Presented at the DLSU Research Congress 2016
De La Salle University, Manila, Philippines
March 7-9, 2016

Development of a Controller Board with On-board Sensors for Rotor-Based Unmanned Aerial Vehicles

Alexander Abad[1], Elmer Magsino[1], Karl Obias[2], John Paul Samarista[2], Marc Say[2], and John Amos Tan[2]

De La Salle University Electronics and Communications Engineering Faculty[1]
De La Salle University Electronics and Communications Engineering Undergraduate Students[2], Research Assistants[2]

alexander.abad@dlsu.edu.ph
elmer,magsino@dlsu.edu.ph
john_amos_tan@dlsu.edu.ph

Abstract: Unmanned aerial vehicles (UAV) research works have grown immensely over the past decades due to its maneuverability and vast possible applications. These applications are always dependent on its controller board and on-board sensors. This research aims to develop a controller board equipped with various sensors such as an Inertial Measurement Unit (IMU) for stability of the roll and pitch, a magnetometer for stability with regards to yaw, a barometric pressure sensor and an ultrasonic sensor for height, and a GPS for location mapping. Filters are used for IMU, barometric pressure sensor and as well as the ultrasonic sensor for a well-defined reading. These sensors are necessary to achieve a stable flight for a rotor-based unmanned aerial vehicle for four, six and eight rotors. A remote controller is incorporated to the controller board for future developments when it is used in actual flight. This can be used as a switch to fly the UAV autonomously, or maneuver the UAV from one place to another. Such controller board must be able to control at most eight motors using PWM signals sent to the ESC. The controller board would allow further studies to incorporate control systems to the board. The traces of the controller board was designed using the software EAGLE and its components were placed specifically to control a UAV. It uses an ATMEGA2560 microcontroller and is programmed by Arduino using C language. The different sensors will be controlled by the microcontroller using different techniques such as Serial and I2C. It is then implemented to an octocopter to ensure that the controller board could control 8 simultaneous motors.

Key Words: UAV; Octocopter; Drone; Controller Board

1. INTRODUCTION

Applications for UAV have increased over the past years because of its vast applications. Manufacturers have made different types of UAVs that use controller boards. These controller boards however are difficult to disassemble and to reprogram. This research aims to give the researchers the freedom to program and control the UAV with a control system they designed. The commercially available flight controllers such as the uMNAV100CA from Crossbow vary on prices and specifications depending on the sensors installed. The mentioned flight controller is limited to tri-axis accelerometers, tri-axis gyroscopes, tri-axis magnetometers and a GPS receiver module and can also drive up to eight (8) servos via PWM channels. The cost of this kit on the year 2007 however was at $1495.00 which brings to a disadvantage when trying to pursue research in UAV. Researchers would now have a choice on maximizing which sensors to use and at the same time minimizing the cost. In this research, the group tested five types of sensors namely IMU, magnetometer, ultrasonic sensor, barometer and GPS. The group also programmed PWM at different frequencies to run the BLDC motors. This paper will discuss how the controller board was made and how it was able to acquire data and output PWM frequencies.

2. METHODOLOGY

2.1 Controller Board

The flight controller was made using a double sided PCB board with surface mount components on the top layer and a ground plane with through hole components soldered on the bottom part. It was designed with the use of EAGLE CAD. It consists of multiple parts such as the power section, and microcontroller section. Headers are also placed for outside connection with the board such as the sensors, the ESC, and the remote controller.

Headers were strategically placed in the different parts of the board to accommodate the ESCs, the IMU, and the GPS. Each corners of the board has two sets of pins connected to the ESC. The PWM pins are located at the upper side of the microcontroller. Analog pins are located at the right side of the board while the digital pins are located at the bottom corner. There is a section for 5V and 3.3V in case other hardware will be connected. Unused communication pins are also present for further additions to the project.

Bootloading was needed to be done with the ATMEGA 2560 to allow the FT-232 (programmer) to write the program using the Arduino to the microcontroller. The programmer was then connected to the computer via USB and connected to the TX and RX pins of the microcontroller to allow the Arduino IDE to program the controller board. The FT-232 can also be used to transmit data to be received in the computer real time via the serial monitor.

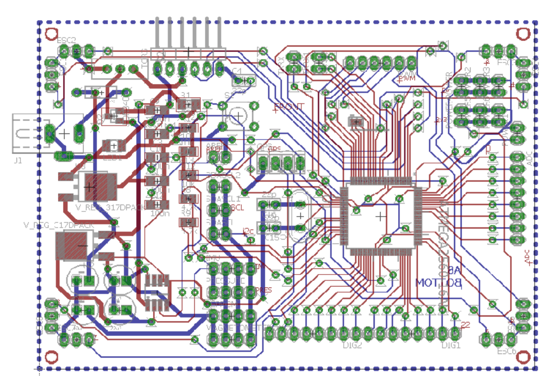

Figure 1.1: Controller Board in Eagle CAD

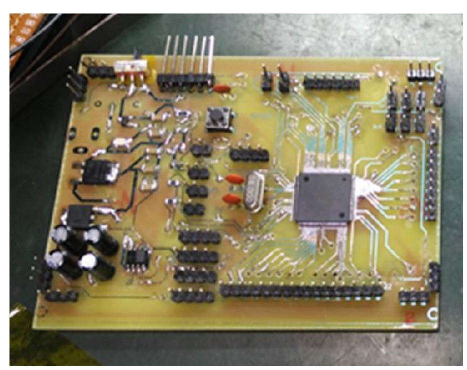

Figure 1.2 Fabricated Controller Board

ISSN 2449-3309

2.2 Sensors

The sensors were used for the acquisition of the attitude and altitude feedback for the octocopter. For the attitude feedback of the system, a combination of IMU, and magnetometer was utilized to attain the angles for the pitch, roll and yaw. As for the altitude feedback of the system, an ultrasonic sensor, and barometer was operated to obtain the distance of the octocopter with respect to the ground.

2.2.1 Inertial Measurement Unit

The IMU used comprises of an accelerometer (ADXL345) and gyroscope (ITG3200) which both gives the angles for roll and pitch. Since the accelerometer and gyroscope has short and long term fluctuations respectively, a complementary filter was used to accurately give the pitch and roll. On the other hand, the magnetometer (HMC5883L) generates the heading or yaw direction of the octocopter. The heading obtained by the magnetometer gives the direction of the relative North, thus can be utilized to attain the yaw angle of the system. A tilt compensation system is made with the aid of the accelerometer for more accurate readings of the magnetometer. Both the IMU and magnetometer is interfaced through Inter-Integrated Circuits (I2C).

2.2.2 Ultrasonic Sensor

The ultrasonic sensor (LV MaxSonar EZ4 RangeFinder) uses sound waves to get the distance from the octocopter to the ground. A trigger pulse is generated by the sensor. After hitting an object which in this case the ground, an echo pulse is then reflected back to the sensor. The time duration is entered as a relative voltage which is converted to the distance between the two objects. The communication of the ultrasonic sensor and the system is made by the connection of the analog pin of the sensor to one of the analog pins of the microcontroller. Consequently, a power supply filter is used to filter short term fluctuations of the sensor.

2.2.3 Barometric Pressure Sensor

Another sensor used for measuring the height is the barometric pressure sensor (BMP180). Because the ultrasonic sensor has a maximum range, a pressure sensor was used to measure height more than the maximum range of the ultrasonic sensor. To measure the height, this pressure sensor first acquires the atmospheric pressure which is the amount of air above a certain object in the origin state. Then, based on the concept that as an object increases its height, the pressure lowers, the height can be achieved. The atmospheric pressure at the point of destination and relative ground pressure at the point of origin are factors to be entered to a formula below to achieve the height of the object with respect to the ground.

2.2.4 GPS

The latitude and longitude of the UAV was measured using a GPS module. There are various NMEA sentences which a GPS module outputs and this sentences contains various data. Two of the most commonly used NMEA sentence are $GPRMC and $GPGGA. This two sentences contain all the minimum required data which is the latitude and longitude. Out of the two sentences, the $GPRMC was used.

$GPRMC,123519,A,4807.038,N,01131.000,E,022.4
,084.4,230394,003.1,W*6A

The line above is an example of a $GPRMC sentence. The value 123519 is the Coordinated Universal Time in UTC. The next part is the status of the GPS whether if the data received is Void (V) or Active (A). This indicates whether the GPS module is receiving proper signal. After the status of the GPS module, the next four parts are the required data, the latitude, latitude direction, longitude, and longitude direction. The value 4807.038 and N is translated to 48 degrees, 07.038 minutes, in the Northern Hemisphere, while the value of 01131.000 and E is translated to 11 degrees, 31 minutes in the Eastern Hemisphere.

2.3 Octocopter System

The octocopter is composed of four pairs of fixed pitched propeller, four having a clockwise rotation and the remaining a counter clockwise rotation. The propeller were arranged by alternating the placement of the four pairs of propeller, this is to mimic the propeller arrangement of a quadcopter.

The motors of the octocopter are controlled using an Electronic Speed Controller (ESC). The ESC can adjust the speed of rotation of the rotor by changing the input duty cycle. The ESC, aside from adjusting the motor speed, was also utilized to determine the rotation of the motor by changing the connections of the wires from the ESC to the motor.

The frame of the octocopter used is made of carbon fiber while the landing gear is made of aluminum. This makes it ideal for multirotor which lessens the payload carried by the multirotor and ensures that it would remain intact upon impact or during flight. The frame of the octocopter is around 1.07 m in diameter without the propellers, this is common for octocopter frames making it easier to stabilize compared to smaller multirotor.

3. DATA AND RESULTS

Presented below are the data and results of the acquisition of data for the controller board. The group tested the sensors in different testbeds and acquired the values using the serial print function of the Arduino IDE.

3.1 Angles (IMU)

The octocopter platform was set on a test bed having an inclination of 10 degrees. All 8 motors were turned on without the propellers. This was done to verify the credibility of the IMU. As seen from Figure 3.1, the angle measured centers on 10 degrees but having spikes ranging from about -2 to 17 degrees because of the vibration caused by the motors. This test was also done with the propellers having the motors run at slower speed in such a way that the octocopter is not trying to take-off.

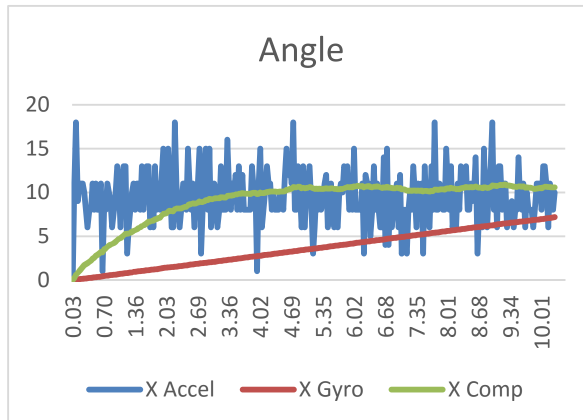

Figure 3.1: Angle value for pitch at 10 degrees

3.2 Magnetometer

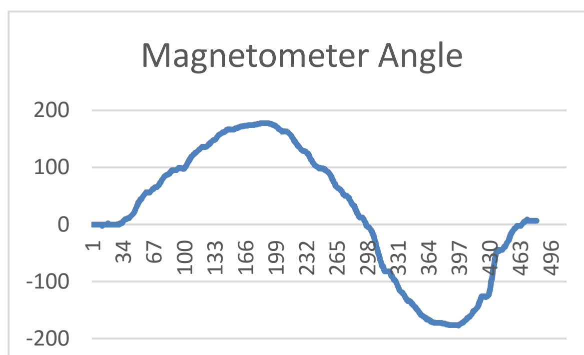

Figure 3.2: Magnetometer Angle Values

The group was able to obtain heading values from the magnetometer. Unlike with the IMU, there was no filtering done to the magnetometer. The test done here was rotating the octocopter clockwise by 180 degrees, return back to original position and rotate the octocopter counterclockwise by 180 degrees and again returning it to its original position. This was verified visually by comparing the reading from the actual moving of the octocopter.

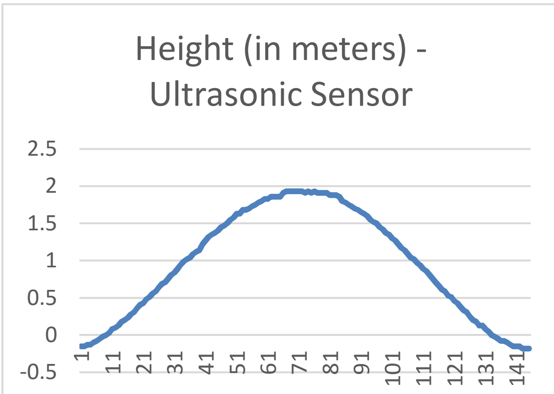

Figure 3.3: Ultrasonic Sensor Reading

The analog pin of the controller board was used to obtain the values of the ultrasonic sensor. The octocopter was pulled up to at most a height of 2 meters and descended down using a rope. We were able to get the correct height values of the octocopter using this sensor.

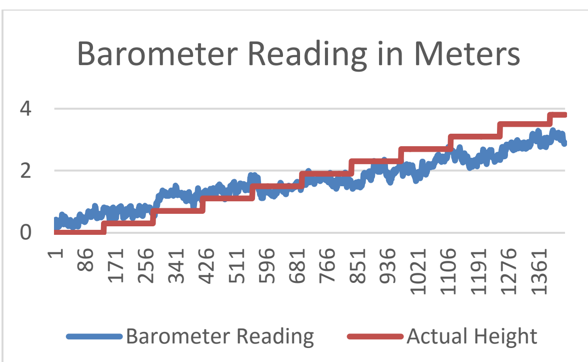

Figure 3.4 : Barometric Pressure Sensor Reading

In this configuration, a barometer was used to measure the height of a flight of stairs. A measurement tape was used to measure each step of the researcher. This then was plotted with the measurements obtained from the barometric pressure sensor. The original output of the barometer is identified to have minor fluctuations in its value. An average filter is used to straighten the output of the barometer. Five samples of data were averaged for each iteration.

3.5 GPS

The code we made for the GPS was able to successfully obtain correct coordinates for the octocopter. However, only tests outdoors were successful.

Figure 3.5: GPS measurement stationary position

Figure 3.5 is a test at a stationary point. It has some drift but it is within the premises of the area. The drift is at around 3m from the original point. We were able to verify this from the datasheet.

Figure 3.6: GPS measurement shifting position

ISSN 2449-3309

Figure 3.6 on the other hand is a test at a moving point. It also consists of some drift but it was able to successfully acquire coordinates from one place to another.

3.6 Octocopter Platform

Using the controller board, the group was able to successfully control motors of the octocopter using PWM.

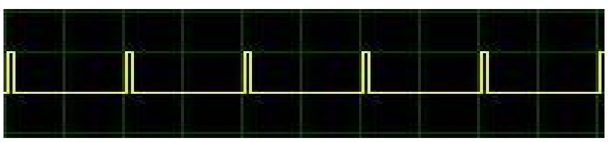

Figure 3.7 Duty Cycle from Controller Board (1)

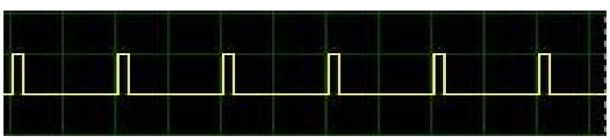

Figure 3.8: Duty Cycle from Controller Board (2)

Using these duty cycles, arming the 8 motors simultaneously and running the motors at full speed was achieved.

Figure 3.9: Octocopter Motors Running

4. CONCLUSION

The group was able to successfully fabricate a functioning controller board specifically designed for an 8-motor UAV. This was verified as the IMU, ultrasonic sensor, barometer, and GPS modules were working as they were connected to the controller board. As seen from the data gathered, each of the sensor was able to print the values through the serial monitor of the Arduino IDE and graphed through Microsoft Excel. During the time that these were tested, failure to produce output data in the serial monitor indicated that there were problems in the controller board because of faulty soldering, cut trace, or shorted components. The design of the controller board also made connections to the ESCs of the UAV more convenient as they were place around the perimeter of the controller and avoid overlapping connections with other sensors. Extra pins were allocated for future purposes in case there will be other external hardware to be connected to the board.

5. ACKNOWLEDGEMENTS

The group would like to acknowledge University Research Coordination Office for funding this research under De La Salle University Science Foundation.

Project number: 25 F U/S 1TAY14-1TAY15

6. REFERENCES

Adafruit Ultimate GPS. (n.d.). Retrieved January 12, 2016, from https://learn.adafruit.com/adafruit-ultimate-gps?view=all

Kelly, N. (2015). A Guide to Ultrasonic Sensor Set Up and Testing Instructions, Limitations, and Sample Applications. Retrieved January 12, 2016, from http://www.egr.msu.edu/classes/ece480/capstone/fall09/group05/docs/ece480_dt5_application_note_nkelly.pdf

Le, T. (2007, June 25). Tony Le - Drexel University - μNAV Tutorial. Retrieved June 1, 2014, from http://dasl.mem.drexel.edu/tonyle/tutorials/mnav-tutorial.html