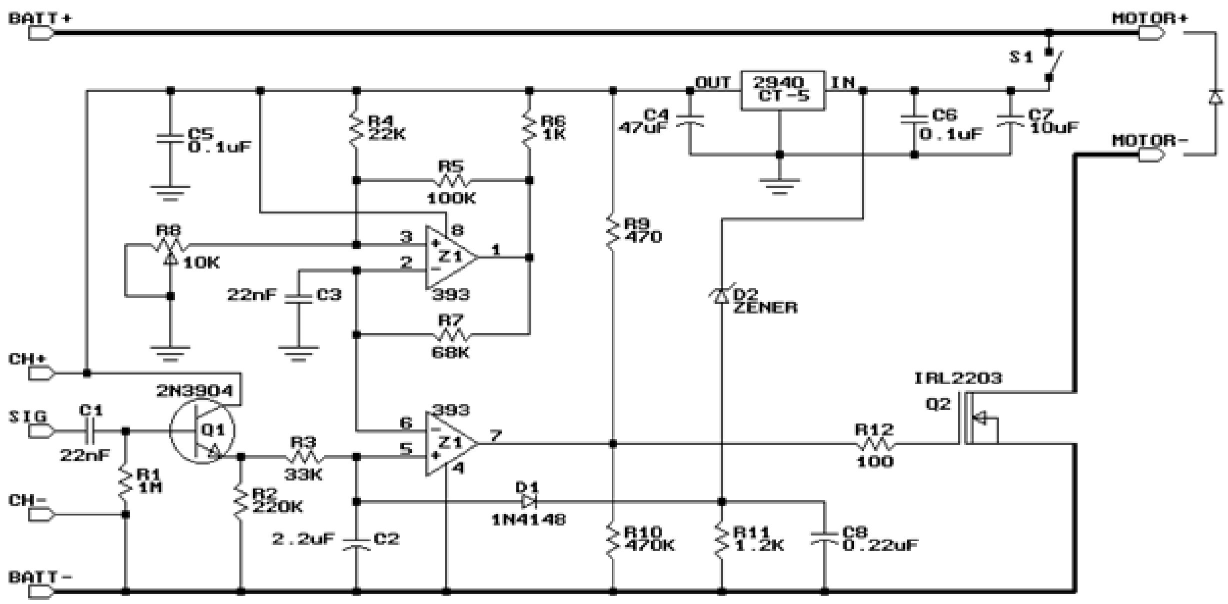


Figure 24: 12A ESC with BEC schematic

Schematic in figure 24 shows the power input in ESC as well as (CH+) power, (CH-) ground, and (SIG) signal inputs from the flight controller. The motor "+" power and "-" for ground is connected the other end of the ESC circuit. The power will be regulated and controlled in the ESC as required for certain rpm of the motors.

Powering each servo individually could be done from each individual ESC-BEC by simply run the power and ground from each ESC-BEC individually and directly to each servo. It is good option for multi motor copter. However, power distributions to each of the ESC could be done through PDB. That is why a common PDB is connected to each of the four ESCs of a quad copter. Just like the motor-ESC connections, ESC-PDB connection has three outlets: one for power (+), one for ground (-), and one for signal (s). These are connected through three pin section each with right angle header.

4.2.3.2 Power Distribution Board

One of the cleaner and safer ways to power motors of the quad copter is by supplying power to them directly from the battery. However, power has to be dropped down and distributed among the each motors. As mentioned above the power module is used to do the job of dropping down the power and power distribution board is used to distribute power which will be discussed now. Since using 3DR's PDB, it would be better specifically to discuss the design of it. 3DR's PDB has four main ports: power connector XT60 for PM, three pins for each ESC connection from the 40 pin right angle header, four wires for ESC's signal from APM, and one pin for ESC +5 volt power output to APM. Following is figure-15 showing the schematic of 3DR Hexa PDB.

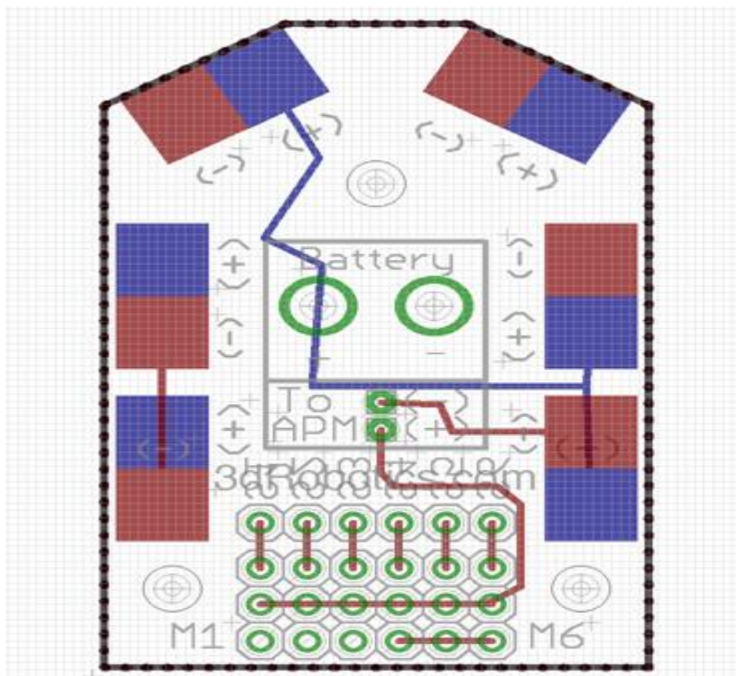


Figure 25: 3DR Hexa schematic

As seen Figure 25, the schematic could be also used for a quad copter by just using four of it outlet pins for ESCs. However it would be better option to use 3DR quad PDB which only has four 3-pin header sections for four esc in that way the space in the quad copter could be saved. 3DR Company provides quad PDB; however it could be easily made by soldering few wires, pins, and headers. Following are few steps of how quad PDB is made.

- APM power pin: solder the thin gauge red & black wire to "GND" and "5V OUT" on the bottom side of the PDB labeled "This Side Down". It could be plugged in the output pins of APM board.
- APM-ESC signal connector: solder the four wire connector to the motor signals starting with the green wire on the edge of the connector to M1 on the PDB.

Work way down the connector soldering the wires in order: Orange to M2, White to M3, and Yellow to M4.

- 3. ESC-PDB signal header: solder the 3 pin headers to the outermost through-hole pads along the perimeter of the PDB.
- 4. PDB power connector: 10/12 AWG cables are used. Solder the wires to the positive and negative female leads of a male Dean's connector or a male XT-60. Strip down the other end of the cables and solder them on PDB labeled "+" for positive and "-" for negative.
- 5. ESC-PDB power connector: this step is one of the two choices:
  - Solder female Dean's connector to the +/– pads along the perimeter of the PDB. This is where the black and red wires of your ESC will plug in. Having a connector will allow you to quickly replace an ESC in the event of a failure. The manual will continue with this method.
  - Solder the black and red cables on your ESC directly to the PDB. This saves a lot of time in building by not soldering connectors to the PDB and ESCs but will make the build slightly more challenging because it will be harder to slide the ESCs '+' PDB through the center of the frame.

4.2.3.3 Power Module

Power module works as voltage regulator between battery and all devices connected to it. As mentioned above in research section, APM power module will be used for this project to supply power to the APM board and ESCs. The input of the power module is battery input power maximum of 18V (up to 4s Li-Po battery) supplied into it. It will modulate this power and deliver to the APM board. When used with the APM, full 90A current sensing range can be used. Following in Figure 26 is the schematic of AMP power module which will be used for this project.

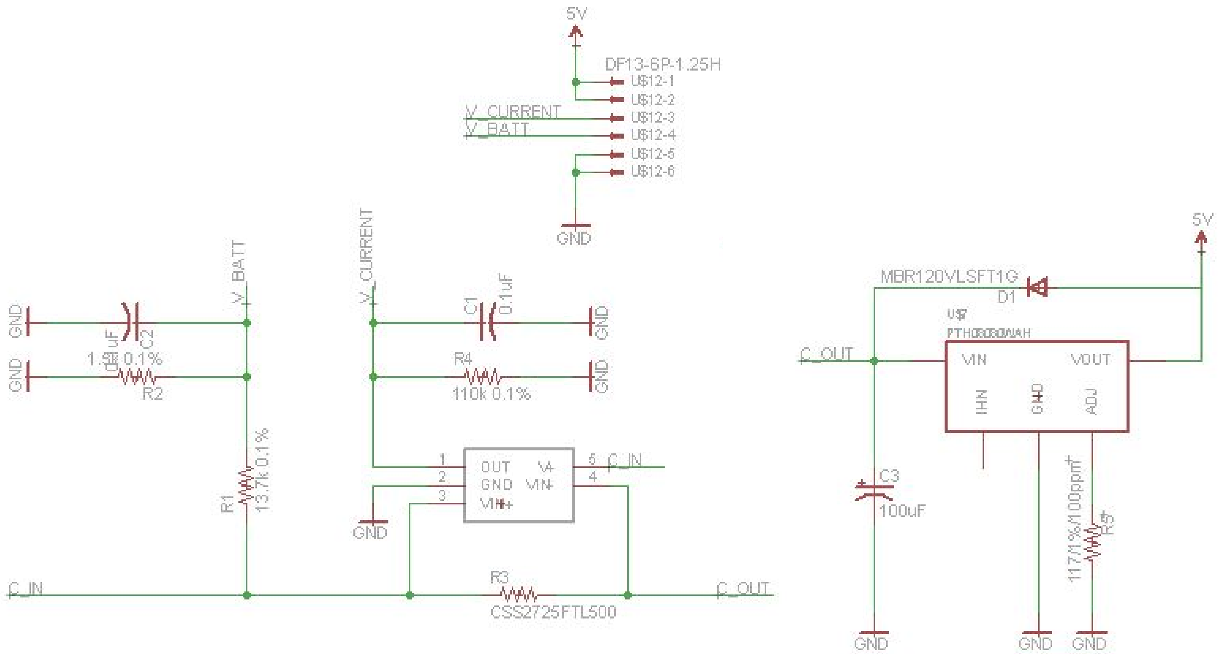


Figure 26: APM PM schematic (Permission Pending)

Generally the APM's JP1 jumper should be removed when using the Power Module which will allow only APM board and receiver to be powered by power module's on-board regulator, not from ESC's. PM module is generally used to power APM board and supply power directly to the ESC's of motors. However, power to the motors could be supplied by two methods: connecting ESCs to autopilot controller directly and drive power from ESC's BEC or using a power distribution board (PDB).

4.2.3.4 Motor

There are two methods of connecting the motor outputs: connect the electronic speed controllers (ESCs) to autopilot controller board directly or use a power distribution board (PDB).

Connect the power (+), ground (-), and signal (s) wires for each ESC to the PDB according to motor number when using PDB. For different types of drones, the motor orders will be different which usually determines if motor will spin CW or CCW. That means when plugging in ESC to either APM board or to the PDB, numbers should be checked and matched according to manual. If connecting the signal wires from the PDB to the main output signal pins on the flight controller board (ensuring that the motor order numbers match the main output pin numbers on the controller).

If using a power module, it is optional to connect the power and ground wires from the PDB to the flight controller board. If like to use these cables in addition to or instead of the power module or as a common point for low current servos, connect the ground (-) wire to a main output ground (-) pin and the power (+) wire to a main output power (+) pin.

These brushless motors are essentially 3-phase motors, the ESC pulses the three wires in sequential order. The direction they spin is down to the order of the wires. Therefore connect the three wires however needed, and if it spins the wrong way swap any two of them over and that will reverse the motor. Since motor's wires are connected to the ESC, it would be good to check the datasheet and pins for the connections.

4.2.3.5 Battery

The design part of the battery is very simple thing to figure. It contains two important ports: power connector and JST/HX balance plug. For this project Zippy Compact 5800mah 3s 6C Li-Po pack is used due to its high performance.

This battery has two cables, which are balance plug, JST/HX and discharge plug, XT-60 connector. Balance plug is used for charging this battery pack where else power connector or discharging plug is used for providing power to drone system including flight controller APM 2.8 and each of the four motors. The flight time with this battery is approximately 15 minutes but it could be more or less depending on weight and other factors, which will be discussed in the testing sections.

Due to low power supply to the flight controller APM 2.8 and power decapitation to motors power module is being used for this project, which is 3DR power module. High current connector or power connector is connected to the input of this power module and from the power module power is supplied to the drone components. Following section will be design of power module and brief description of how it will be connected to battery, flight controller APM 2.8, and PDB.

4.2.4Signal Receiver

4.2.4.1 Wi-Fi Camera

The Wi-Fi camera that is going to be used for this project is the Fly360. This camera is well equipped with lots of features that are going to make the design of the whole project unique. One the features of the Fly360 are that it has its own rechargeable internal lithium battery. This is going to be perfect for the design on hand, because powering the camera will not be of an issue. In other words, the camera will save the team some power that could be used to make the quadcopter fly for more time. Moreover, this camera will hold the charge for at least an hour after it is fully charged. The Fly360 is also Wi-Fi capable. This capability will be used to live stream videos and pictures to the same application that is controlling the drone.

The Fly360 camera is equipped with a 32 GB internal memory which will be used to save all the streamed data. This storage will allow to team to capture good quality pictures and videos and therefore allow editing. Figure 27 explains the way the Fly360 and the built application are going to work.

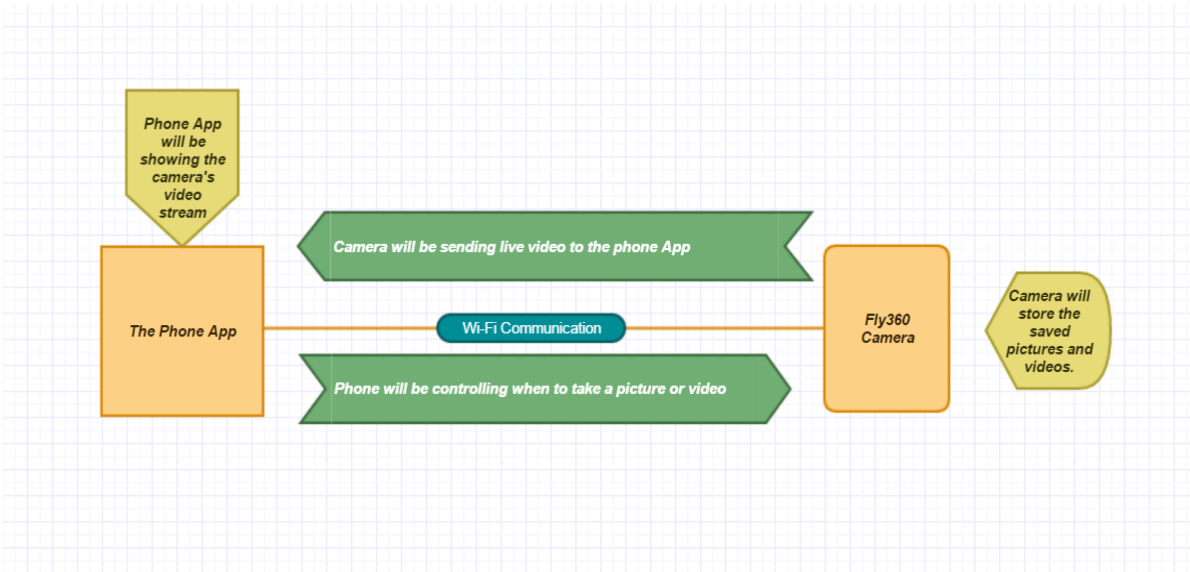


Figure 27: Fly360 Camera & Mobile App Communication

4.2.4.2 CC3100 Wi-Fi Module

The CC3100 is a device that makes Wi-Fi connectivity possible by integrating all protocols for Wi-Fi and internet. This minimizes host MCU software requirements. The CC3100 provides a built in security protocols that are robust and easy to implement. The Wi-Fi network processor subsystem features a Wi-Fi Internet-on-a-Chip and contains an additional dedicated ARM MCU that completely offloads the host MCU. The CC3100 device has the ability to connect to either 8, 16, or 32-bit MCU over the SPI or UART Interface. The host MCU in the case of the project on hand is the MSP430F5529.

The CC3100 device is a complete platform solution including various tools and software and will be used to communicate to the MSP430F5529 through its Wi-Fi capability. The CC3100 device can work with Station, Access Point, and Wi-Fi Direct modes. It also supports WPA2 personal and enterprise security and WPS 2.0. This subsystem includes embedded TCP/IP and TLS/SSL stacks, HTTP server, and multiple internet protocols. Figure 28 below shows a schematic that was gotten through Eagle CAD.

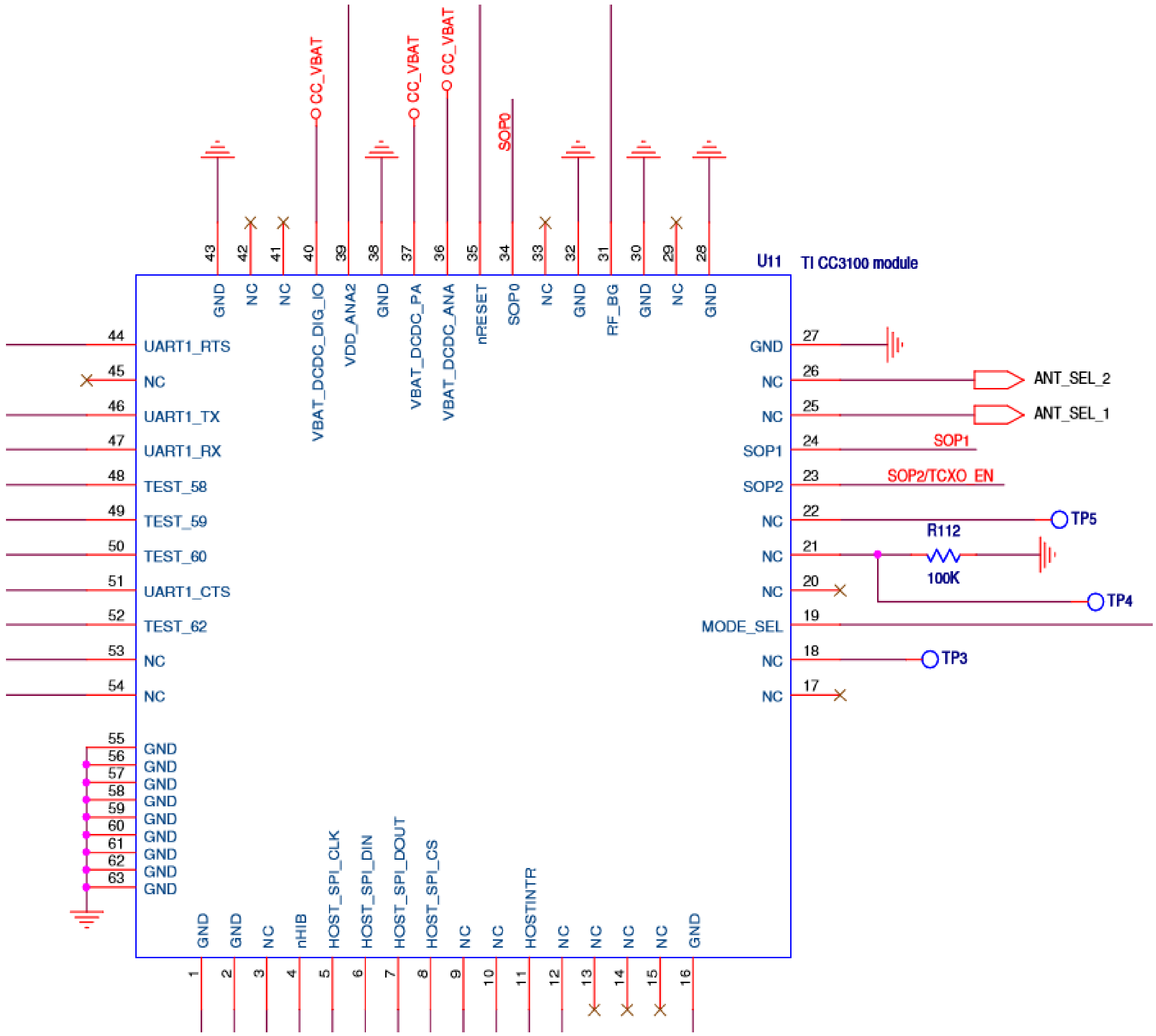


Figure 28: CC3100 Eagle CAD Schematic

The CC3100 will be implemented first by using the BoosterPack. Then, it will be connected to the MSP430F5529 Launchpad which has the onboard emulator support. The debugging and programing will be done through the Launchpad at the beginning. Then, once the device is built onto a PCB board, the onboard emulator will be used to program and debug. The following Figure 29 is a functional diagram of MSP430 and the CC3100.

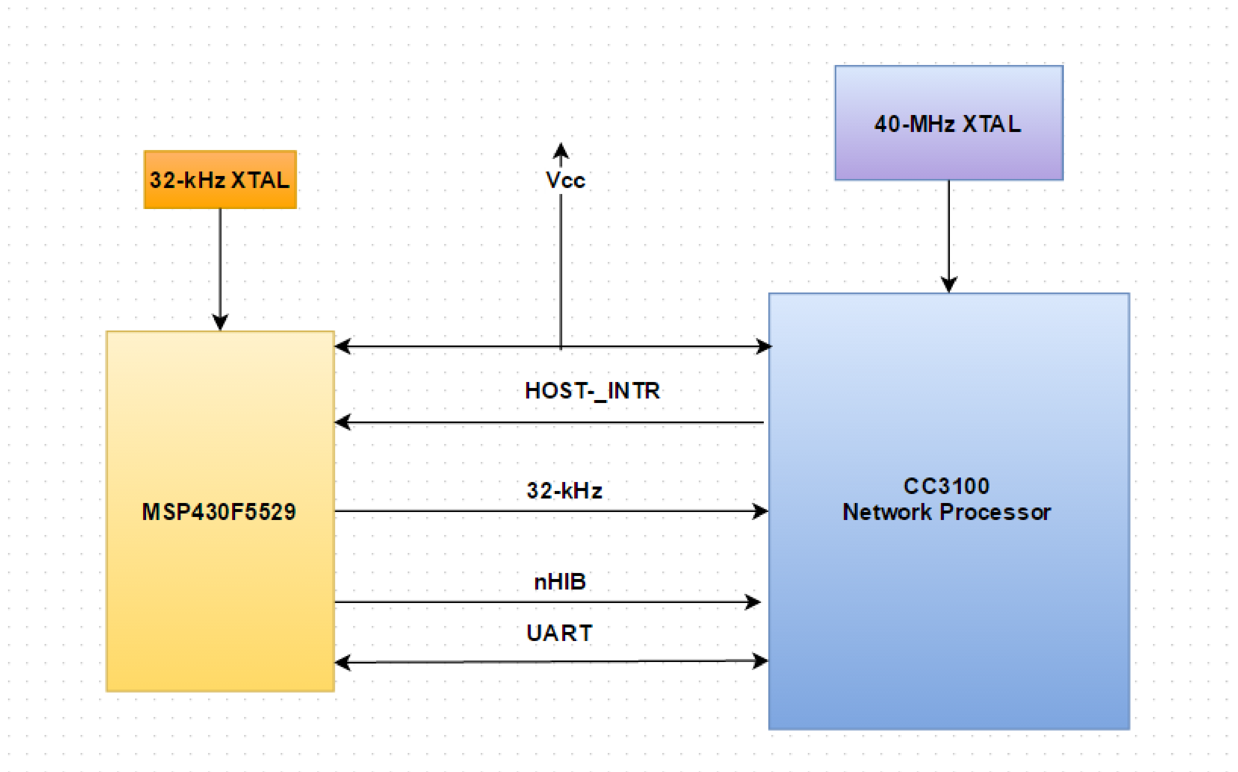


Figure 29: Functional Diagram of MSP430 and CC3100

The CC3100 driver minimizes the host memory footprint because it only requires less than 7KB of code memory and 700 B of RAM for a TCP client application. Because of the integrated DC-DC converters, the CC3100 device supports a wide range of supply voltages. In the case of the project on hand, the CC3100 will be powered through the MSP430 Launchpad with a voltage supply of 3.3V. The integrated DC-DC converters enable low-power consumption modes, like the Hibernate RTC Mode, That require about 4uA of current. This will ensure minimum power consumption for the project on hand.

4.2.5Proximity Sensors

4.2.5.1 Proximity Sensor for Height

The implementation of the proximity sensors into the design on hand will be of a challenge. On the research part and after a good consideration, it turns out that a single forward oriented narrow beam would sufficient for the design on hand. Such beam must be given from a sensor that has a narrower beam and must have less noise interferences.

The choice was the MaxSonar EZ2. This sensor offers a good combination between small object detection and narrow beam width. The MaxSonar EZ2 sensors utilize a frequency of 42 kHz and have an effective range from 6 to 254 inches (6.45 meters), which is well suited to the specifications pertaining to distance sensors. The sensors operate between 2.5 and 5.5 volts at a ballpark 2 mA and offer an output choice of analog, serial, and PWM signals. A higher supply voltage yields a slight increase in the range of the sensor. The beam patterns differ between a 3.3V and 5V supply and also the size of the detection field depends upon the size of the object being detected. The MaxSonar EZ2 is a single forward oriented sensor and it would be effective in alerting the quad-copter to obstacles in its path when flying in an autonomous mode. See Figure 30 below:

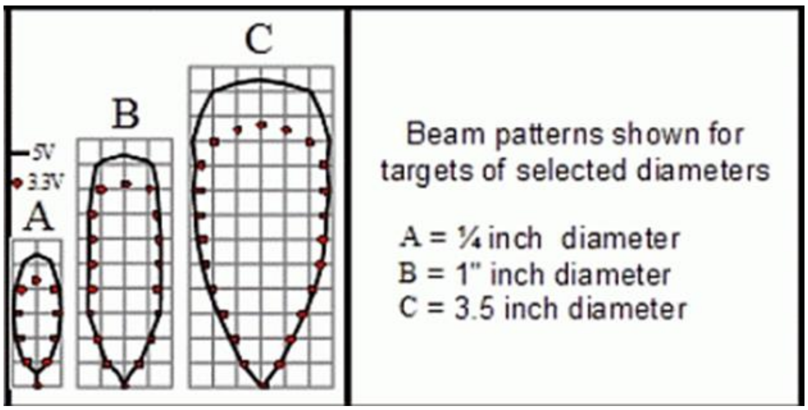
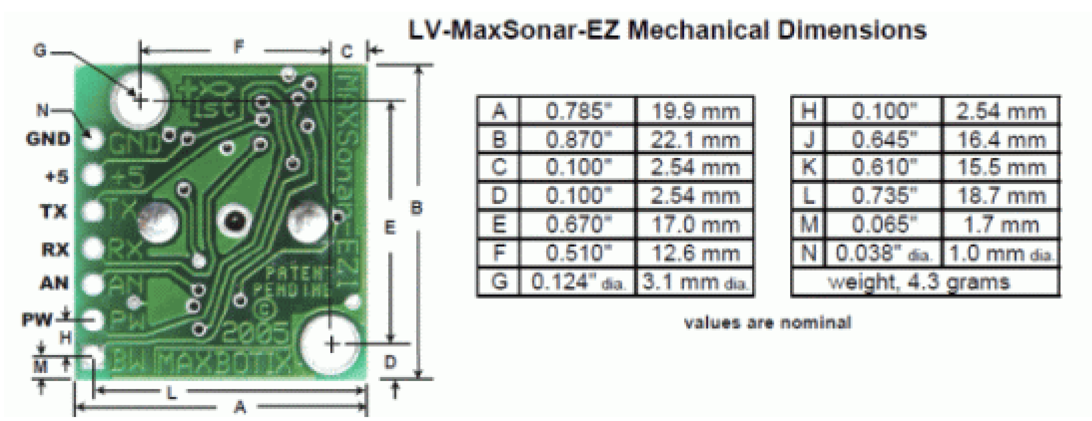


Figure 30: MaxSonar EZ beam pattern diagram. (Pending permission)

The sensor will be placed and mounted in the middle of the quadcopter using the two holes on its base. The sensor will be facing down to the ground. Two screws will be used to make sure the sensor stay connected to the frame of the drone. To eliminate vibrations, a cushion of light weight/soft material might be added. Mechanical dimensions of the EZ sensor are shown in Figure 31 below including the .124" diameter mounting holes [G].



A	0.785"	19.9 mm	H	0.100"	2.54 mm
B	0.870"	22.1 mm	J	0.645"	16.4 mm
C	0.100"	2.54 mm	K	0.610"	15.5 mm
D	0.100"	2.54 mm	L	0.735"	18.7 mm
E	0.670"	17.0 mm	M	0.065"	1.7 mm
F	0.510"	12.6 mm	N	0.038" dia.	1.0 mm dia.
G	0.124" dia.	3.1 mm dia.	weight, 4.3 grams		

Figure 31: Mechanical dimensions of the MaxSonar-EZ Sensor. (Pending permission)

This type of sensors is less resilient to electrical noise when the adjacent electrical components are powered. The developer recommendation is to place a 10 Ω resistor in series with the V+, along with a 100uF capacitor to ground. By connecting this effective filter, it will work against any noise that might affect the functionality of the sensor. This combination is shown in the Figure 32 below:

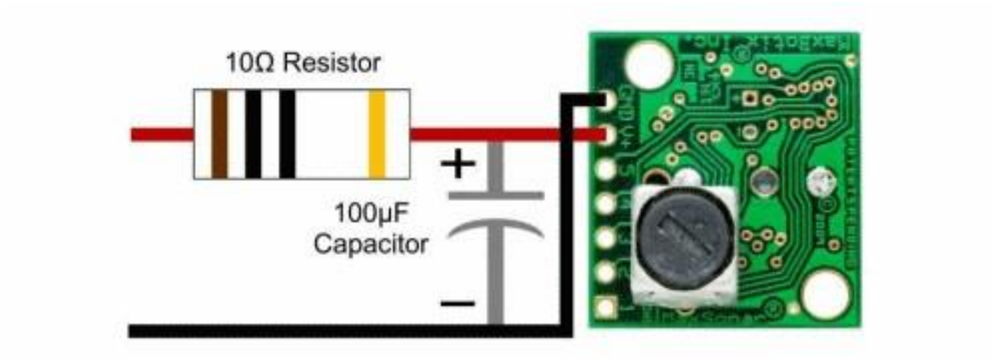


Figure 32: MaxBotix recommended low-pass filter. (Pending permission)

Since an analog operation is desired for the use of the ultrasonic sensor, only three pins will be used. The GND pin is to be connected to the ground. The V+ pin is to be connected to the voltage source through a voltage regulator (The voltage regulator is to convert the voltage from 11.1V to the desired voltage of the sensor which is 5V). The AN pin is to be connected to a 5V ADC on the MCU. According to MaxBotix, the analog voltage is scaled at (Vcc/ 512) / inch which, in the case of a 5V supply yields ~9.8mV/ inch scaling. See Figure 33 below:

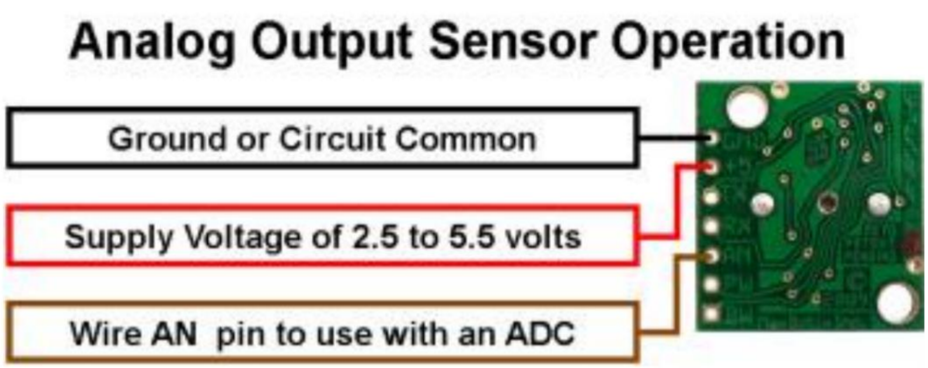


Figure 33: MaxBotix EZ Wiring Diagram

4.2.5.2 IR sensor for collision avoidance

The implementation of the IRCF360 sensor into the design will requires a 5v regulated power supply, which normally can be provided directly from the main controller. The IRCF360 has no reversed connection protection, so it is important to pay attention to the polarity of the power supply; otherwise the IRCF360 microcontroller may be destroyed. To prevent connecting the connector the wrong way, a peg in one of the unused pins will be implemented to cover each pin while working on the others. The following Figure 34 shows how the IRCF360 will be connected to the microcontroller:

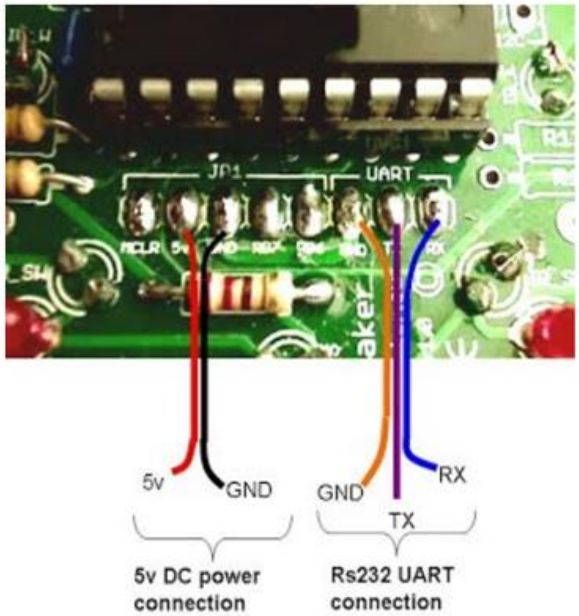


Figure 34: IRCF360 Wiring

The other concern that must be considered is to check that the power supply on the controller is the correct voltage and can supply the necessary current. Also, it is important that the measured voltages and currents from the controller are accurate so connection will not destroy the controller or the IRCF360. The main benefits with this design are that it can be connected directly to the microcontroller UART port or software configured port without any external RS232 levelling translator. This will be of great for the design on hand.

4.2.6 ArduPilot/MSP430 Communication

The MSP430 will be communicating to the APM 2.8 via UART. In this type of communication, there will be connection that works between the APM 2.8 and the MSP430 and have a support for hardware flow control. The UART interface has no master/slave relationship which will assure data exchange between the MSP430 and the APM 2.8. This data exchange will be transferred independently from side to side in full duplex mode. The block circuitry for UART is the peace responsible for implementing serial communication. The UART acts as an intermediary between parallel and serial interfaces. On one end of the UART there is a bus of eight-or-so data lines and also some pins. On the other end there is the two serial wires called RX and TX. Figure 35 shows a simplified UART interface that most of microcontrollers have.

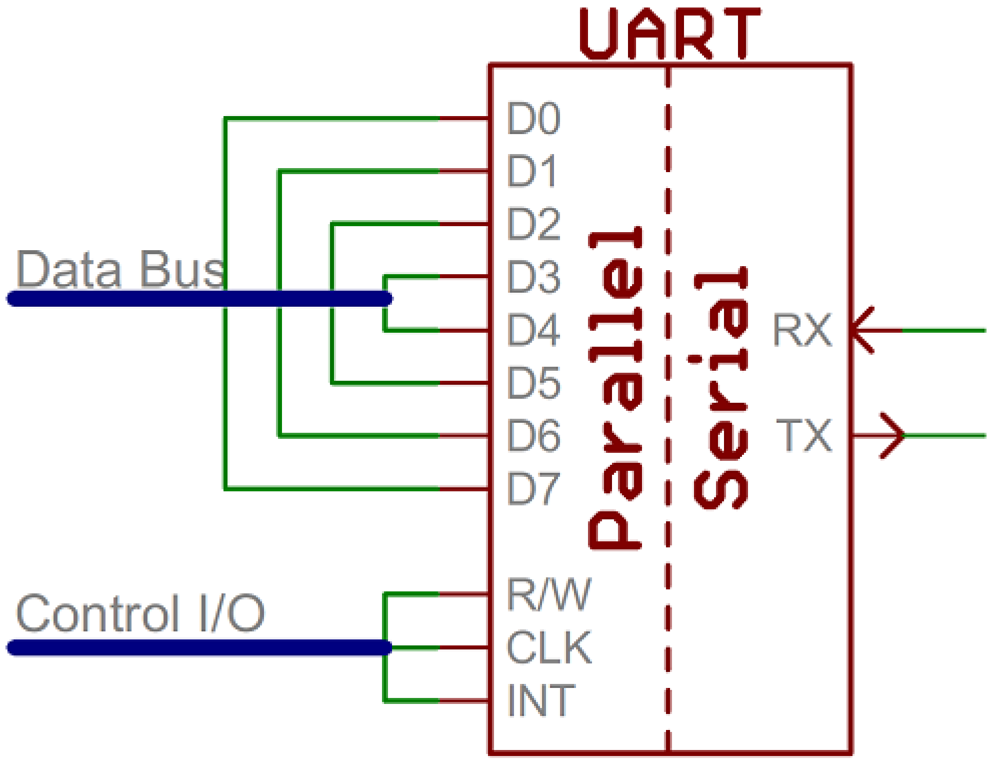


Figure 35: Simplified UART interface. (Pending permission)

Both the MSP430 and the APM 2.8 used in the project are equipped with a UART interfaces. The hardware flow control makes use of two hardware lines, RTS (Request to Send) and CTS (Clear to Send) to allow each side indicate to the other side if is ready to handle data. TX (pin number 40) and RX (pin number 41) of the MSP430F5529 will be connected respectively to RX (pin number 45) and TX (pin number 46) on the APM 2.8. Figure 36 is a schematic that shows how to interface between the MSP430 and APM 2.8 utilizing UART.

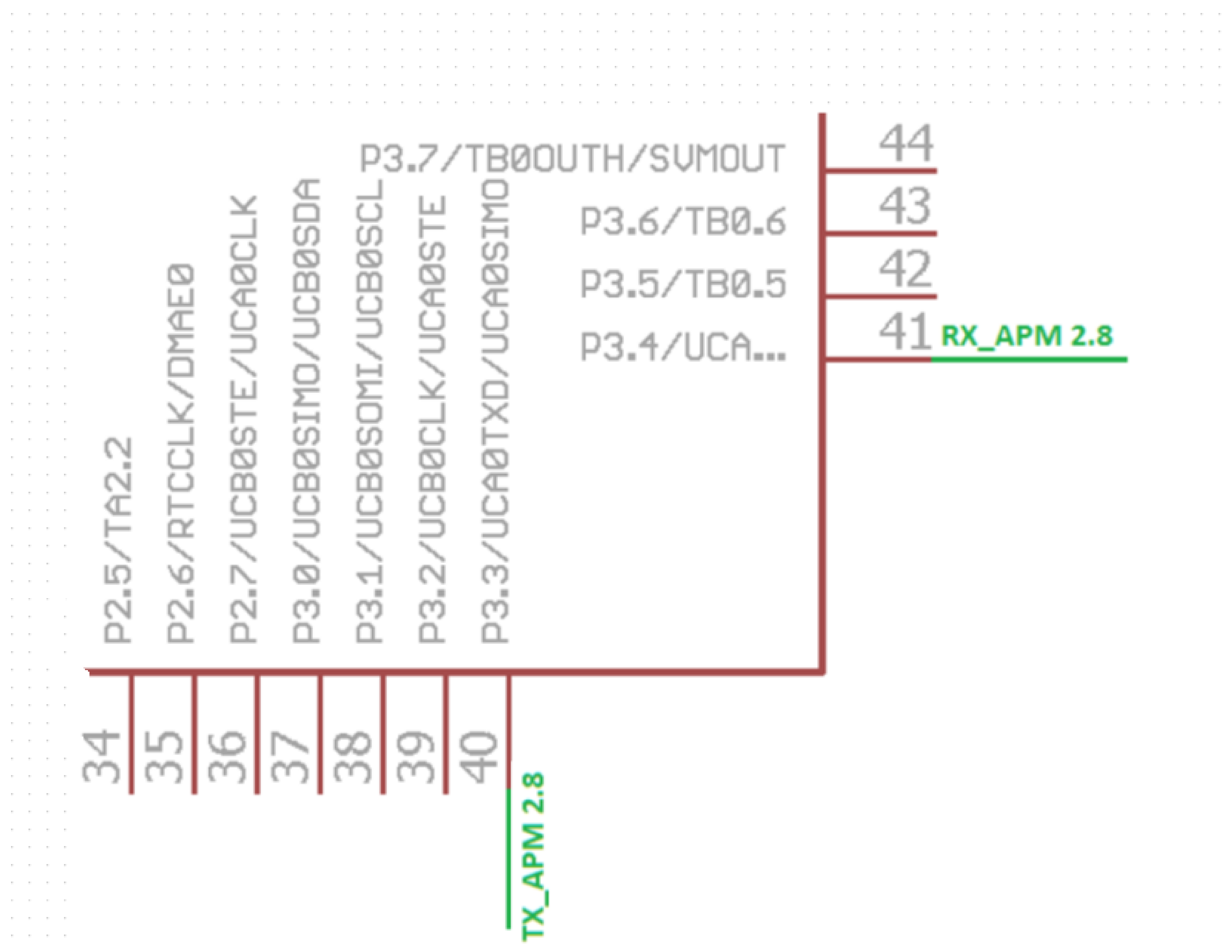


Figure 36: MSP430 interfaced with APM 2.8, Eagle schematic

4.3 Software

4.3.1Flight control

The main goal of the project was not to develop any software for flight controller. Moreover it was for to design and customize microcontroller to work with a flight controller. The autopilot however was a tough decision to make as it is the back bone of any Unmanned Arial Vehicle. To design, simulate, integrate and the actual testing of flight controller for modern UAVs are challenging task. A flight controller is an integrated circuit that is made up of a microprocessor, sensors with input and output pins.

Drone flight controller systems are many and vary from one another. Many of them were GPS enabled autopilot systems with two way telemetry links to basic stabilization system using radio control hardware. Many modern flight controllers have their roots back to R/C helicopters.

Today's flight controller has many sensors built into them-GPS, barometer, and air speed sensors, and so on. The major contributor to flight controller system is the accelerometer with gyros. Accelerometer measures acceleration due to gravity, a high G turn, or stopping force. Gyros measures rate of rotation about an axis.

Multi-rotors are unique in a sense of no human is capable of controlling the rotational speeds of more than three motors simultaneously with precision to balance a craft. This role is well played by a flight controller is needed in quadcopters. A flight controller's function is to direct the RPM of each motors in response to an input. For example, an input is a command from the user of the UAVs to move forward is fed into the flight controller, which knows how to manipulate the motors accordingly. Sensors built into this flight controllers further extends their functionality to supplement their calculations.

With the proper flight controller setup, user's control inputs should correspond exactly to the behavior of the Quadcopter. All flight controllers are configurable, and programmable. This allows users to make adjustments based on varies multi-rotors configurations of their interest. Depending on the choice of flight controller, many software is available to write your own settings. Most flight controllers allows users to choose varies flight modes, selectable using a transmitter switch. A simple example would be, GPS lock mode, a self-leveling mode, and a manual mode.

There are many flight controller available in market for quadcopters. Depending on which platform you using, flight controllers features varies as well as the appetite for customization. For this project our goal was to find a flight controller that has Gyroscopes, Accelerometer, Barometer, Magnetometer, and GPS. Gyroscope is for orientation, barometer is for holding altitudes and GPS will be used for auto-pilot. Many Flight controller have hardware in common but they all have different software and calculation algorithm. This results in different flight characteristics, and user interface. Perhaps this is the reason why same multicomputer flies differently. Tables 14 below, there are some comparison between different flight controllers we made before finalizing the one for this project.

FC Name	Price	RX Modes	Baro/Compass	GPS	MicroController
APM 2.6	$50	PWM, PPM	External	Yes	8-bit, 16MHz
BrainFPV	$130	PWM, PPM, S.Bus, DSM, HoTT	Internal/External	Yes	32-bit, 168MHz
CC3D	$14	PWM, PPM, S.Bus, DSM	No	Limited	32-bit, 72MHz
Crius AIO	$48	PWM, PPM	Internal/External	Yes	8-bit, 16MHz
Flip32	$24	PWM, PPM, S.Bus	No	Limited	32-bit, 72MHz
KK2.1.5	$22	PWM, PPM	No	No	8-bit, 16MHz
Multiwii SE 2.5	$15	PWM, PPM	Internal	Yes	8-bit, 16MHz
Naza M Lite	$170	PWM, PPM, S.Bus	External	Yes	unknown
Naza M V2	$300	PWM, PPM, S.Bus	External	Yes	unknown
Naze32 Acro	$25	PWM, PPM, S.Bus	No	Limited	32-bit, 72MHz
Naze32 Full	$53	PWM, PPM, S.Bus	Yes	Yes	32-bit, 72MHz
Quanton	$66	PWM, PPM, S.Bus, DSM, HoTT	Internal/External	Yes	32-bit, 168MHz
Revo	$130	PWM, PPM, S.Bus, DSM	Internal/External	Yes	32-bit, 168MHz
Sparky	$60	PPM, S.Bus, DSM	Internal	Yes	32-bit, 72MHz
Sparky 2	$35	PPM, SBUS, DSM			32-bit,
SPRacing F3	$65	PPM, SBUS, DSM			32-bit,
Tornado F3	$29	PPM, SBUS, DSM			32-bit,
DoDo F3	$50	PPM, SBUS, DSM			32-bit,

Table 14: Flight Controller Comparison

4.3.1.1 ArduPilot

ArduPilot or APM is an open source autopilot that supports multi-copters, helicopters, and fixed wing aircraft and rovers. It is developed by many large communities of enthusiasts. They always welcome new developers. The name “Ardu” comes from Arduino. The APM1 autopilot system was based around Arduino development environment. Now it has much outgrown the Arduino environment and supports vast variety of development environment.

The ArduPilot source code is written on top of the AP-HAL hardware abstraction layer. This makes it possible to port the code to much range of autopilot hardware boards.

After long research, we finally decided to go with ArduPilot Mega 2.8. ArduPilot Mega is a professional IMU autopilot system that is based on the Arduino Mega platform. APM 2.8 can control multi-rotor helicopters, wing aircraft, and also traditional helicopters. It has full autopilot capacity for autonomous stabilization, way-point based navigation and two way telemetry with Xbee wireless module. This supports 8 RC channels with 4 serial ports. ArduPilot 2.8 consists of the main processor board and the IMU shield. Another advantage of this Flight Controller is that the open source control software is constantly being updated with many new features. This software is updated by team of 30 core developers, and supported by over 10000 community members.

APM has many useful features that will support our project tremendously. It comes with simple setup process and firmware loading via simple click. There is absolutely no programming required. If a person wants to play around the code and modify it, you can with the easiest embedded programming toolkit like Arduino. This project does not need any further programming. It has full mission scripting with simple click desktop utilities. It supports hundreds of 3D waypoints. It has two-way telemetry and in flight command using the MAVLink protocol. ArduPilot Mega gives a choice of Ground Stations, including the state of the art HK GCS. This includes mission panning, in air parameter setting, on- board video display, voice synthesis, and full data logging with replay.

Another useful feature of ArduPilot Mega is Autonomous takeoff, landing and special action commands such as video and camera controls. With Xplane and Flight Gear, this APM supports full “hardware in the loop” simulation. This board comes with 4MB of data logging memory. Missions can be automatically data logged and cam be exported to KML. The built in hardware failsafe processor can return to launch on radio loss or in our project in case of Wi-Fi loss. As mentioned earlier, with many useful featured and supported functionality of this Autopilot, APM 2.8 makes the best Autopilot for this project.

APM Hardware

The figure 37 below shows the APM hardware. This physical board contains the sensors and processor. The board inside can be thought as the small PC that runs the autopilot software.

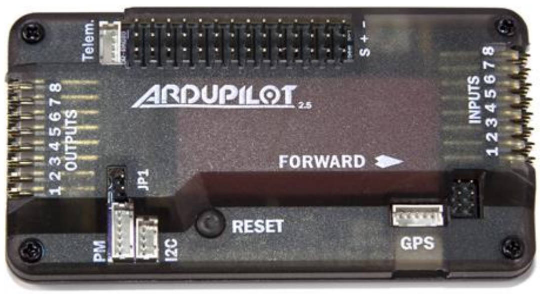


Figure 37: Picture of Ardupilot 2.8 (Mega) (Permission Pending)

APM Firmware

The firmware can be described as the code that runs on the board. There are plenty of firmware base that user can choose from. Depending on what code you want to load, you can use the APM to control multi rotors, aircraft, helicopters and the ground rovers. The figure 38 shows all the firmware available for APM 2.8. First step is to install a missional planner to the PC. After the installation of the mission planner, connect the APM 2.8 board to PC using the micro USB cable.

Windows should detect the hardware automatically and install the correct driver software. After this, open the mission planner and select the COM port drop down. Select AUTO for the board and set the Baud rate to be 115200. Now on the mission planner initial setup, click on the Install Firmware button on the left side of the screen. After the mission planner detects the board you using, press OK button. Dragon Bee is a quad copter so multi-rotor firmware is chosen. If all goes well then the firmware will be uploaded and it will display the message on the screen.

Figure 38: APM Firmware

APM Mandatory Hardware Configuration

After the initial setup it is required to configure some hardware components before the first flight mission. This process includes selecting firmware orientation, configuring RC transmitter/receiver, compass, and accelerometer using the mission planner. Addition to this mandatory calibration process, we choose to configure optional Hardware including battery monitor, proximity and IR sensors, and camera gimbal and antenna tracker.

The first configuration to choose from was the Frame Type. Dragon bee will be X configuration. This is also a default configuration in the firmware. Frame Configuration is shown in figure 39 below.

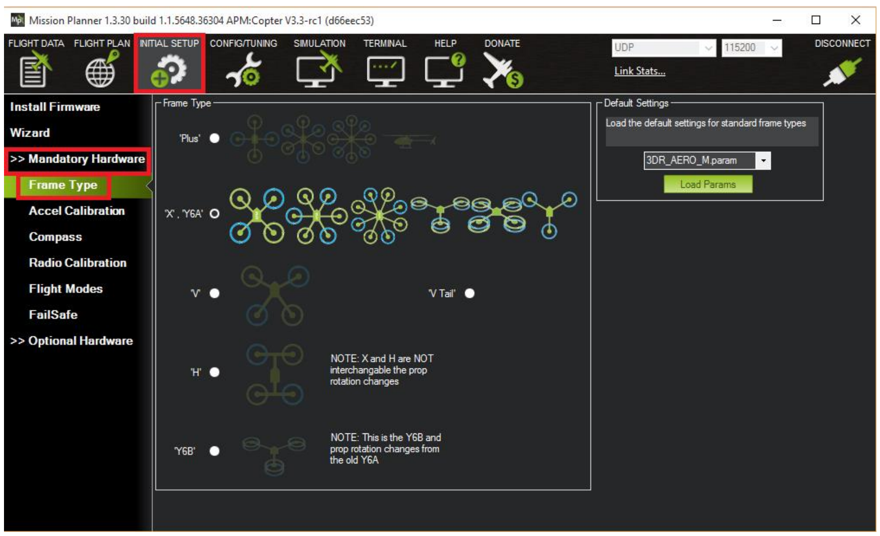


Figure 39: Frame Type (Permission Pending)

Second calibration to set is for the Compass. It is important to first set the correct orientation for the setup. Next step is to insure the enable and AutoDec boxes are checked. Live calibration is must as it will ask you to move the board on all direction 360 degree for few times to set the correct orientation. If correct orientation is not set in this calibration than user will not correctly be able to fly the drone. Under the autopilot configuration window, select APM with onboard compass because ArduPilot 2.8 comes with built in compass. These choices will automatically enter the correct orientation for the Ardupilot. User must make sure to mount the GPS with compass with the arrow facing towards the front of the vehicle and in the same direction as the arrow on the autopilot. The figure 40 shows the compass calibration.

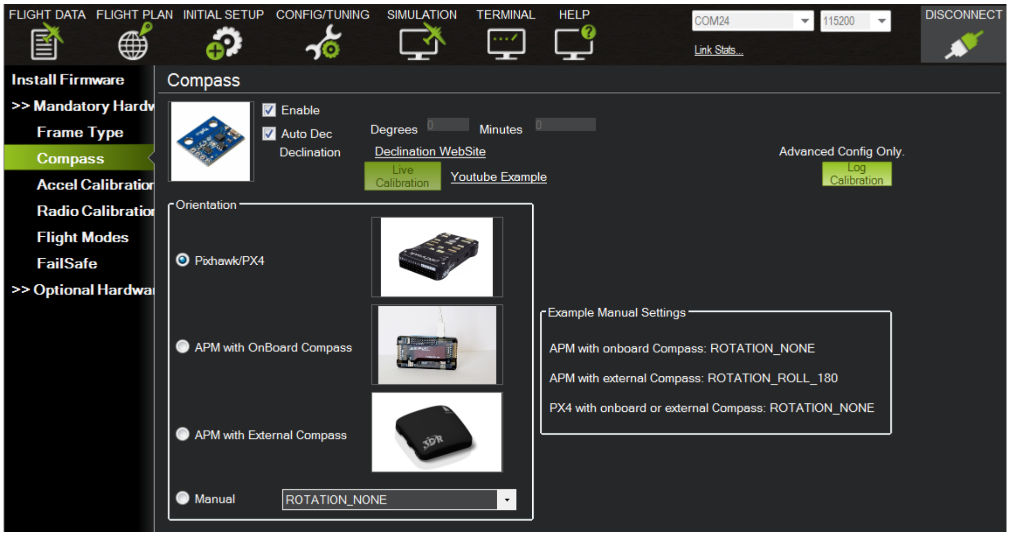


Figure 40: Compass Calibration (Permission Pending)

This project is using Wi-Fi as the controlling tool for the quadcopter. So the radio calibration is not needed. Instead of radio, Wi-Fi calibration will be used after setting Wi-Fi module on the msp430 board. This calibration will be calibrated later in the project. This is one of the most important steps because this is the actual controlling of the drone. In order to fly the drone, we have to calibrate using the Wi-Fi. This calibration requires the android app to be built so Wi-Fi can be used instead of radio signal. The figure 41 shows the radio calibration.

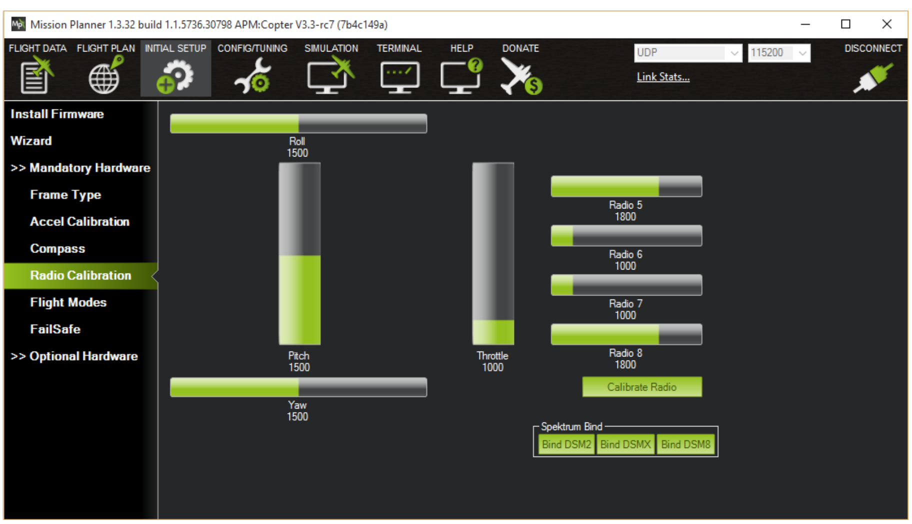


Figure 41: Radio Calibration (Permission Pending)

Another most important calibration to set is for Accelerometer. Under the Accel Calibration tab, click the calibrate Accel to begin the 3-axis accel calibration. The calibration positions are level, left side, right side, nose down, nose up, and on its back.

This is done using the key on the keyboard. The figure 42 shows the accelerometer orientation calibration.

Figure 42: Accelerometer Calibration Positions (copter) (Permission Pending)

The mapping between flight mode and switch position is set under the Mission Planner Flight mode. The flight mode channel is the input radio channel the board monitors for mode change. For the dragon bee it will always be channel 5. The quadcopter firmware has 15 flight modes, 10 of them are regularly used. This modes supports different types of flight stabilization, a sophisticated autopilot and most importantly a follow me mode. Originally, the flight modes are controlled through the radio transmitter, or using the mission commands. For the goal of this project this task will be done via Wi-Fi transmission. Those 15 flight modes are;

- **Stabilize:** Stabilize mode allows you to fly your vehicle manually, but self-levels the roll and pitch axis.
- **ALT Hold:** Copter maintains a consistent altitude while allowing roll, pitch, and yaw to be controlled normally.
- **Loiter:** Loiter Mode automatically attempts to maintain the current location, heading and altitude.
- **RTL:** RTL mode (Return To Launch mode) navigates Copter from its current position to hover above the home position.
- **Auto:** the copter will follow a pre-programmed mission script stored in the autopilot which is made up of navigation commands (i.e. waypoints) and “do” commands.
- **Acro:** uses the RC sticks to control the angular velocity of the copter. Release the sticks and the vehicle will maintain its current attitude and will not return to level.
- **Sport:** Sport Mode is also known as “rate controlled stabilize” plus Altitude Hold.
- **Drift:** provides tips for flying in Drift Mode and methods for tuning your copter to fly optimally in Drift Mode.
- **Guided:** Guided mode is a capability of Copter to dynamically guide the copter to a target location wirelessly using a telemetry radio module and ground station application.
- **Circle:** Circle will orbit a point of interest with the nose of the vehicle pointed towards the center.
- **PosHold:** similar to Loiter in that the vehicle maintains a constant location, heading, and altitude but is generally more popular because the pilot stick inputs directly control the vehicle’s lean angle providing a more “natural” feel.
- **Land:** LAND Mode attempts to bring the copter straight down

- **Brake:** simple flight mode simply stops the vehicle as soon as possible using the loiter controller
- **Follow Me:** Follow Me mode makes it possible for you to have your copter follow you as you move
- **Simple and super simple:** “Simple” and “Super Simple” modes allow the pilot to control the movement of the copter from the pilot’s point of view regardless of which way the copter is facing.

Dragon bee will use many of these modes including Stabilize, Auto, Follow Me, Circle and RTL. Flight modes requiring GPS must also require an active GPS lock prior to take off. Loiter, RTL, Auto, Guided, Drift, PosHold, Follow Me, and circle mode requires GPS lock before takeoff. The goal is to support 6 modes if the time permits. To do this, the transmitter will need to emit PWM widths of around 1165, 1295, 1425, 1555, 1685, and 1815 milliseconds. There is still some research left to do on how to actually configure transmitters from Wi-Fi. The flight mode figure 43 helps choose the mode accordingly.

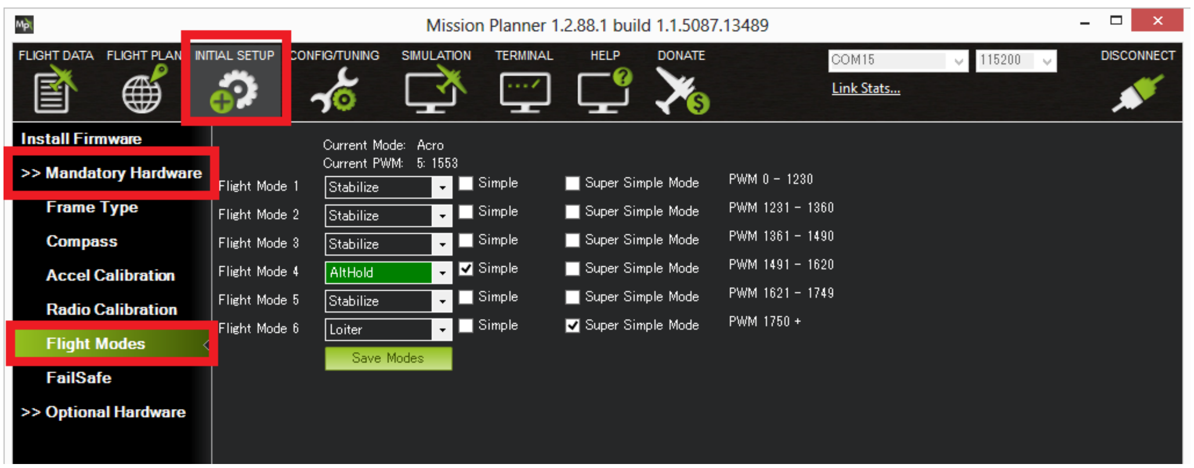


Figure 43: Flight Mode In mission planner (Permission Pending)

The last calibration that must be done before the first flight is the electronic speed controller. It is responsible for spinning the motors at the speed requested by the autopilot. So ESC needs to be calibrated so that it knows the minimum and maximum pwm values that the flight controller will send. For this project, ESC will be Wi-Fi transmission done through the android app. The command will be sent to the msp430 will then transfers the command to the flight controller.

APM software runs on the pc and it is used to load firmware, and change the settings on APM board. This software is very useful tool to plan mission and monitor the drone on the map. It is very powerful ground control software that easily plan any mission you want from the ground enabling the user to track the UAV in real time. Use can also change the mission while UAV is in the air. The figure 44 shows how GUI of APM software.

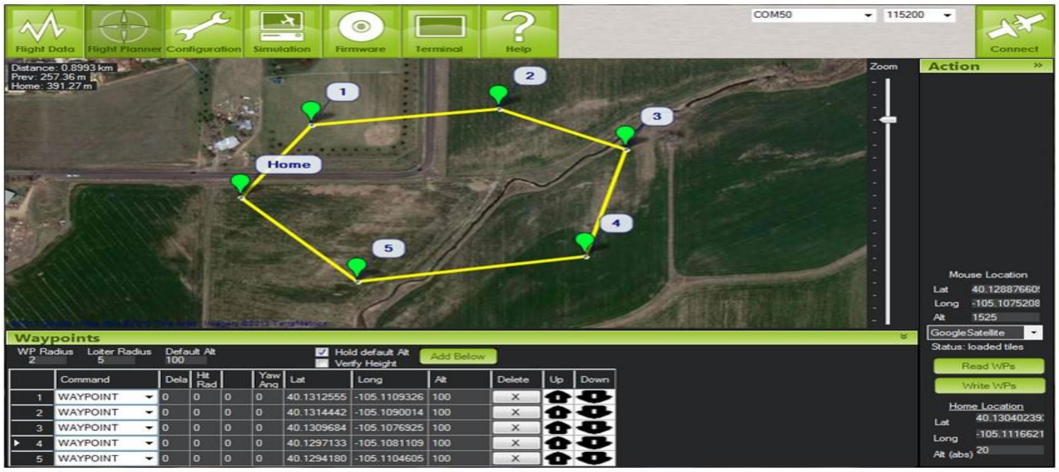


Figure 44: APM Software(Permission Pending)

4.3.2 Microcontroller design software

Microcontroller (aka System on a Chip) is small a self-contained system computer on an integrated circuit that usually comes with processor, memory, and input/output peripherals, and most usage is for low power consumption systems. Typically microcontroller programs must fit on the available on-chip memory. Dragon Bee will be carrying two microcontrollers an Ardupilot and a custom designed MCU with MSP430 as processor core.

Ardupilot comes with a firmware that supports quadcopters. It is an autopilot that provides autonomous stabilization, way-point based navigation and bi-directional. Ardupilot requires no coding except installing ready firmware through Mega Mission Planner software.

The custom designed microcontroller MSP430 processor core based is responsible for communications between the user and autopilot. All functions and command will be processed in the MSP430 core then pushed to Ardupilot during a mission. Implementing these functions in such a low power microcontrollers, compilers and assemblers convert human-read code such as high-level language and assembler language to machine code that can be stored into microcontroller memory.

Originally, assembly language were the only way to program a microcontroller, but nowadays, many high-level programming languages support MCUs. These languages can be written either through an integrated development environment (IDE) designed particularly for the purpose or through a general purpose integrated development environment (IDE) such as C programming language. This latter will put some restrictions on the compiler to support microcontrollers requirements. For the simplicity of the project and time constraints, team members decided to focus IDEs that are designed for microcontroller. Some of the popular IDEs that support MSP430 are listed below:

- Eclipse
- Energia
- IAR Embedded Workbench

- TI Code Composer Studio
- Open Source GCC for MSP

After a significant time of searching for IDEs, TI Code Composer Studio is selected as the appropriate integrated development environment for this project since it is the official tool for developing stable and efficient programs for this project and it runs on MSP430 chips.

4.3.2.1 TI Code Composer Studio 6.1.1

Code Composer Studio (CCS) version 6.1.1 is a complete and free, Eclipse-based integrated development environment (IDE) that supports all Texas Instrument MSP microcontroller devices. It comes with a free license that supports a 16KB code size limit for the optimized TI compiler on MSP430 which will help take into the account the code size while coding to not exceed the amount allowed to be installed on MSP430 MCUs.

Code Composer Studio consists of a series of embedded software utilities for developing and debugging embedded applications. It includes a lot of advanced features such as an enhanced C/C++ compiler, friendly source code editor, real time debugger and many other features.

From Getting started window, Code Composer offers a handy and unique set of add-ons and utilities to take full advantage of MSP microcontroller and the following are the main addon-ons

- MSPWare is a set of tutorials, user's guides, code examples, and many other resources for all MSP products. It can be navigated through the TI Resource Explorer window in Code Composer Studio. It has a lot of feature such as collection of MSP design resources, sleek & intuitive GUI for browsing content, automatic filtering of content using a unique 2-pane view, auto-updates through the web and features the MSP Driver Library.
- Optimizer Assistant helps obtain the best possible performance while staying within code size constraints.
- EnergyTrace Technology is a useful add-on that helps trace energy consumption of a program in real-time.
- ULP (Ultra-Low Power) Advisor helps inspect a code against a thorough ULP checklist to clean the code from any non-relevant lines that can be a waste of power.
- Hardware Debugging helps track functionality of each part in TI embedded processors from general purpose registers to stack pointers and other registers. The figure 6 below shows the available debugging options

4.3.3 MCU Application

4.3.3.1 TI-RTOS

The advanced technology of microcontroller allows the multiple programs to execute at the same time to not be only features of general purpose computers but also microcontrollers. Implementing an advanced scheduler algorithm for real time tasks, many chip companies were able to come up with a real time operating system which allows developer to take advantage of multitasking programs in embedded systems without missing any real time requirements.

Texas Instrument has also adopted the idea of real time operating system, and has come up with TI-RTOS. This latter is a scalable real-time operating system for TI devices, including MSP430 series and it is available as free license. TI-RTOS helps accelerate the development without need to start a basic system software functions from scratch. The figure 45 below shows the configuration tools interface.

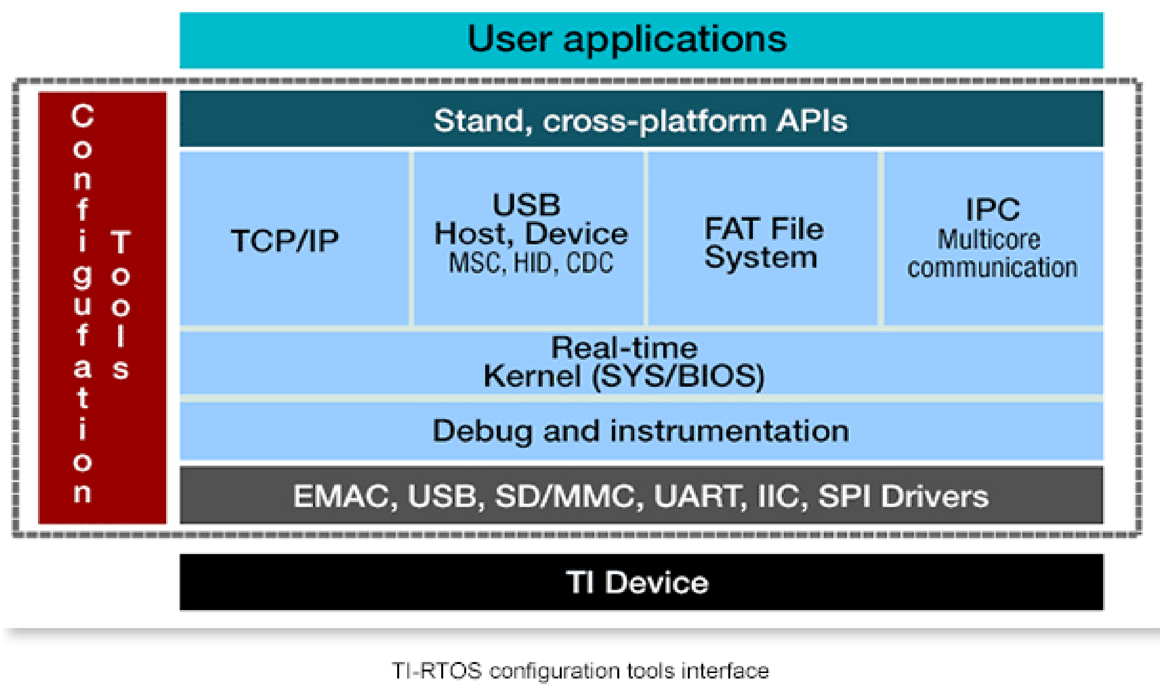


Figure 45: TI-RTOS Configuration (request pending)

It is built from a sophisticated kernel called TI-RTOS Kernel (formerly known as SYS/BIOS) and the table 15 below provides TI-RTOS Kernel services overview.

Kernel Service	**Description**
Cache	Cache configuration and management
Clock	Time-triggered functions
Diags	User-configurable tracing including asserts for parameter and state checking
Error	Define, raise, and check error-handlers
Event	Wait on any combination of multiple RTOS or custom events
GateMutex	Binary mutex with priority inheritance
HeapBuf	Fast, deterministic fixed-size buffer pools
HeapMem	Variable-sized dynamic heaps
HeapMultiBuf	Variable-sized, deterministic dynamic heaps based on multiple buffer pools
Hardware Interrupts (HWI)	Interface from hardware interrupts to the RTOS
Log	Low-overhead logging and print statements
Mailbox	Synchronized data exchange between tasks
Memory	Memory allocation interface
Semaphores	Counting semaphores
Software Interrupts (SWI)	Lightweight preemptible threads that use the program stack but cannot yield
System	General system functions such as abort, exit, and system printf
Task	Independent threads of execution that can yield the processor
Timer	Interface to hardware timers
Timestamp	32- and 64-bit timestamping services

Table 15: TI-RTOS Kernel services (permission request pending)

TI-RTOS kernel maintains between multiple software components which makes TI-RTOS carry existing proven software components to ensure reliability and quality. TI-RTOS offers the components described in table 16.

TI-RTOS Module	**Description**
TI-RTOS Kernel	TI-RTOS Kernel (formerly known as SYS/BIOS) provides deterministic preemptive multithreading and synchronization services, memory management, and interrupt handling.
TI-RTOS Device Drivers and Board Initialization	TI-RTOS Drivers and Board Initialization provides a set of device driver APIs, such as Ethernet, UART and I2C, that are standard across all devices, as well as initialization code for all supported boards. All driver and board initialization APIs are built on the TivaWare, MWare, CCWare, or MSPWare libraries.
TI-RTOS Networking	TI-RTOS Networking (formerly known as the NDK) provides an IPv4 and IPv6-compliant TCP/IP stack along with associated network applications such as DNS, HTTP, and DHCP.
TI-RTOS SSL	TI-RTOS SSL provides TLS/SSL and DTLS along with an extensive cipher library including support for on-chip cryptographic accelerators. It is based on wolfSSL. This product requires a fee (see above). An evaluation version (GPL license) is available here.
TI-RTOS Wireless Connectivity	TI-RTOS is fully integrated with the wireless connectivity stacks provided with the SimpleLink™ Wireless MCU families, including Wi-Fi, Bluetooth Smart (Bluetooth Low Energy), and ZigBee®.
TI-RTOS File System	TI-RTOS File System is a FAT-compatible file system based on the open source Fatfs product.
TI-RTOS USB	TI-RTOS USB provides both USB Host and Device stacks, as well as MSC, CDC, and HID class drivers.
TI-RTOS Power Manager	The TI-RTOS Power Manager provides pre-implemented, ultra-low power modes and can automatically determine the optimal low-power mode when the CPU becomes idle. TI-RTOS drivers are power-aware and communicate with the Power Manager to ensure peripherals are powered-down when not in use. See our Power Management whitepaper for more details.
TI-RTOS Instrumentation	TI-RTOS Instrumentation allows developers to include debug instrumentation in their application that enables run-time behavior, including context-switching, to be displayed by system-level analysis tools.

Table 16: Software Components of RTOS (Permission request pending)

Installing TI-RTOS in MSP430 will accelerate coding the main functionalities of Dragon Bee without worrying about TCP/IP algorithms and wireless module driver.

4.3.3.2 UML Diagrams and Flowchart

Dragon Bee quad-copter project consists of four main parts that require communication Android smart phone, Wi-Fi built in camera, MSP430 MCU and Flight control “Ardupilot”. Wi-Fi built in camera and Ardupilot are included with its own software platforms.

MSP430 MCU application and Android app will be designed to communicate with both camera and Ardupilot. Flowcharts below demonstrate the functionality of each component.

The android app will initiate two TCP/IP connections. First one will be used for unit control and shown in figure 46, and the second one will be used for video streaming as seen in the figure 47.

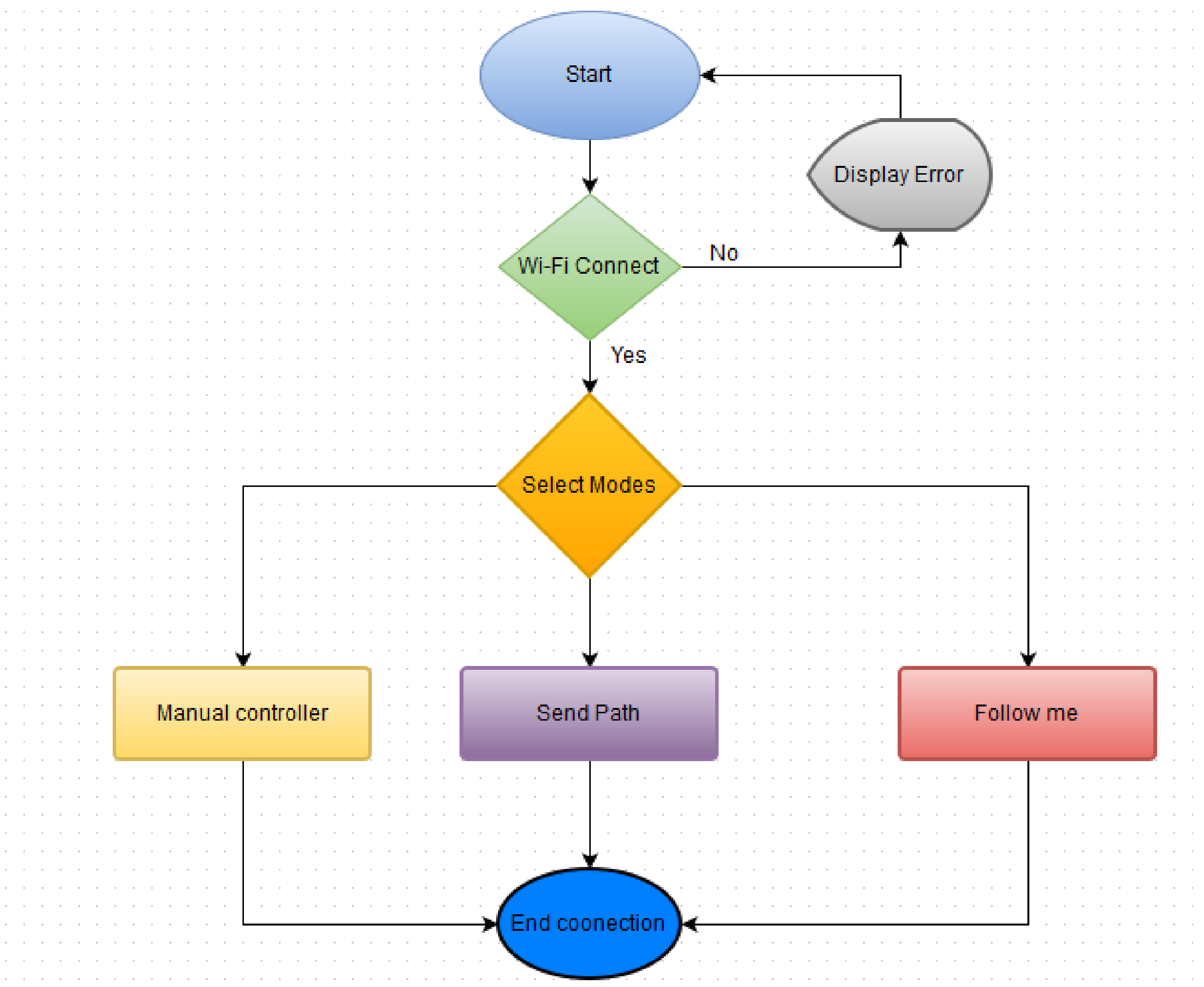


Figure 46: Modes selection

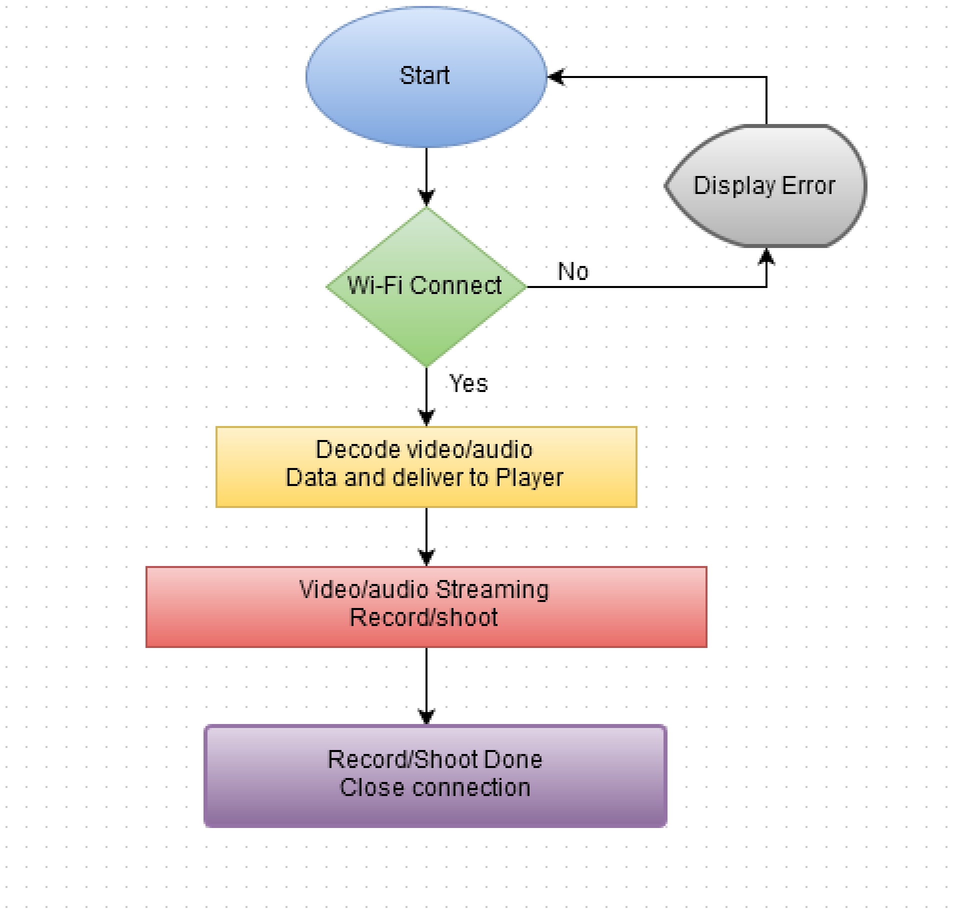


Figure 47: Video stream receiver

The figure 48 flowchart demonstrates the video stream sender from the Wi-Fi built in camera.

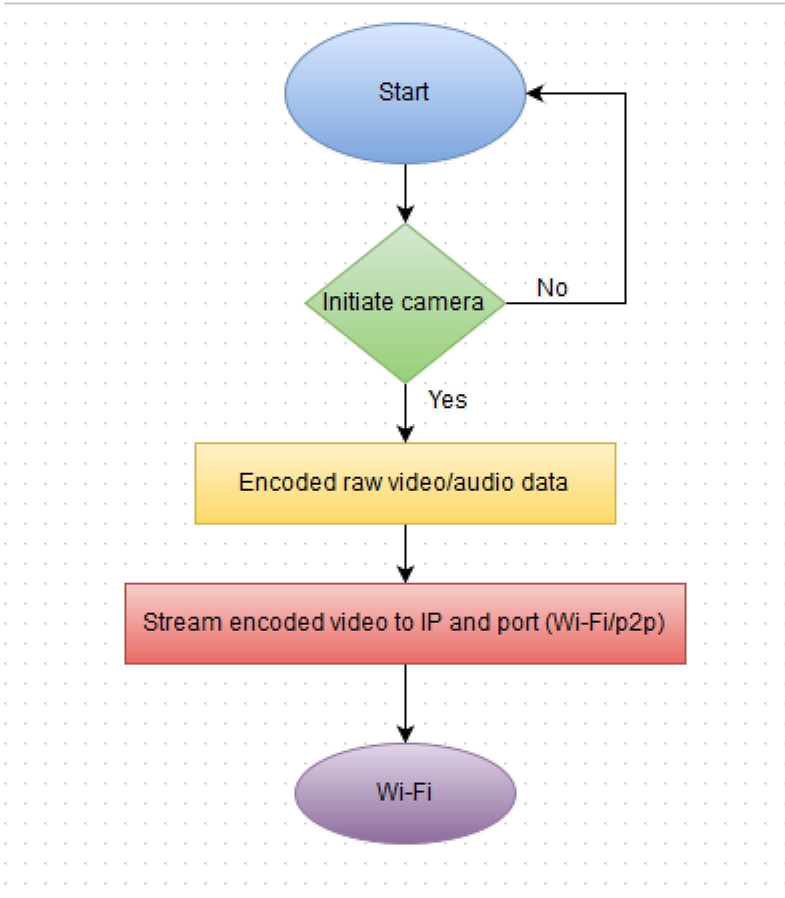


Figure 48: Video sender flow diagram

The figure 49 is the use case diagram for an android app. This diagram is considered while constructing the application.

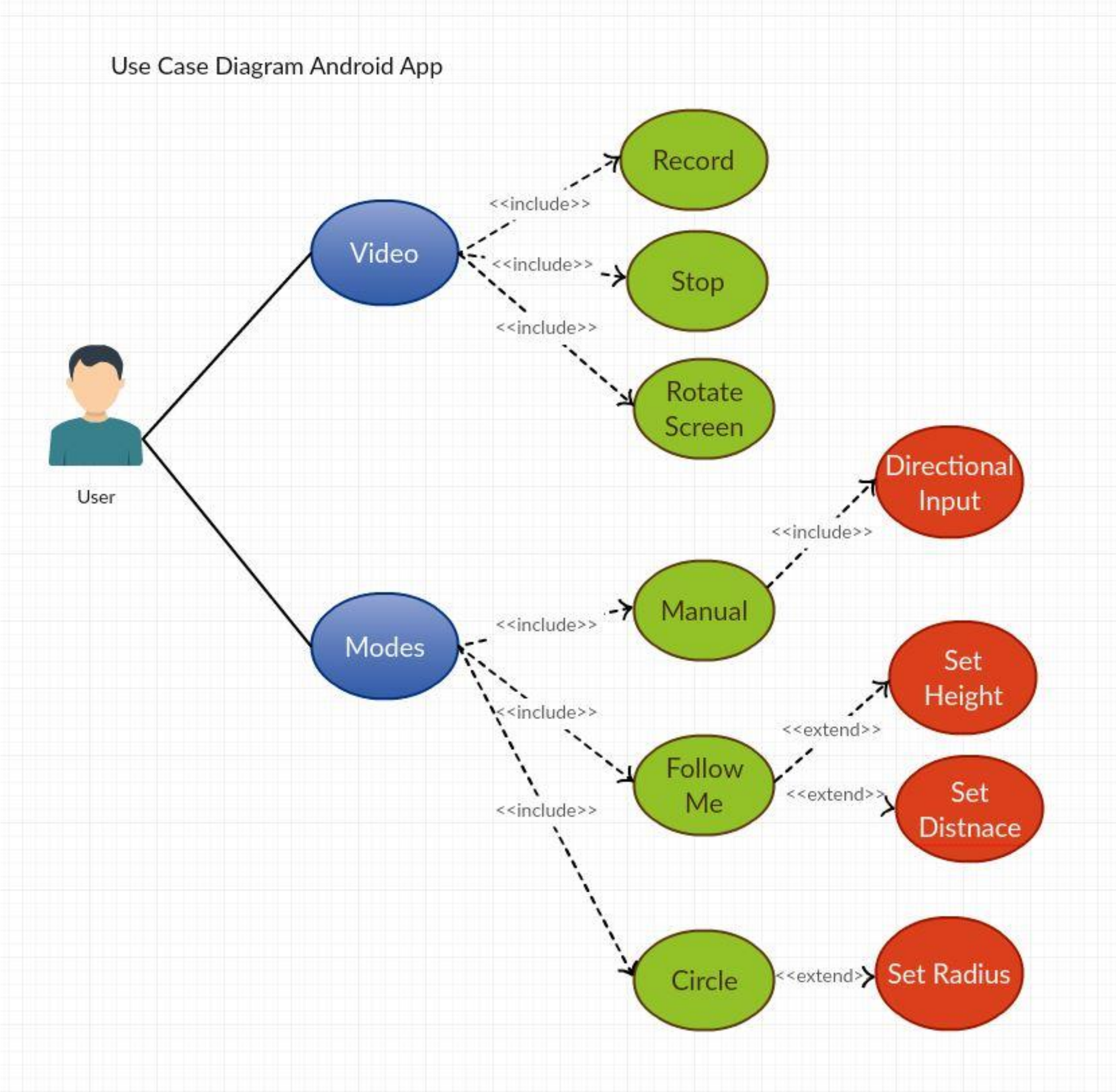


Figure 49: Use Case Diagram

Class Diagram

Class Diagram in the figure 50 below is a form of the main classes and objects that will implemented for this project. Each of the components of the diagrams including its relation to other classes and objects will be explained briefly.

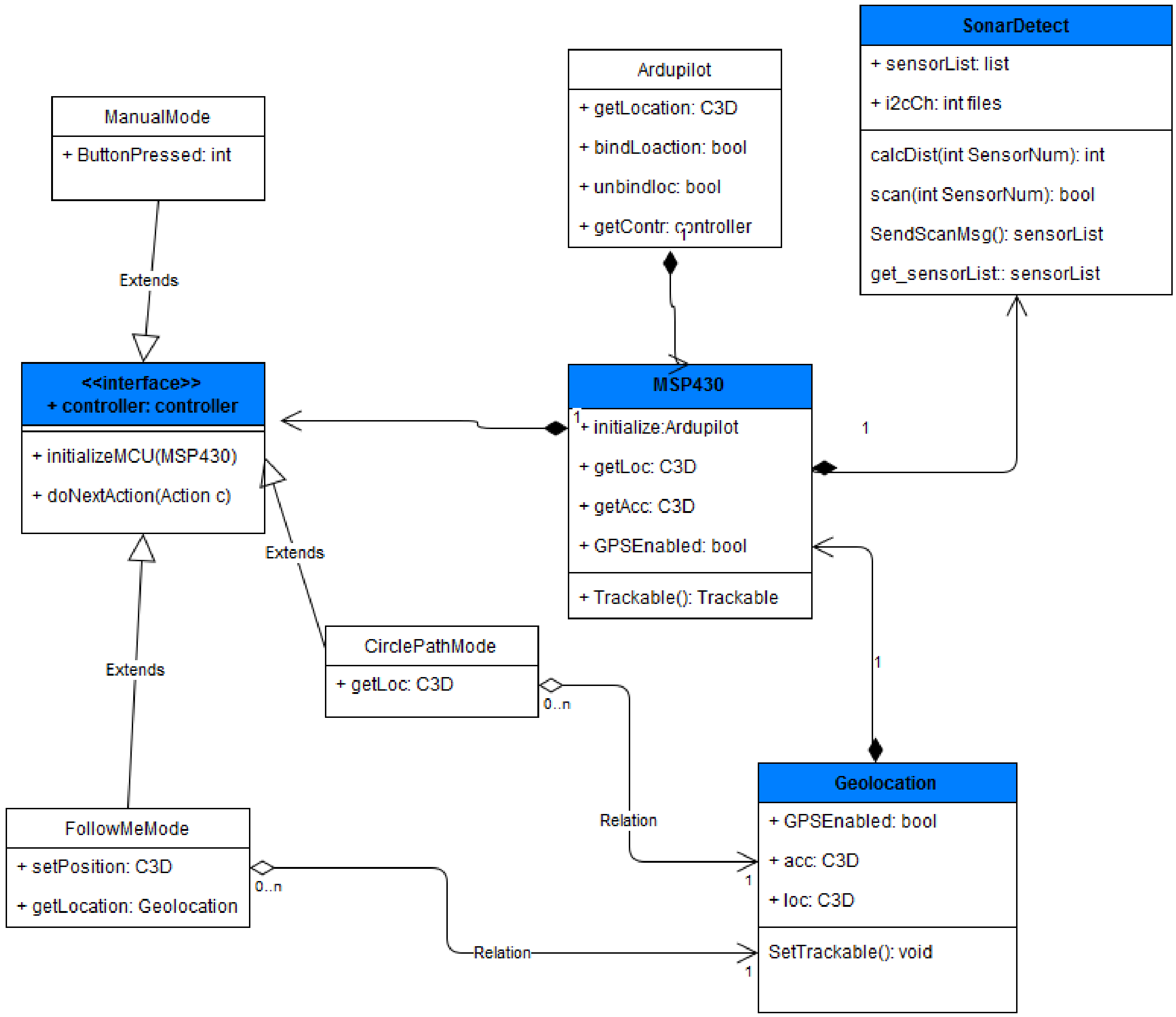
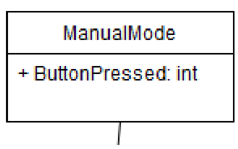


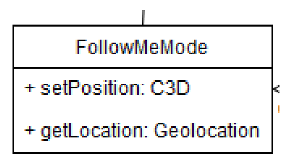
Figure 50: Class diagram for MSP430

The following figures are the main class diagram components broken down into parts with brief description.

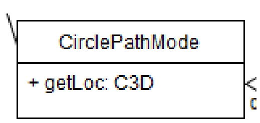
- Manual mode will rely on button press only through user interface. No Geo-location will be involved. See figure 51 a).
- Also, FollowMeMode will be done through user interface. It will be getting continuously Location info from handheld device location services. See figure 51 b).
- The third mode will get handheld device location info for once. And it'll be set as circle center. See figure 51 c).
- Controller is the main interface for all classes that are related to control techniques for applying Strategy Design Pattern intention. See figure 51 d).
- From the an Android SDK, Geo-location API will be implemented to continuously update GPS location info. See figure 51 e).
- This is the main class that will running on the MSP430 core. Acts as the backbone of this project design. See figure 51 f).
- Ardupilot class is a prototype class that explains transactions that go through MSP430 coming from other classes. See figure 51 g).
- Sonar detector will spark an interrupt each time detects something approached its way. See figure 51 h).



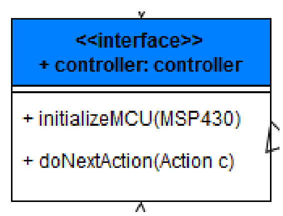
a) ManualMode Class



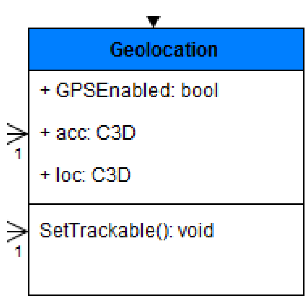
b) FollowMeMode Class



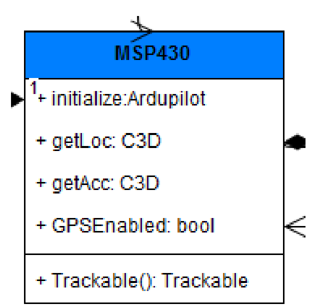
c) CirclePath Class



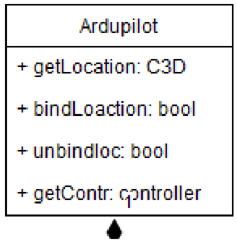
d) Controller interface class



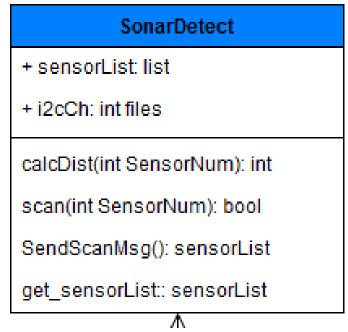
e) Geolocation Class



f) MSP430 Main Class



g) ArduPilot class prototype



h) SonarDetect Object Class

Figure 51: Class Diagram Elements

Finally, the other TCP/IP connection will be independently running between the Wi-Fi built in camera and an independent class for streaming frames received from the camera class. The following class diagram figure 52 demonstrates the frame streaming.

Figure 52: Class Diagram of the camera streams.

State diagrams

Two state diagrams will be required for this project; first one is for streaming states and the second one is for control states. Both state diagrams report in flying state as seen in the figure 53 and 54.

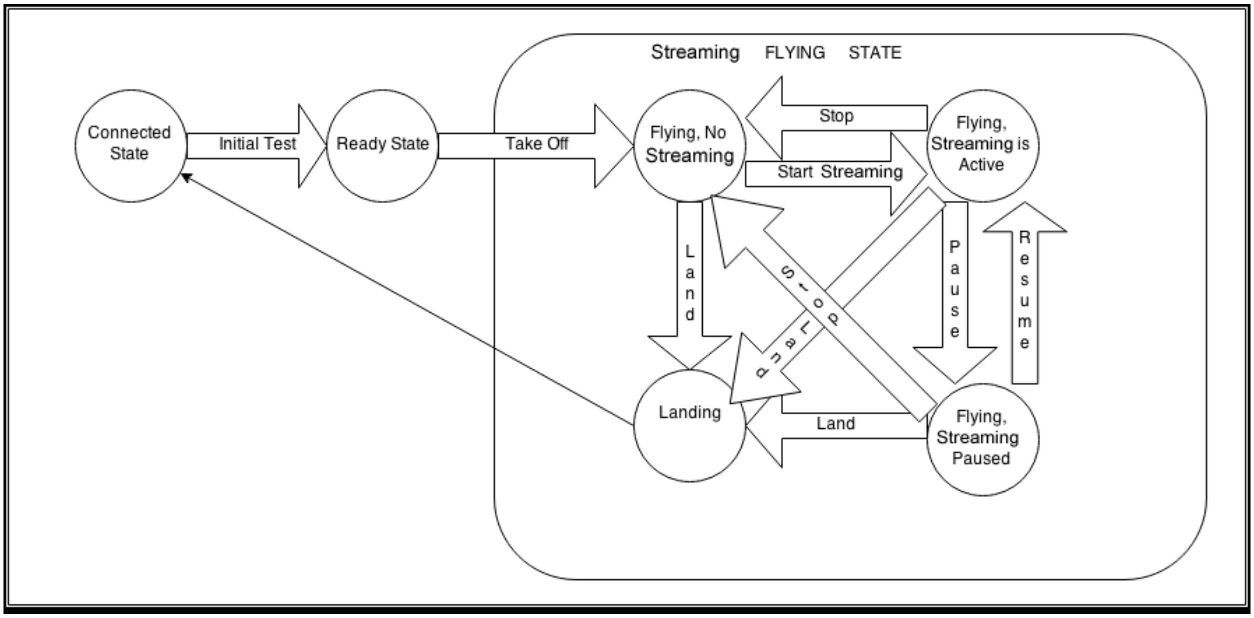


Figure 53: State transition diagram for streaming

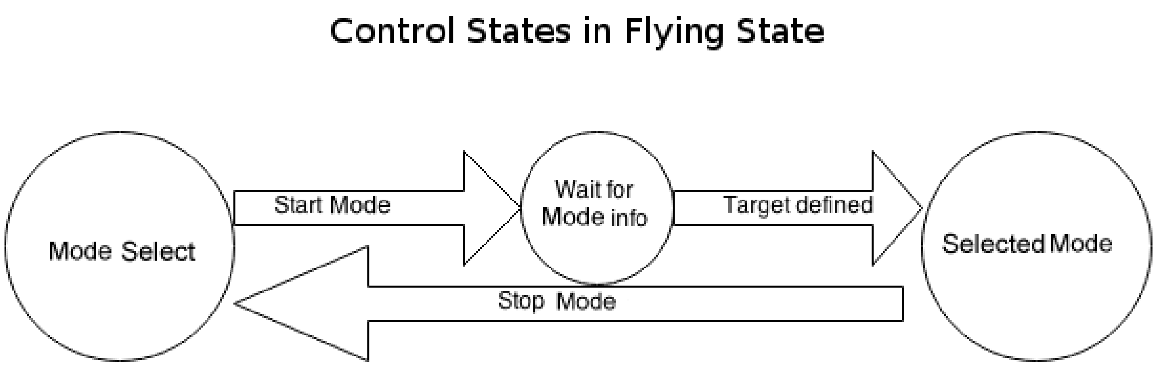


Figure 54: State Diagrams for Control

5. Final Production

In the Final production topic like assembly of whole structure and the final layout of how android app will look like will be talked. Therefore, just like research and design, final production could be divided in to two categories: Hardware and Software.

Basically in the hardware part, the assembly of the frame itself, mounting of the parts, and extra information of wiring will be covered. On the other hand, software side will include how the drone control app is designed in the smart phone will be covered. Additionally, how the software and programming is done will be comprised in the final production sections.

Following in figure 55 shows how overall “dragon Bee” drone will look like after the final production.

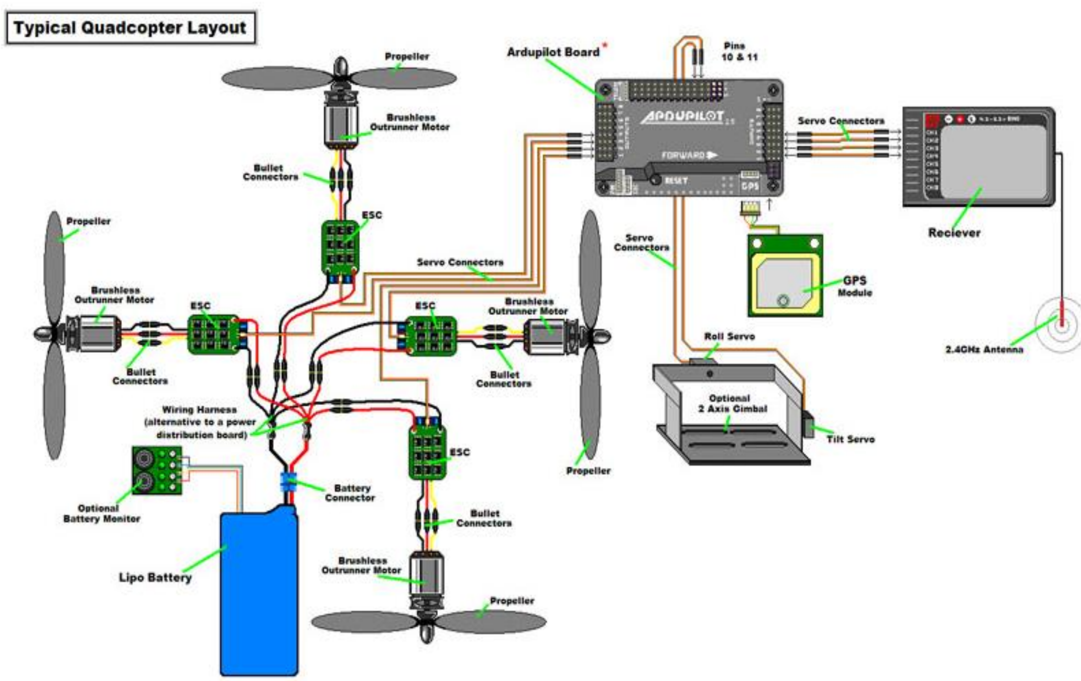


Figure 55: Overall layout of “Dragon Bee” drone

5.1 Printed Circuit Board

Printed circuit boards (PCBs) are the backbone of every electronic device out there. These boards are essential to making all components in a circuit connect together just right. With PCB’s, it is possible to get rid of all the wires and bulky look of a certain electric design. This type of boards must have, interconnection with other circuits, placement, and the approximate final dimensions. The circuit schematic is drawn based on the concept of the project. In the case of the project on hand, the concept will be to short size all the components used. The electrical implementation of each function of the PCB will be taken into consideration. With the schematic drawn, a realistic drawing of the final PCB dimensions will be completed with areas designated for each of the circuit's schematic. Figure 56 shows the steps that will be taken to create the PCB board for the project on hand.

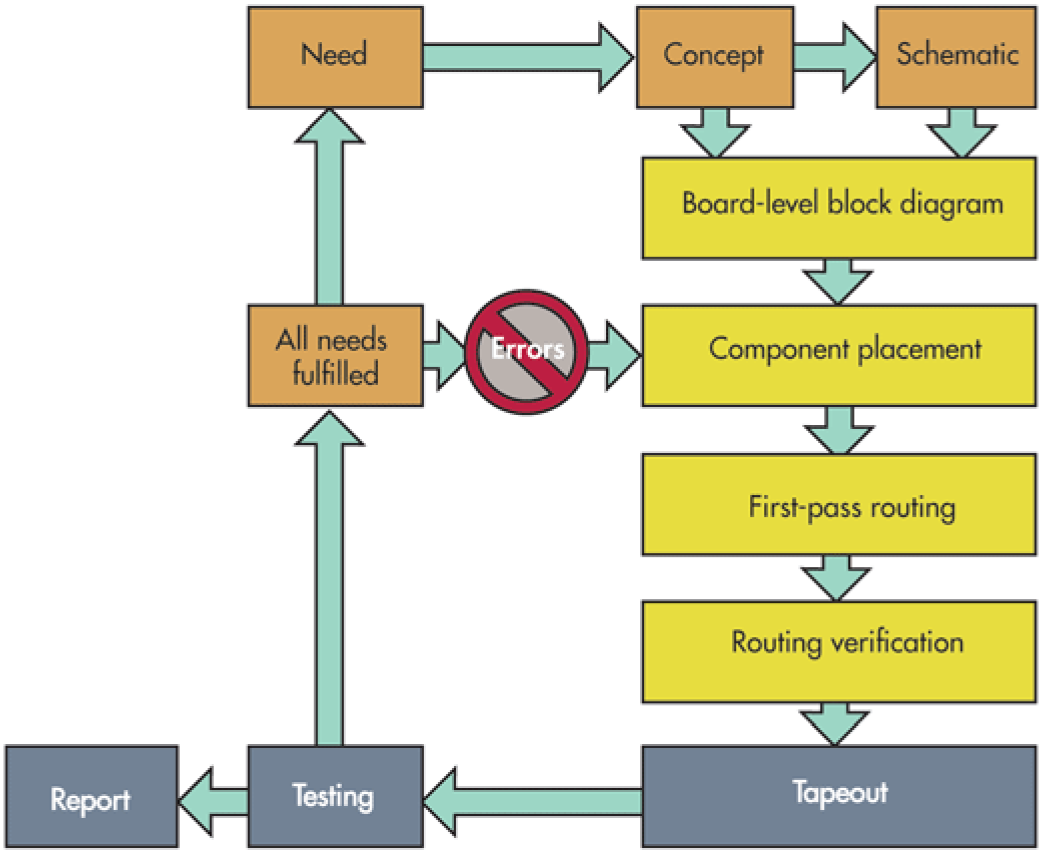


Figure 56: PCB Fabrication Steps

As was mentioned in the design part all the programming and debugging, of the MSP430F5529 and CC3100 Wi-Fi module, will be done through the Launchpad and the booster pack at the beginning. Then, once everything is up and running, the device will be built onto a PCB as follow:

- Schematic capture and simulation tools – A schematic capture program will allow the team to draw a document representing the electrical component symbols and the interconnections between them in a graphical way.
- PCB layout tools – A PCB layout program generates the mechanical and wiring connection structure of the PCB from the netlist. The layout program will allow the wiring connection structure to be placed on multiple layers and, once complete, will allow the team to generate the computer aided design (CAD) files needed to manufacture a PCB.
- Gerber files – The CAD files that will be sent to a PCB manufacturer so it can build the PCB layer structure are called Gerber files.
- Printed circuit board (PCB) – A wafer board defining the mechanical and copper wire structure of the circuit.

This PCB board will have all the components needed for the microprocessor and the Wi-Fi module to work properly. The other items that will be added to the PCB board are going to be capacitors, resistors, and conductors etc. It will also hold all the sensors, voltage regulators and power distributors.

The software that will be used to fabricate the PCB is going to be CadSoft Eagle PCB Design Software. This software was chosen for the PCB design for many reasons. First, tens of thousands of free component libraries are available. Second, Extensions there are hundreds of video tutorials available online. This will make learning the software easy. Third, there is regular free online trainings and free support through dedicated experts. Finally, there is active user forums that help solve design problems and give guidance.

Printing the PCB is something that the team will eventually have to do to complete the project on hand. There are few companies that can make the printing of the PCB possible at some affordable prices. Some of these vendors are as follow:

- **4PCB** - is an online company that manufactures printed circuit boards. 4PCB provides student with different to create their boards. The pricing is $33.00 for 2 layer board covering 60 square inches of circuit board space, and $66.00 for a 4 layer board covering 60 square inches of circuit board. 4PCB also provides free manufacturing tests to ensure that the customer's boards will meet the standards for PCB fabrication.
- **OSH Park** - is another online vendor that manufactures PCB's. As far as pricing, OSH Park prices their boards per square inch. A 2 layer board will cost $5.00 per square inch or a 4 layer board will cost $10.00 per square inch. OSH Park offers 3 copies of the PCB at no charge.
- **Express PCB** - is also another online vendor to fabricate PCB's. This manufacturer offers free CAD software that could be used to design PCB layout. The pricing of their products is $166.00 for an 80 double layer board with a maximum size of 21 inches, and $195.00 for four boards.

5.2 Drone 3K-QAV250

5.2.1Assembly

Assembling the quadcopter is the most important step in making the project come to life. First of all the frame of the quadcopter is going to be assembled based on the online manual provided on the Lumenier website (the brand name for the quadcopter used in this project). Then, the motors will go next on the assembly line. Each one of the four motors will be placed at each corner of the frame. Furthermore, the propellers will be installed on each one of the motor. The middle of the frame will be used to attach the battery with a strap. The need of a strap is necessary for the battery, because this last will be taken out few times to get charged. Figure 57 shows the frame 3K-QAV250 along with motors, propellers and battery.

Figure 57: Final Look of 3K-QAV250, Motors, Propellers& Battery

Since the assembly of the APM board, MSP 430 PCB board, motors and a battery is done on the ZMR250 structure, the next phase will be placing connections among them such as PM, PDB, and ESC's. Most of those will be mounted on the bottom part of the frame of ZMR 250. ESCs will be mounted on the middle of the arms of the frame.

PM: Main power supply to all devices will be provided by the main Li-Po battery. However it has to be regulated since some devices consume more or less voltages. Therefore a power module (PM) is connected to the Li-Po battery. Since power module has short length of wires and small integrated circuit in it, it could be placed on strapped at the middle of top and bottom part of the frame. Reason why on top is cause it could be easily connected to the battery to receive power from it, and reason for having the other half on the bottom is because it also supplies the power to APM board.

PDB: PDB is the main source for distributing the power to the ESC, therefore motors, and it is also the main communication source between ESCs and APM board, it should be places on the bottom of the frame adjacent to APM board and ESCs. One side of it is connected to the PM through XT-60 connector and the other side of it connected to ESCs for power distribution. If 3DR PDB is used then PDB could be used to supply +5V power to the APM because this PDB board comes with APM power supplier pin.

ESCs: ESCs are programmable and they are used to run the motors with certain rpm; therefore, ESCs should be placed as close to motors as possible for no other interference. Since ESCs are small and they have short length of wire output for motors, they should be places on the bottom arms of the ZMR 250 frame. There would be right spot for it because the surface area at that region is flat and it's close to motors.

Following is the figure 58 where it can be seen the approximate places of each of the above parts.

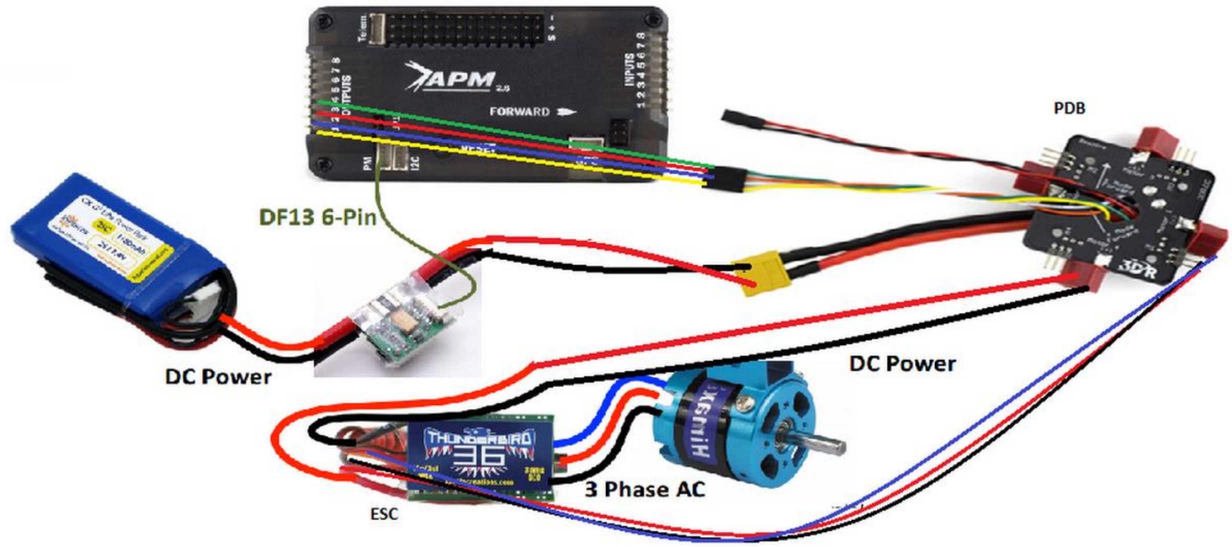


Figure 58: Wiring connections between APM, battery, PM,PDB,ESC, and motor

5.2.2 Mounting of MCU and Autopilot

The MSP430F5529 chip, the CC3100 Wi-Fi module, the IR 360 sensor and the rest of the elements will be built onto the PCB. Then this board will be connected to the APM 2.8 through wires. Both the PCB and the APM will be directly mounted to the top of the quadcopter's frame. This will allow the inter-connection of the rest of the components such as ESC's, power module, and voltage regulators etc. Figure 59 shows where the MSP430 & the APM 2.8 will be mounted.

Figure 59: MSP430 & APM 2.8 Locations

After that, the proximity sensors MaxSonar EZ will be mounted to the bottom space where the motors are. The reason why these sensors are connected in such way is because they will provide feedback to the MCU about the height of the drone.

5.2.3 Mounting of Camera

The Fly360 maximum dimensions are 5.59x5.59x5.59 inches and it has a total weight of 139g. This does not include any additional size or weight given to the camera by a lens. The camera on hand comes with a variety of accessories. Two of them are the action camera adapter and the tilt mount with curved and flat baseplates. These two accessories can be mounted on any standard 1/4-20 screw, a standard tripod mounting screw. The use of these brackets will make the connection of the camera realizable. This provides a versatile mechanical interfacing platform. The center of gravity relative to the camera is located in the center of the camera. It makes the mounting of this camera easy.

The Fly360 will be mounted on the bottom of the drone to make capturing pictures and videos easy. Also, the dimensions of this camera work perfectly with the quadcopter frame picked for this project. The 360 view of the camera helps eliminating the problem of rotation and gimbal controller. The team will simply focus on securing the camera and designing the App that will view the live stream of the camera.

5.3 Cell phone application design

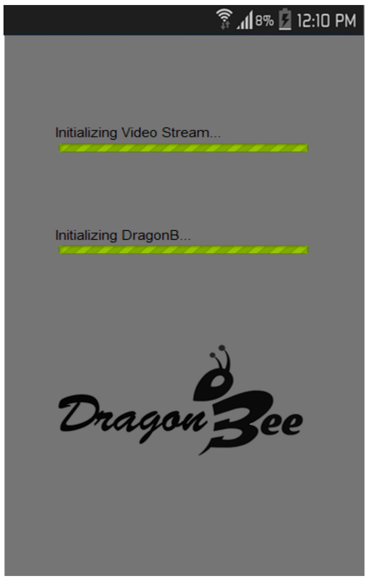
5.3.1 User interface

In this project, team members decided to make an app to control DragonB available only for android devices. This Android app allows streaming live videos from DragonB mounted camera to an android device; it will remote control DragonB through modes which will be available to users to choose the desired mode. Considering time management, it will be available only three modes FollowMe, Manual, and circle path. The following screenshots demonstrate interface look and available options for video stream and control.

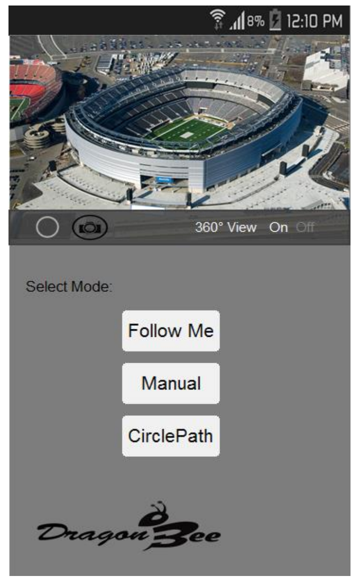
- The first screenshot in the figure 60 a) represents a splash screen interface and it stays on while initializing the required connections through Wi-Fi.
- The interface in the figure 60 b) is the first that allows for user interaction. The screen is divided into two parts; the upper part is responsible for video streaming, and the lower part is responsible for all control tasks and what not.
- Moving to the third figure 60 c), it is a result of pressing FollowMe mode button. On this interface, users will have two fields included with signs + and – for each field. One field allows users to increase and decrease the quadcopter height and the second one allows to increase and decrease the distance between the user and quadcopter.
- If a user selected the manual mode from the mode options screen, the figure 60 d) shows up offering a joystick control at the lower part of the screen. At this interface, user will have full manual control of the drone.
- The third option selected shows up the interface in the figure 60 e) which represent the CirclePath mode; it is a random mode was chosen by the team

members to demonstrate the capability of DragonB on adopting multiple mode. This mode will require user to select the radius in which DragonB will circle around user while recoding a video shot. The entered radius will allow users to adjust distance between quadcopter and user.

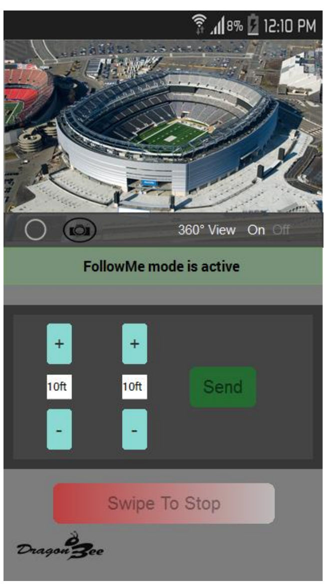
Each mode interface will have stop button at the bottom of the screen and it will take action only on swipe to avoid accidental presses resulting in frustrating random flight stops. In both FollowMe and CirclePath modes, pressing send button will be required at each selected entry to avoid accidental change in the flight reference.



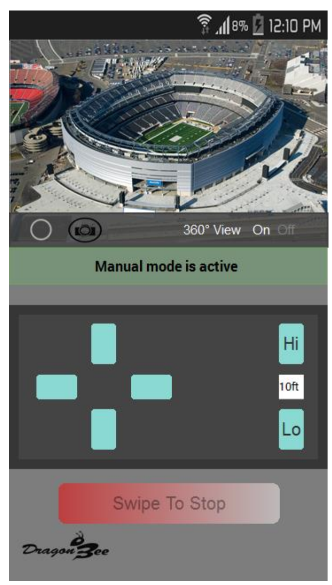
a): Splash Screen



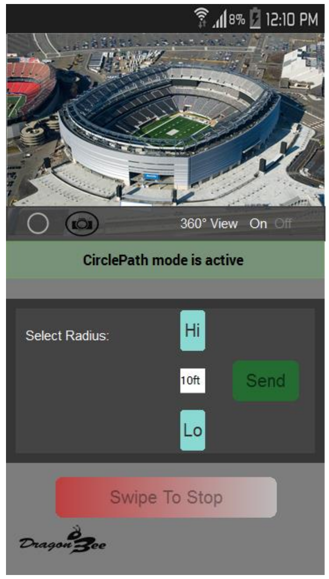
b): Mode selection



c): FollowMe Mode



d): Manual Mode



e): CirclePath

Figure 60: Available interfaces for DragonB app

5.3.2Specification

5.3.2.1 Drone controller

Drone controller is designed to be the lower half of the app's user interface. It allows user to control Dragon Bee based on the selected mode. In manual mode, Dragon Bee needs to be manually controlled in way where user can move Dragon Bee to every direction. Those directions are specified to be front, back, right, left, up, and down. The second mode is an autonomous mode. Even though it is an auto mode, the app will allow users to adjust the height level in which Dragon Bee operate as follow me. Then the third mode will be random mode called CirclePath which the user will have the option to control the radius for the Dragon Bee to circle around.

5.3.2.2 Video streaming

The initial plan of the project was to no have the live video streaming. Instead, it was to store the video and photo to the external storage dive like a SD card. To make things interesting, the idea of live streaming was introduced by a group member. There are many ways to live video stream.

One way to go about is to have a raspberry pie board with a wife camera module attached to it. After some research it was found out that actual Wi-Fi streaming from the raspberry pie would far more difficult to implement. Another we thought was to have a regular board like MSP430 and video stream it from there. It was later found to be not supported by the MSP430 because it takes more power for a PSB board to video stream as it has to compress the video and send it via Wi-Fi. The video format that is used in the app is H.264

The easiest way was found. The actual Wi-Fi camera with some storage capacity was thought to put it use. This camera was mentioned earlier section of the draft. Using this camera, it was really easy to store, stream and control the camera from a distance. Another great idea came to mind in one of our teammates. He mentioned about 360 degree camera that will shoot video in 360 degree. This camera really made an impression in our mind. The team loved the idea. The World is not flat and using 360 degree camera the video won't be flat either.

After a long research, we finalized our decision to go with 360Fly camera. The 360Fly camera covers every angle, every POV of our life in full interactive 360 degree HD video. It can shoot and lets you share and swipe the most epic adventures, creative concept and memorable moments. The price of the first camera was quite cheaper than this one. The actual HD Wi-Fi FPV camera was under $150. This 360Fly camera is priced at around $400. This 360 camera has a lot to offer for this price. It has so many useful features. The table 17 gives some technical overview of 360Fly.

It takes Panoramic 360 degree HD video. The Accelerometer sensor inside determines the camera orientation. This camera can record in both upside down and right side up. This is a great feature for drone enthusiast and four our project. The 360Fly App and Director App will adjust the view to compensate for the orientation automatically.

This is also very light weighted camera. It weighs only 4.9 oz. The good thing about this camera is that it has magnetic strip below it that will stick to any metal surface. Wear it or place it, this camera have a mount to capture every shot. 360Fly is resistant to rain, liquid, sweat, sand and dust. This protects the camera from any activity or situation. The feature helps the drone in rainy weather or in case of any water damage. Also, it protects the camera if the drone were to fly below certain height with the presence of any dusts. In the table below, the technical details of the 360Fly camera is given.

The video streaming will be implemented in our Android App. The 360Fly camera has a Wi-Fi built in it. Using this technology, we will find the API for the camera to use in App with the help of android studio. This camera has an android and Apple app that user can download for free and watch the live streaming from the camera. For this project, we will be using the Wi-Fi link of the camera to sync with our app. All this work will be done in Android studio.

Video Format	H.264
Video Mode	1504x1504 at 27.97fps
Audio Format	Mono, 48kHz
Field of View	240*
Microphone	Built In
Storage	Internal 32Gb
Wi-Fi	IEEE 802.11 b/g/n (2.4GHz band)
Bluetooth	Bluetooth Smart Device
USB	USB 2.0
Supported Mobile OS	iOS 8+, Android 4.3+
PC Software	10.8 or later/Windows 7
Supported PC OS	Mac OS x, Windows
Water-resistant	5 ATM
Dust resistant	IP6x
Shock-resistant	Up to 1.5 M
Power Source	Built in Li-Polymer battery 1600mA
Battery Life	2+ hours

Table 17: 360Fly Technical Details (Permission Pending)

Figure 61: 360Fly Camera (Permission Pending)

5.3.2.3 Data storing

The Android app that will be built will not support the data storing for the captured video. However, the storing the data will take place inside the camera. The 360Fly camera comes with the internal storage of 32GB. This space is sufficient to capture HD videos and Photos. This stored data inside the camera will then be extracted using the computer vie USB 2.0 cable.

The android app will show the live feed from the camera. If the time permits, the team will handle the task to store the video and picture to the phone. In the android device, it give the option to save the video on either internal or external storage. This will be the removable storage media such as an SD card. Using the external storage, the files can be modifies by the user when they transfer files on the computer.

In the order to read and write files on the external storage, the app will be required to system permission. It will be done using the command like READ EXTERNAL STORAGE or WRITE EXTERNAL STORAGE. This storage files will be covered from using the network connection. Thus, to do the network operations we will be using the classes like java.net.* and android.net.*

The written application code will be saved internal storage. There are different storage options that can be considered while implementing this task. The graph in the figure 62 below describes the different storage option in Android.

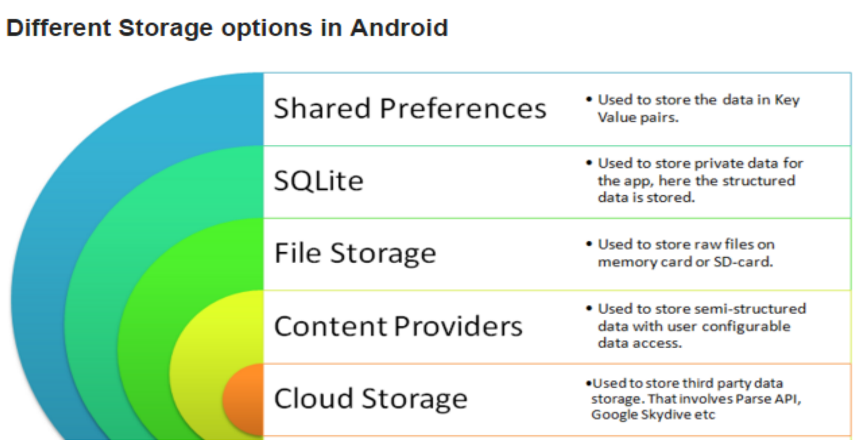


Figure 62: Graph 1 Storage option in Android5

5.4 Budget

The initial design phase of this project requires all components and parts listed on the table 18 below. The table gives an estimated price for the project as a whole. The total amount needed for the parts is going to be $1060. This grand total will be split between all team members equally.

Item	Price
3K-QAV250 Quadcopter Kit	$100
Zippy 5800mAh LiPo Battery	$55
IRCF360 Infrared Sensor	$30
MaxSonar EZ2 (4)	$108
ArduPilot Kit 2.8	$95
MSP430F5529	$35
PCB	$66
CC3100 Wi-Fi Module	$71
Fly360 Camera	$400
Total	$ 1060

Table 18: Budget of the Project

6. Project Prototype Testing

6.1 Flight Control Testing

6.1.1Follow me testing

Follow me mode makes it easier for user to follow as he moves; this is done using a telemetry radio and a ground station. APM planner for OS x laptops, Mission Planner for Windows laptop and Droid Planner for Android devices supports Follow Me mode. For this project a android phone with a an custom application is used as a ground station. This mode uses the Copter dynamic waypoint feature and MAVLink telemetry commands.

To set up the Follow me mode and to test it, we first need a laptop with ArduPilot connected to the Mission Planner. The next step is to have a phone ready with a Wi-Fi connection. Now on the Mission planner set the flight mode to be Loiter. Then set up the copter at the field and establish a MAVLink connection over wireless telemetry. After that, plug in the GPS USB dongle to the laptop. Ensure that the GPS module is working and you have the GPS lock. Now take off the copter and once in the air, switch to Loiter Mode on the mission planner.

Now in the mission planner fight data screen, right click on a nearby spot and select Fly to Here. If the copter moves to that point, we are ready to try Follow Me mode. Time to finally set follow me mode, enter Control F in the mission planner. This will open following window in the figure 63 and then click on "Follow Me".

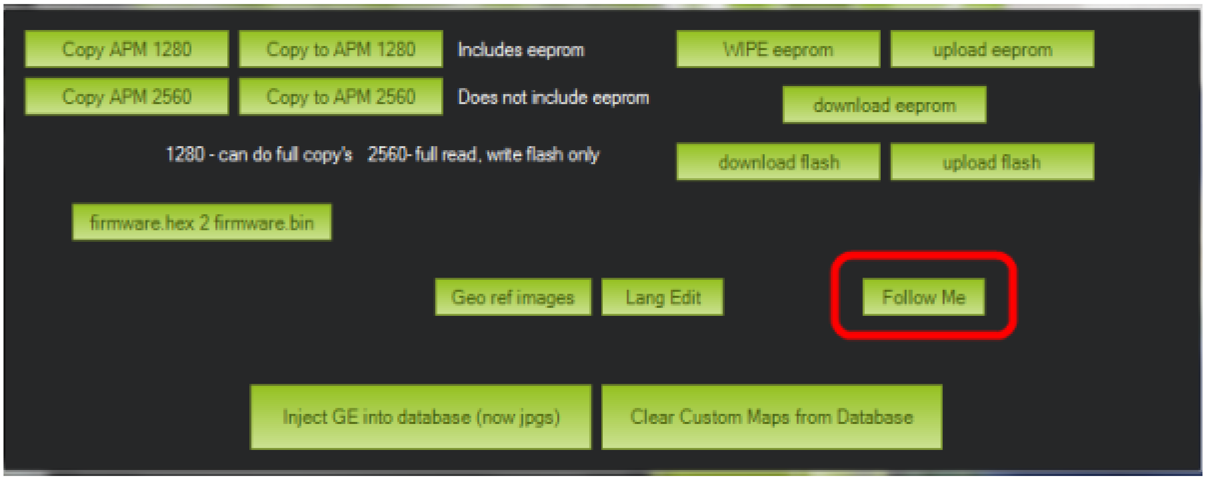


Figure 63: Loiter Mode Screen(Permission Pending)

Once you click on the Follow Me mode, it window will open up the window shown below. On this drop down menu, select the serial port that is assigned to the GPS device and whatever baud rate it uses. This device is the Android Phone with a Dragon Bee Application. Now hit connect and mission planner will read the GPS data from the phone and send it to the quadcopter as fly to here commands every two seconds.

To finally test this mode, select the "Follow Me" mode inside the app and start walking around. The copter should start following ling you. The altitude is set to be 5 feet by default. The user should go out of this range in order to test the function. If the copter follows you, we have achieved our goal.

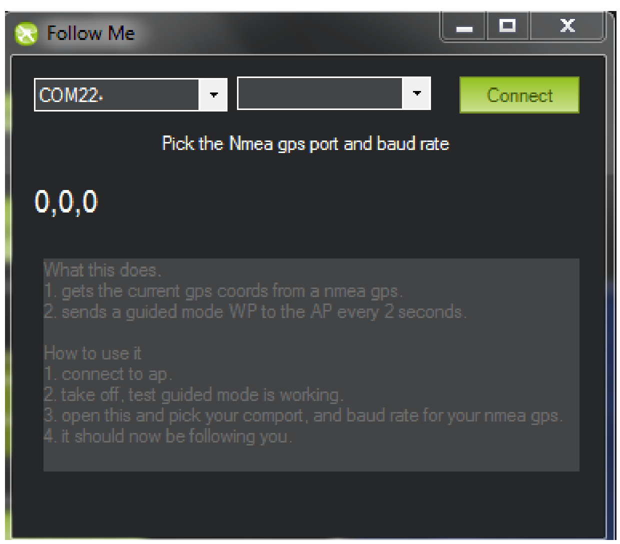


Figure 64: Follow Me Mode Screen(Permission Pending)

6.1.2 Battery lifetime testing

Battery life testing could be estimated using the manual and description of it. However, there many factors take part when testing the battery life. First of all battery itself, second weight of the whole drone system, and third power consumption by all parts especially motors and APM board.

Battery: It is important to choose a battery with high milliamps/hour (mah), higher the mAh is longer the battery last when using in drone. Also weight of the battery itself should be checked and considered because it would increase the weight of overall system of the drone therefore will shorten the time of flight.

Weight of whole drone system: Weight of drone is the second main factor, other than the motor power supply, that could affect the battery life. The more weight the less battery life; therefore, it should be important to not add any unnecessary weight. Additionally since we have chosen the carbon fiber drone, light weight motors, battery and APM board, the expected flight time is about 15 minutes considering all weights are included?

APM board / Motors: Third and the most affected factors in power consumption in battery are by APM board and motors. Power in the APM board increases as more sensors and modules are added to it. APM board itself takes about 12A of power for program functioning and data transmits. Power is distributed among APM and motors, but motor consume most of the power. Powers from the motors consumption is one of the top factors for battery lifetime going down. The more revs the lesser the battery life due to higher consumption by motors. Motors drive more power when the load increases; therefore, motors with different loads will be tested to see how much it could lifts up and how much battery it consume.

6.1.3 Motor speeds and ESC

There are many ways a Brushless Motor can fail; simply connecting it to an ESC and verifying that it is not enough to diagnose most problems. A motor can fail for the following reason:

- Worn bearing
- Worn magnet
- Unbalanced Motor/Prop
- Wrong timing on ESC
- Loose shaft or prop hub
- Short winding
- Open winding
- Corrosion inside connector (won't be visible)

Few of these will not cause a catastrophic failure immediately but will cause issue over time. It can damage the winding because the motor has to do more work thus gets hotter, which degrade the magnet quicker and makes the motor work even more. Result of that overheating could make the cycle continues until your winding break.

A split or short winding will cause a catastrophic failure. Depending on the motor winding and time it flies, configuration it might not even start. When the winding is using several smaller gauge wires instead of a thicker single wire, it can cause a failure in flight when one of the braids is worn. It should be checked before every flight or even after hard lending or in the case of crash. Few other things to check before testing are loose screw, bearing and to check for winding issues. Following are some steps how to check the winding issues.

- With a multi-meter, check the resistance of every combination of motor wire. We have 3 wires coming out of the motor and could be named A, B and C arbitrarily as the exact order doesn't matter.
- Note the resistance of A to B, B to C, and A to C
- Make sure they are ALL EQUAL or at least extremely close if your ohm meter is very precise
- Make sure none of them is open

If one of the pair has a lower value than the other then it means that there is a short in the winding. Now that multi-meter handy, connection for bad solder joint or corrosion can be checked. Following are some of the guideline of how to test the connector:

Attaching the motor to the ESC, make sure it’s working.

- Attaching one of the lead of the ohm meter to the wire coming out of the ESC, before the solder joint, it is safe to strip a bit of insulation, electrical tape can be put back.
- Attaching the 2nd lead of the ohm meter to the wire going to the motor of the same wire. The resistance of the connectors will be measured, including the solder joint, while under load so need to measure voltage.
- Powering the motor and measuring the voltage across one connector. If there is something significant, that means there is a resistance which causes heat and therefore failure.

For ESCs connectors between motors and PDB board should be checked before giving any power to them. It should be checked power (+) of ESC is plugged into (+) of PDB and same rules apply to (-) and (s) connectors. Furthermore, changing the connector to PDB, we can check which if motors are running either CW or CCW. Also commands could be checked by changing modes and checking the functionality of the drone.

Final check would be testing ESCs and motors at 50% of the full throttle. If there is more heat in one motor than the other it is more likely to get failure and same testing is applied to the connectors.

6.1.4 Ground distance sensors testing

The testing of the ground distance sensors will be done in three phases. The first test will take place in an indoor environment such as the house. In order to discuss the testing of the MaxSonar EZ2, few components must be available. These components are going to be as follow:

- MaxSonar EZ2 – this is the component being tested
- MSP430F5529 Launchpad – this will be used to read data from the sensor
- Breadboard – this is used to eliminate the use of some extra wires
- Code – this is a C-code that will be used to read data from the MaxSonar EZ2 and display results on the computer screen.
- Computer – this will be used to load the code, through the Launchpad, to the MaxSonar EZ2
- Multi-meter – this is going to be used to check if the voltages and currents readings are accurate.

After gathering all the necessary components for testing, everything else will be done in few steps. First, the MaxSonar EZ2 sensor will be prototyped on a breadboard and then programmed through the Launchpad of the MSP430F5529. Second, a connection is to be set between the Launchpad and the computer. A code will be then loaded to the computer to test the functionality of the sensor. Based on how the testing will go, measurement will be taken to see how effective these sensors are. The test will be tried few times just to make sure all data is right.

The second testing of the MaxSonar EZ2 will be outside in a sunny day with no wind. The same set up as in test one will be conducted. Then this test will be tried few time and data will be collected. The results from the second test will be compared to the first one. Then, the information received will analyzed to see if there will be any effect on the ultrasound sensors being inside or outside.

The third testing of the MaxSonar EZ2 will be outside in windy day. Same steps as in test one and test two will be taken. After collection of data, the results from all tests will be compared. The three test should give the team an idea of how the ultrasound sensors will work. It will also help the team decide if any adjustments are to be made.

6.1.5 IR sensor collision avoidance testing

The same process used to test the ultrasound sensors will be repeated for the IRCF360 infrared sensor. There will be a slight change for the IR sensor testing. First of all, all needed equipment will be gathered. These equipment are basically the IRCF360 sensor, breadboard, computer, C-code, the MSP430F5529 Launchpad, and a multi-meter. The reason for using these components is the same as the previous testing.

Three tests will be conducted for testing this sensor. The first test will in an indoor environment where no wind or high temperature is present. The same way as in testing the ultrasound sensors, data will be collected after running this test few times. The second test will be outside on a sunny day and no wind. Same process will be conducted and data will be collected. The last test will be outside on a windy day. One again, data will be saved and compared to the previous tests to see if there are any changes in the functionality of the IRCF360 infrared sensor.

6.2 Communication

6.2.1Wi-Fi communication

As mentioned in the research and design section, there will be two Wi-Fi communications. The first connection is established between an android App to 360Fly camera. The second connection will be established between an android app and the MCU for drone controlling. The first connection uses the UDP protocol and the second connection uses TCP protocol for transporting data. All data will be transferred using the 802.11g protocol with the frequency of 2.4GHz and maximum data rate of about 54Mbps.

The things like wall, your Amirah's, water cooler and mirrors weakens and even kill the Wi-Fi signals moving that way. Therefor flying the Dragon Bee outdoor, where there are fewer obstacles is the best way to get stable connection. The second best thing to set is the Wi-Fi sleep policy. We want to set the Wi-Fi sleep policy to Never. This option drains the battery faster but it keeps the Wi-Fi connected on a more consistent basis.

The team has designed the TEST MY CONNECTION button on the app to test the Wi-Fi connection. This window should pop up every time the user opens the app. The screen will display number one and it will transit to number 5. If the connection strength is good then it will display a message of successful connection test. If for some reason the connection is poor, it will display the message in red asking user to test the connection again. The message is displayed in green and red to indicate the best and worst connection. This function works really well with msp430. The android app will send the integer 2 to MCU. The MCU will multiply this integer by 2 and send the result back to android. The android will send this number back to MCU. This cycle will continue until the integer reaches 32. If the connection is good then it will reach to this number and android App will detect the number and display the GOOD CONNECTION message to the user. The users can then proceed to fly the copter.

Figure 65: Wi-Fi Testing Initial Screen

The figure 65 shows the initial screen for Wi-Fi testing. The figure 66 shows the transition of screen the user will see during the Wi-Fi testing. If the test is successful and there is a strong stable connection then it will display a successful message in green like in figure 67. Otherwise, it will message the unstable connection to the screen so user can retest the connection as displayed in figure 68.

Figure 66: Wi-Fi Testing In Progress

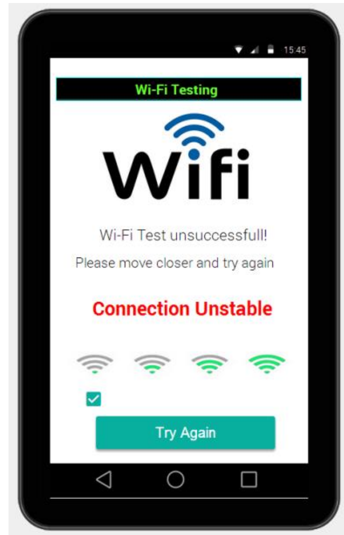


Figure 67: Successful Wi-Fi Test

Figure 68: Unsuccessful Wi-Fi Test

Another tool can be used test the connection. There are some free android applications that can be used to test the Wi-Fi connection. We will test our app on Wi-Fi Analyzer first. This application analyzes the Wi-Fi bandwidth in real time. If the arrow is pointing to the green section then we have good stable connection. We will be using this app to test the Wi-Fi connection prior to take off. This app can also be used while the copter is in the air. If the arrow shifts from green to yellow we have average connection. If the arrow moves to gray area then we should have poor connection. The goal is to not have the arrow on gray section at any time during the flight.

Figure 69: Wi-Fi Analyzer (Permission Pending)

6.2.2 MSP430/ArduPilot communication

Since none of the team members can't expect what could happen while testing quadcopter on the run; it may fly out of control causing multiple damages such as injuries, property damage, and even quadcopter itself. In this case, team members came up with solution to test the communication between MSP430 core and Ardupilot. In order to achieve a successful testing, team members have investigated what kind of protocols Ardupilot uses to communicate with Ground Control Station (GCS) as called in the official website.

Ardupilot is documented in the official website uses MavLink communication protocol. MavLink is a protocol that sends message bundle formed as packet of length 17 bytes and these 17 bytes contain some headers, a payload, and luckily Checksum algorithm for error detection. After the base station receives these packets, payload data is extracted to construct the data was sent from Ardupilot. In this case, base station will be the MSP430 Core.

Bi-directional UART connection will be used as means of data transfer. Next semester, while performing necessary parts acquisition, MSP430 core will be adopting the MavLink protocol to fully understand data structure sent by Ardupilot. To perform UART communication test between MSP430 core and Ardupilot under those circumstances, MavLink is required only in this communication. Since user will communicate to MSP430 through a Wi-Fi connection, it is possible to read that data at the user end interface and vice versa at the backend of MSP430 code.

A temporarily user interface will be created for the Android app that displays all the data was sensed and sent by Ardupilot. Also a text entry field will be available in this interface that allows sending data back to Ardupilot. A Bi-directional communication as seen in the figure 70 below will require testing both ways communication.

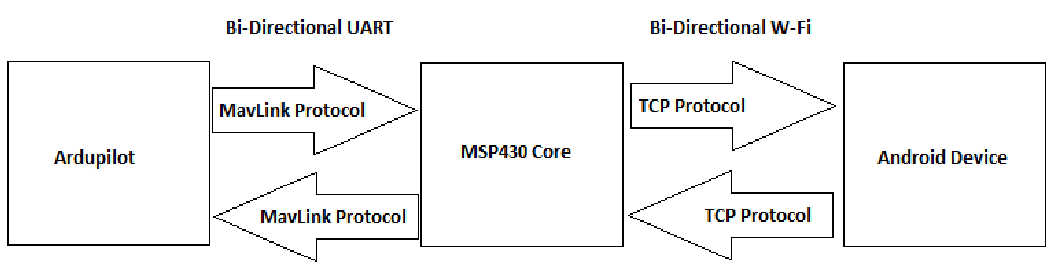


Figure 70: Bi-directional Communication

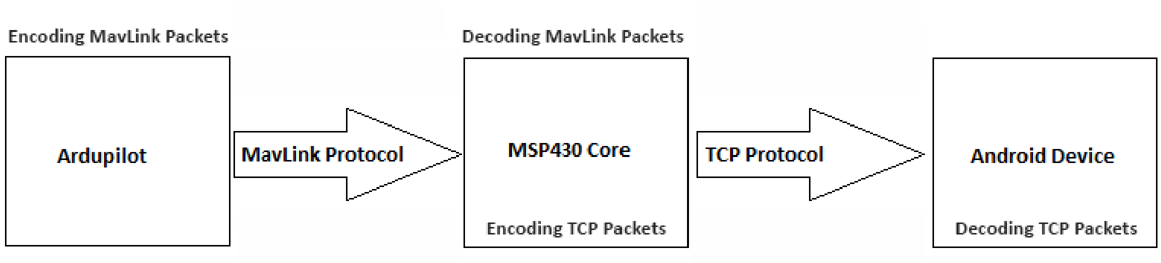


Figure 71: ArduPilot Sending Data

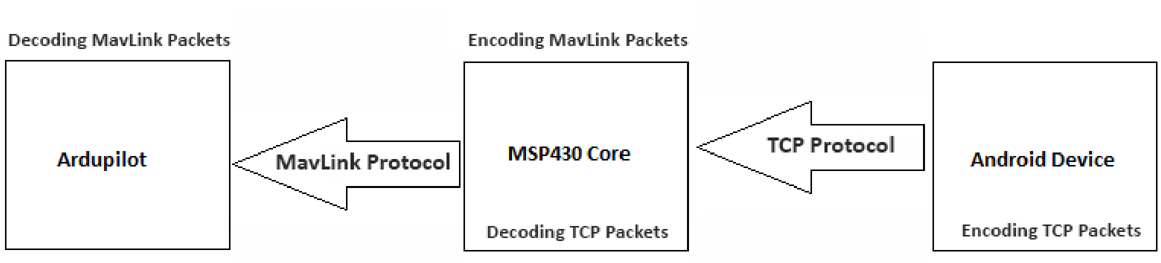


Figure 72: AdruPilot Receiving Data

As a successful test for this part, GPS data from Ardupilot has to reach user interface as described in the figure 71; thus it will be done through measuring GPS coordinate in multiple locations far apart, a distance longer than the accuracy of GPS module without performing an actual flight. Based on GPS module documentation, the accuracy is 2.5m. Those measured waypoints will be measured at the same time with a smart phone GPS. Finally, a comparison will be conducted between the measured GPS data from Ardupilot and the one measured using smart phone GPS service. If the data received by Ardupilot provides almost the same accuracy as Smart phone GPS data, the UART communication is properly functioning as well as the GPS module accuracy.

The second way communication in the figure 72 will be tested by sending commands from smart phone to Ardupilot, then measure motors reaction. If all drone motors respond to the given commands, UART communication is working properly.

Initially, before communication between MSP430 core and Ardupilot is acquired, it is required to test Ardupilot without using MSP430 to operate the quadcopter. This initial test will be done through RF communication between a computer with mission planner installed and Ardupilot.

6.3 Android application

6.3.1 Live video streaming

No special environment is required to test the live video stream. However the weather is always an issue for camera shooting. The live video is taken from 360Fly camera from the quadcopter. The first thing to make sure is the Wi-Fi connection. The app will first test the Wi-Fi connection before start up. If the Wi-Fi connection to the camera is well then there must be live streaming.

Once the app is started, there must be video footage from camera. Live video streaming test will take place before mounting it to the copter. This test will be done in the one of the teammate's garage. We will start the camera and connect it to the phone using Wi-Fi. The next step is to start the camera and app. Now, we will point the camera towards two of the group member and they will waive their hands to say hi. The other two members will hold the phone to see if the video shows what the other teammates did. If the video is live then this function is working. However there might be small amount of delay. This delay will be significantly low so it can be neglected.

6.3.2 Dragon Bee Manual Control

Manual control mode is one of the less complicated tests. Testing environment should be a wide open outdoor without trees or people around for safety purpose. One of the cheapest ways is to attach Dragon Bee to a long enough fishing line with at least .013 diameters. Manual mode simply will be tested by pressing buttons located in the bottom of the screen with one button at a time. And each button will be pressed long enough to test if Dragon Bee will not exceed the limit range. If Dragon Bee reacts to each button accordingly, then Manual Mode is fully functional.

6.3.3 Data Storing

Data Storing doesn't require any special environment to test. It only requires a full battery in the camera and android phone. As explained earlier in the report, the data storing takes place at two places, one in the camera and one inside the phone. The recording on the phones starts when user presses record button. The camera has a 32 GB in built space to store the recording. This recording can be tested after the flight. For this, we will need a mini UCB cable and the laptop. Next step is to plug in one end of the mini USB to 360Fly camera and the other end to the laptop. The computer will start detecting the hardware and start installing the appropriate drive for the camera. Once this process is done, the user can see the recording from MyComputer. It will be saved as a video file with H.264 format. If the video is playable then the Data storing for the camera is passed. The video resolution is 1504 at 29.97 frames per second which is better than an iPhone 5 that has 1080 at 30 fps. User will be able to capture 46 minutes of video in a single session. This restriction is due to the battery limitation. However, 360Fly is able to capture video for over 2 hours.

The other data storage will save video files directly on the android devices' internal storage. To test this, user must exit the app. Files saved to the internal storage are private to the application that saved them by default and other application cannot access them. However, our app will save the video directly into the video section of the app so user can access them at any time. The user should be able to play the video by just clicking on it. If the video plays, video is successfully stored in the phone. User will have full access to the recorded video and will be able to share and edit at any time. User can keep track of data usage on the phone. If the user wants to check if the video file is saved, he can track the storage before and after the flight to confirm the storage. The figure 73 below shows the overall data storage, free and occupied space.

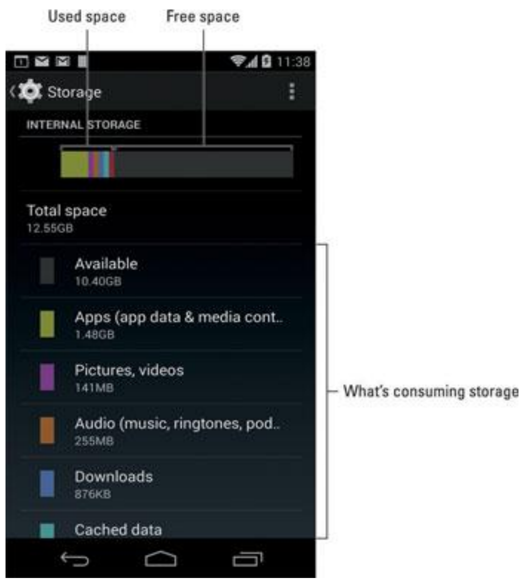


Figure 73: Data Storage Screen (Permission Pending)

7. Appendix

Data Sheet

1. MSP430F5529 Microcontroller:

http://www.ti.com/product/MSP430F5529/datasheet

2. CC3100 Wi-Fi Module:

http://www.ti.com/product/CC3100/datasheet

3. ArduPilot 2.8:

http://copter.ardupilot.com/wiki/common-apm25-and-26-overview/

4. MaxBotix EZ2 Sensor:

http://maxbotix.com/documents/LV-MaxSonar-EZ_Datasheet.pdf

5. IRCF 360 Infrared Sensor:

http://www.robotmaker.eu/products-2/ircf360

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Figures Reference

Tables References