Journal of Engineering and Applied Sciences 12 (1): 1-9, 2017
ISSN: 1816-949X

Build and Design of Atmospheric Balloon Altitude Control Based on Multiwii

[1]Agit Zulharman, [1]Agus Mulyana and [2]Ginaldi Ari Nugroho
[1]Department of Computer Systems, Faculty of Engineering and Computer Science,
Universitas Komputer Indonesia, Bandung, Indonesia
[2]Center For Atmospheric Science and Technology, LAPAN, Bogor, Jawa Barat, Indonesia

Abstract: Atmosphere balloon for weather monitoring and research application have long been developed in Indonesia. However, the lack of this atmosphere balloon were difficult to control for its movement. By reducing the vertical movement of the balloon, it could controlled the balloon in certain altitude. Atmosphere balloon altitude control that proposed in this research is by using air control method applied in a ballast totex balloon. The control are conducted by filling the air into ballast using dual head pump NOOA-FRD and discharge the air naturally using air pressure inside the ballast controlled by valve integrated with servo motor as an actuator. If the uplift of the atmosphere balloon filled with hydrogen reaching zero due to the ballast, then balloon will float in certain altitude above surface. Control activation process in the payload conducted wirelessly through radio signal transmission in 433 MHz frequency. Combination of all the component with this method will result a control system that able to resist the uplift of an atmosphere balloon, unfortunately this system in still unstable on floating in the desired altitude. This system still needs to be developed in the part of filled and discharge of the ballast more efficiently.

Key words: Atmosphere balloon, Multiwii, ballast, payload, altitude control

INTRODUCTION

Disadvantages of the balloon atmosphere is difficult to control the movement, both horizontal and vertical motion. If the vertical movement of the balloon can be reduced, the balloons can be set at a certain height. So it is very useful for the measurement of atmospheric vertical profiles as well as in aeronautics research such as UAVs, radiosonde and so forth. Research conducted by several foreign institution have succeed in developing atmosphere monitoring using balloon in certain altitude. Among this developed system are the zero-pressure hellium balloon, superpressure hellium balloon and infrared montgolfiere. The point of this developed system is how to create a balancing system between uplift caused by helium/hydrogen gas inside the balloon with the ballast system so that balloon could adjust in certain altitude.

This research would make benefit for researcher in conducting the atmosphere and space monitoring. This device expected to able to reduce the cost for conducting research in the atmospheric observation field since in general for one atmospheric observation it will took one atmospheric balloon and a payload sensor. Meanwhile, if the developed system applied in the atmospheric observation, the used balloon could be lowered back into the surface or let it floated in the atmosphere so that the balloon and the payload can be reused for another observation.

Purpose: The purpose of this invention is as follow: Build and design a system that able to control the vertical movement of atmospheric balloon in the free air. Developed an altitude control system of atmospheric balloon using control algorithm for atmospheric profile research and observation application.

MATERIALS AND METHODS

Theory

Atmosphere balloon: Atmospheric balloon have a flexible substance contain latex rubber and also synthetic latex using polychloroprene. Basically atmospheric balloon filled with light weight density gases compared with surrounding environment. There are 2 typical gases that were used which is helium and hydrogen. Balloon are able to lift heavy payload compared to its own weight by increasing the gases that will enlarge the volume of the balloon (Fig.1).

Altitude control theory: The upward bouyant force in the atmospheric balloon in technical term is called the gross uplift (T). This value can be calculate based on Eq. 1. Each parameter value will change along with the altitude changes of an atmospheric balloon:

Corresponding Author: Agit Zulharman, Department of Computer Systems, Faculty of Engineering and Computer Science, Universitas Komputer Indonesia, Bandung, Indnesia

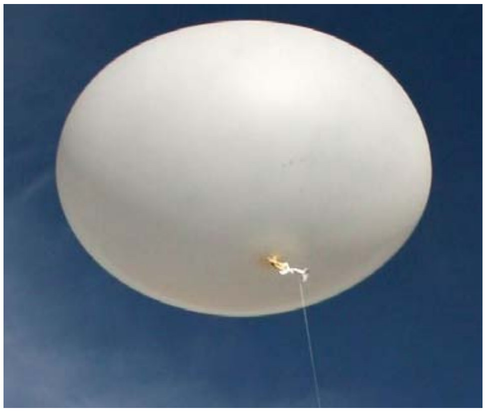

Fig. 1: Atmosphere balloon (www.balloonchallenge.org)

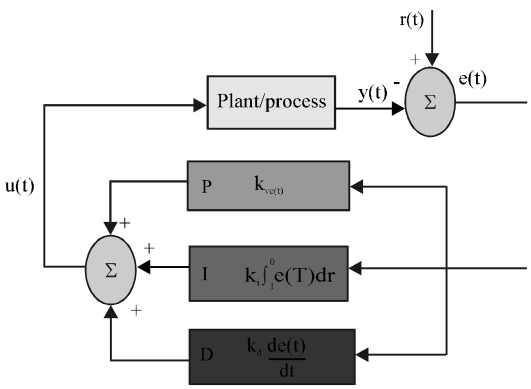

Fig. 2: PID control block diagram (www.en.wikipedia.org)

$$T = V (p-p_g) \quad (1)$$

Where:

T = Gross lift
V = Balloon volume
p = Air density
p_g = Chosen gas density inside the balloon (example: hydrogen, helium)

Free lift is the uplift needed for carry the payload with certain velocity. The free lift value (L) is show in Eq. 2:

$$L = T - W \quad (2)$$

where, W is the total payload weight from the balloon weight and payloads weight. If L is close to zero or total lift is equal to the total payload weight then atmosphere balloon can not moved up or down and so the balloon will be floated in the air (Garry, 2006).

Proportional Integral Derivative (PID) control: A Proportional-Integral-Derivative control (PID controller) is a feedback control mechanism (feedback controller) commonly used in industrial control systems. A PID controller continuously calculates the error value as the difference between the measured process variables and a desired set point (Gunterus, 1997). The controller tried to minimize errors from time to time by adjusting the control variables such as valve position control (Fig. 2).

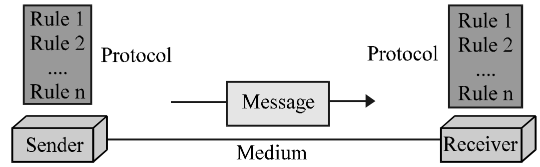

Fig. 3: Data communication component Forouzan

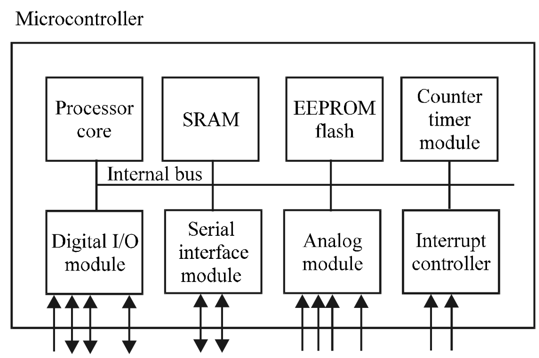

Fig. 4: Block diagram of general microcontroller 3 (Gridling and Weiss, 2007)

Radio communication data theory: Data communication is the exchange process of data between two devices via some form of transmission medium such as cable wire. In order for data communication occurs, communication devices should be part of a communications system consisting of a combination of hardware (physical equipment) and software (program) (Fig. 3).

Microcontroller: A microcontroller is a processor with memory and other components attached or integrated on a chip (integrated chip) (Gridling and Weiss, 2007). A microcontroller contains all the components that allow it to operate independently and has been designed specifically to monitor and/or to control a task. Additionally the processor includes a memory, various interface controller, timers, an interrupt controller and a general purposed I/O that allows directly involve with the environment. The microcontroller also includes a bit operation which allows to change one bit in a byte without interfere with other bit (Fig. 4).

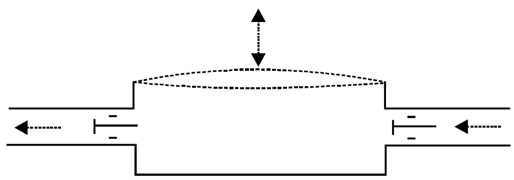

Fig. 5: Diaphragm pump diagram (www.en.wikipedia.org)

Multiwii: Multiwii is multirotor general purpose software to control various multi-rotor radio-controlled models. Originally developed to support gyroscopes and accelerometer console in Nintendo-Wii but now widely used in various sensors. This Multiwii project is an opportunity to develop our own software on Arduino platform. In this project, multiwii being used as a firmware for microcontroller that used as controller. Multiwii program has been modified in such a way that supports the desired control system on this project.

Diaphragm pumps: A diaphragm pump (also known as a pump membrane) is a positive displacement pump that uses a combination of reciprocating action of a diaphragm rubber, thermoplastic or teflon and valves on both sides of the diaphragm (check valve butterfly valves, flap valves, or other form of valve shut-off) to pumping fluid or air (Fig. 5).

DC motor driver with IC L298: L298 is a monolithic integrated circuit which has a high-voltage, driver dual full-bridge high current designed to be able to work at a low logic level TTL (standard) and induces loads such as relays, solenoids, DC motors and stepper motors (Tjahyadi, 2015). Two input-enable are provided to enable or disable the device independently from the input signal. Emitter of the transistor at the bottom of each bridge are connected together and the corresponding external terminal can be used for connection of an external resistor sensing. An auxiliary power supply is provided so that the TTL logic are able to work at low voltage.

Servo control: The minimum and maximum pulse width of the motor servo were vary with each of its manufacturer. Yet, however the value for the neutral position ranges from 1.5 m sec. Usually the minimum pulse width varies from 0.5-1 m sec while the maximum pulse width are varied from 2-3 m sec. Generally, the frequency of the pulse signal in a servo is 50Hz but this can be varied between 30-200 Hz. The voltage was also varied from 2.5-10 V (Fig. 6).

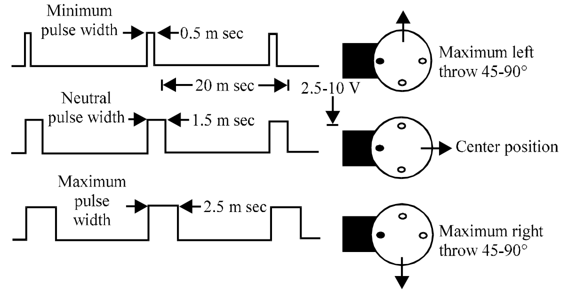

Fig. 6: Servo motor pulse width (Richling, 2012) www.mitchr.me

RESULTS AND DICUSSION

Design

General system design: The image above is a general block diagram of the altitude atmosphere balloon control system (Fig. 7).

Hardware design: Hardware design aims to configure the electrical system on a payload consist of microcontroller and several sensors. The figure below describe the connection between components in the payload and radio component connection as a transmission system. To make it easier to understand, the hardware system design is divided into four sub-systems namely:

- Power supply system
- Processing system
- Actuator system
- Transceiver system

Fourth subsystems have different components in its development and also have different functions. But four of them has a relationship to form a complete system (Fig. 8).

Hardware design of payload embedded board: Embedded board hardware design aims to facilitate the placement and installation of various components of the payload. Besides providing the component location, embedded board also has a circuit that connects the battery into various regulators used in this design.

The PCB were printed into the form of a letter "H" with the purpose to optimize the placement of the hardware components based on the tubular-shape chassis. With this design, all the hardware components will be fitted inside the tube chassis. The following figure is the PCB layout (Fig. 9).

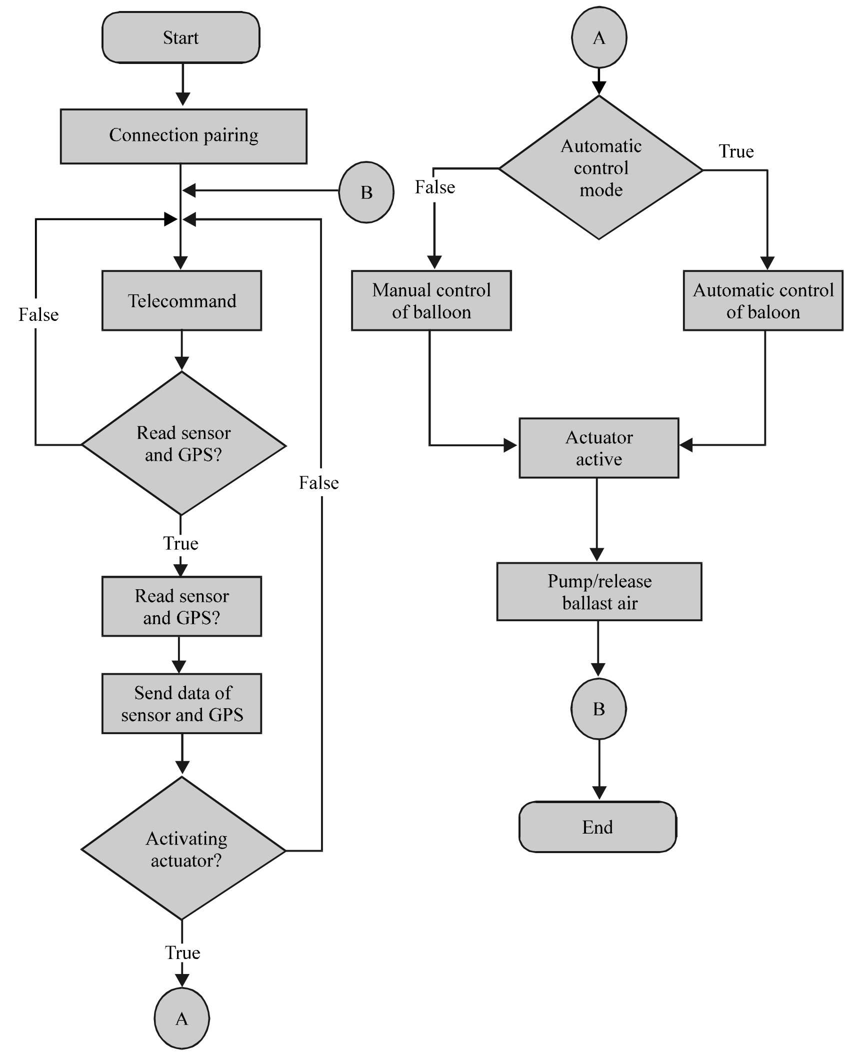

Fig. 7: Flow diagram of altitude control system for atmosphere balloon

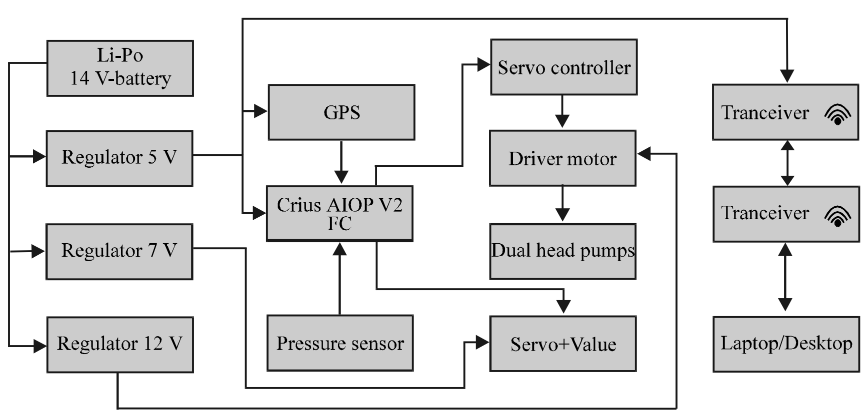

Fig. 8: Block diagram of the system of the hardware

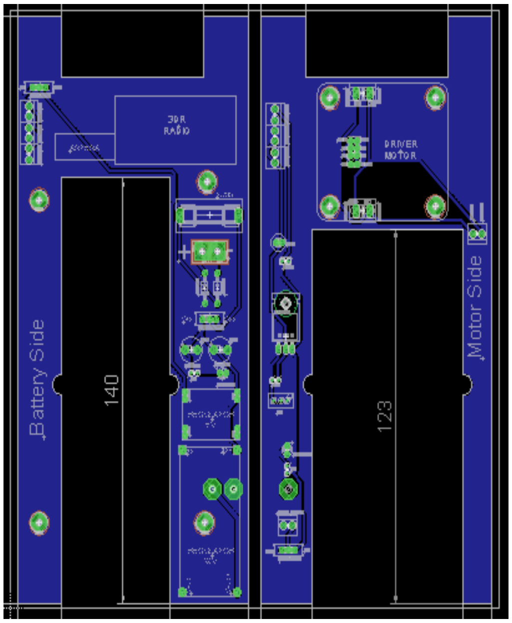

Fig. 9: Embedded board PCB layout

Fig. 10: Payload design

Payload design form: Chassis shape design has become one of the important design because the design form will affect many aspects in controlling the payload in the air. The chosen form for this payload is the shape of a tube. The reason for this is to have a good aerodynamic in the payload and also all of the hardware components can be fitted inside the payload. Figure below is the form design for altitude atmosphere balloon payload (Fig.10).

Design of control systems: Control system design aims to produce a control system capable of controlling the vertical motion of the balloon to be able of float at certain altitudes. Control system used in this design is the PID (Proportional, Integral, Derivative) control system. PID control systems have been selected in order to accelerate the actuator response for controlling the vertical movement of the balloon (Fig. 11).

Design of control balloon GUI (Graphical User Interface): GUI design aims to create an algorithm for the GCS (Ground Control Station) so that the payload could communicate and gave an instruction to perform the operation with GCS. GCS in the form of GUI (Graphical User Interface) are able to monitors and controls the payload on the ground. GCS would provide instructions to the payload such as instructions to activate and deactivate actuators, altitude sensor data request and so on (Fig. 12).

Testing

Testing flow rate of dual head motor pump: Based on the curves in Fig. 13 the significant increase in the pump motor flowrate from minimum to maximum indicated when the value of the pulse is in the range from 1500-1400. At the time of the pulse value is smaller than 1400, large flowrate pump motor does not show significant changes ranged between 9.9-10.2 LPM (Liters Per Minute). So by looking at these curves can be concluded that to control a large pumping of air (from minimum to maximum flowrate) into the balloon, the ballast require only +100 of step pulse value.

Testing PID control response toward actuator: By looking at the curve of PID control response towards output PID value in Fig. 14 it can be concluded that this control can be stated as a control that has underdamped response or sufficient damping response. Then a threshold value from 0-100% were used to measure rise time value of the system. Thereby, the system transient response parameters were measured qualitatively (Ogata, 2002) as follows:

- Delay time for 3 sec
- Rise time for 5.15 sec
- Maximum overshoot for 6.80%
- Settling time for 6.05 sec
- steady-state error for 3.80%

Testing of altitude based on GPS and pressure: Altitude test for the altitude sensor are conducted in several location in different altitude. Testing is done by compare

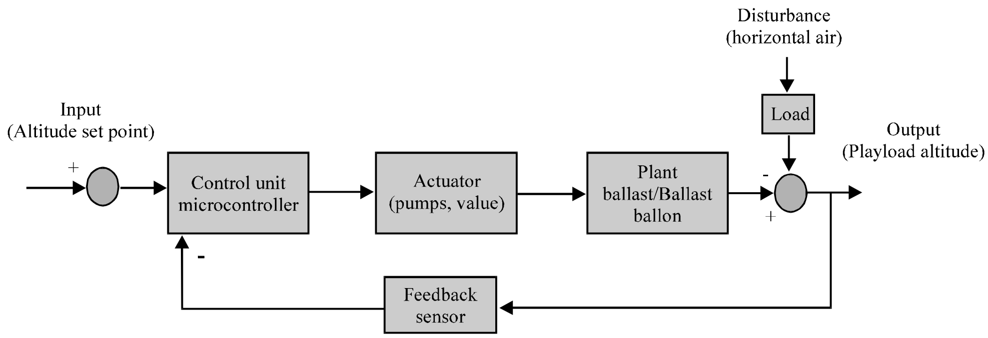

Fig. 11: Closed loop altitude balloon control system

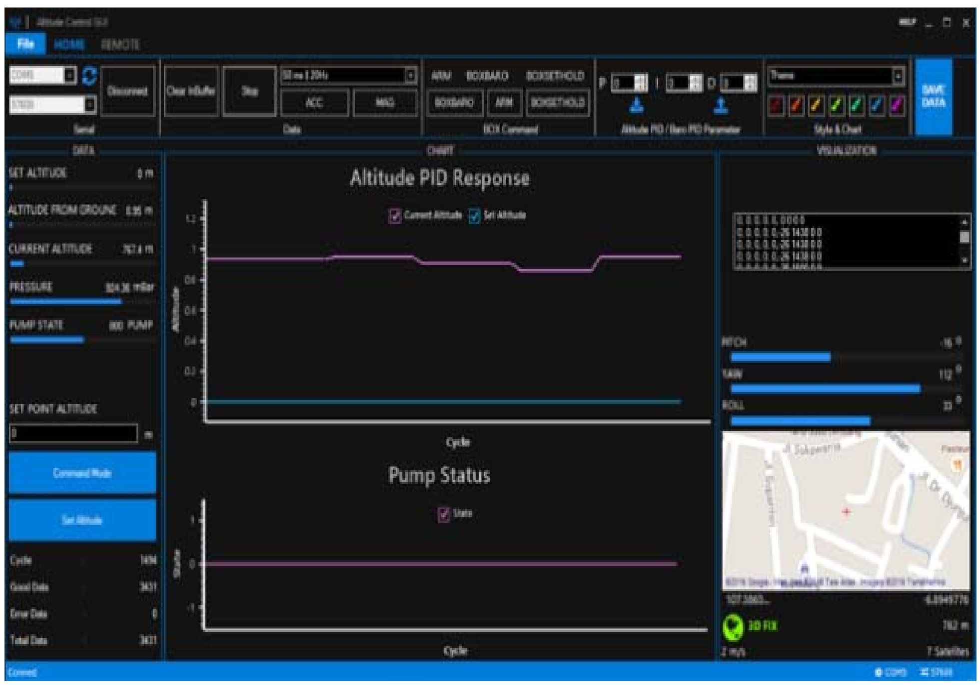

Fig. 12: Design of control balloon GUI (Graphical User Interface)

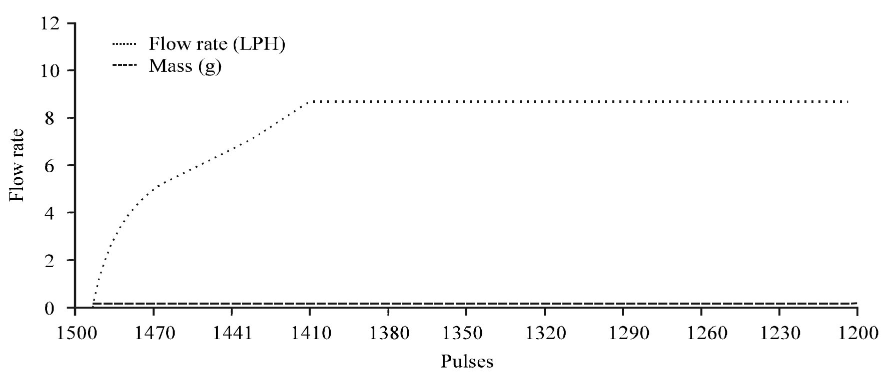

Fig. 13: Effect of pulse throttle to pump flowrate and mass of ballast

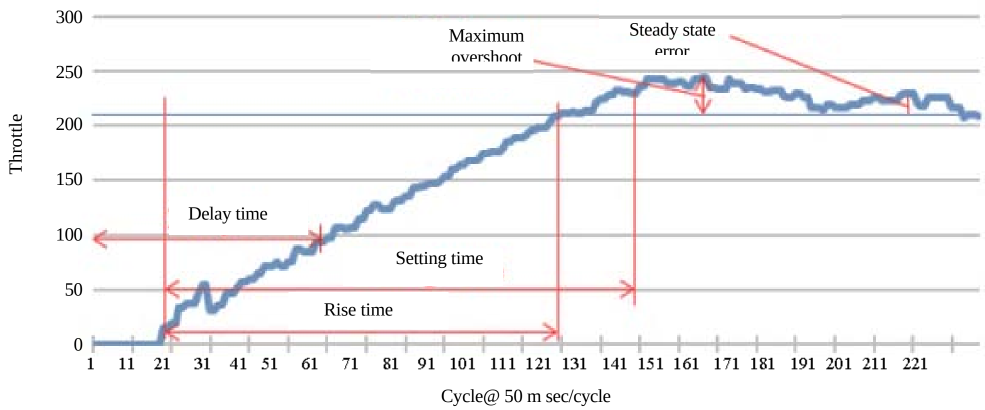

Fig. 14: The response of the PID control towards PID output

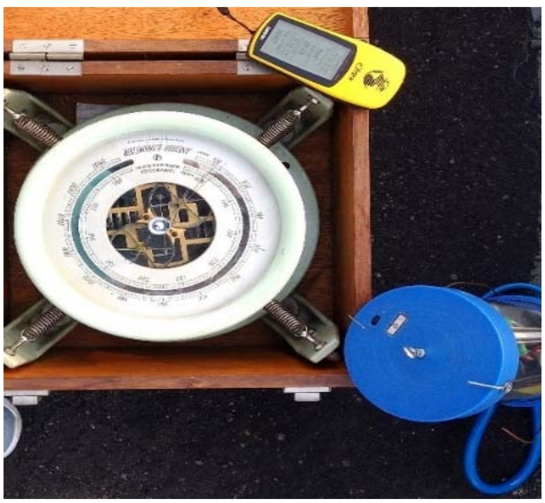

Fig. 15: Testing altitude and pressure with different instruments

Fig. 16: Tether test

pressure and altitude value obtain from various of measuring instruments as shown in Fig. 15. The instrument used to perform the comparison such as portable GPS garmin, GPS GP-635T, analog barometer of Yanagi Gauge and instruments Japan and a pressure sensor MS5611-01BA01 at the same altitude position above ground. By comparing MS5611-01BA01 sensor that was used to do the control, the expected results of the control will achieve good value.

Testing communications of GCS (Ground Control Station) with control payload: The successful percentage level of the data communication refer to the checksum value from the data send equal with the calculated checksum or in other words, data is completely received in full without any missing data. So, the uncompleted data that was detected will be regarded as error data. Tests showed the data of radio communication with a success rate of 100% in 14 trials. Thus, it can be concluded that the radio transceiver with modified antenna and the transmit method with MSP protocol is very reliable on handling of fast data transmission. The system are very suitable for equipment that needs real time control in this term for altitude control atmospheric balloon (Table 1).

Tether test: Tether test is basically a test method by holding the balloon (tether the balloon) so that it does not move around freely in the air. Tether test is the final stage of testing procedure in which will answer the result of design control with ballast, in this case the test will use two balloon , the upper balloon is the atmosphere balloon for lifting the payload and the lower balloon for ballast filled with air to achieve floating condition (Fig. 16).

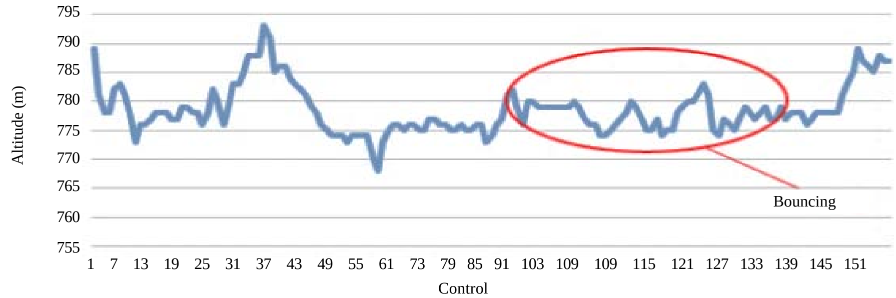

Fig. 17: Curve effect on manual control towards the GPS based altitude

Table 1: Communication testing

Los distance (m)	Total receiving data	Good data	Erorr data	Achievement (%)
10	96	96	0	100
20	84	84	0	100
30	88	88	0	100
40	69	69	0	100
50	69	69	0	100
60	57	57	0	100
70	57	57	0	100
80	54	54	0	100
90	46	46	0	100
100	57	57	0	100
110	61	61	0	100
120	54	54	0	100
130	57	57	0	100
140	65	65	0	100

While doing the tether test, it is found that the air discharge system does not run well on the ballast balloon with weights 1000 g in outdoors condition. It is characterized by small flow of wind that come out from the discharge neck of the balloon when the air valve is opened, this is seem as if the air pressure inside the balloon is almost equal to the air pressure outside the balloon. This situation disrupt the automatic control system with PID algorithms that have been designed previously. Due to this situation, testing procedure then change into manual control performed by an actuator control at GCS to test the ability of ballast. Figure 17 showed that at altitude 775 m above sea level (approximately at a height of 3 m from the ground), the system are able to lower the height of the balloon from time step 1 until time step 57 but the balloon is not stable at these time step. The balloon reach its stability from time step 58 up to 78 but after that the balloon bouncing up and down in less than 3 times in time step 78 sec to 125. This bouncing is probably caused by wind near the surface which drag the upper balloon and also the ballast balloon.

CONCLUSION

Based on observations and data that have been obtained from some testing, the design of control altitude atmosphere balloon based on multiwii with air filled methods and the ballast-air discharge produced the following conclusion.

Has successfully built an atmosphere balloon vertical movement control system using controlled ballast. Ballast control system works against free lift of the balloon atmosphere. The control system is equipped with a wireless data communications transmission via RF radio who has tested and reliable.

In testing control system algorithm with tether test method, it found three constraints that affect the set point, the first is bouncing effect on ballast balloon or lifting balloon. The second factor is temperature affect on PCB surface to pressure sensor. This will affect the result of computing PID control, it will even cause the system to become unstable and generate undamped response (oscillate with growing amplitude). The third factor is the blockage in the neck folds of balloon when shock occur and affect the process of charging/expense of air into/out of the ballast bag. This will complicate the control process because the air flow into the coffers of ballast is clogged. Even this will cause a damage to the pump due to push back the air who should be pumped out.

ACKNOWLEDGEMENTS

This study was supported by the Indonesia National Institute of Aeronautics and Space (LAPAN) and Indonesia Computer University (UNIKOM). I would like to thanks to Mrs. Laras, Mr Heri and team from embedded system research division of UNIKOM for their help in this study.

REFERENCES

Garry, B., 2006. Controlling a helium balloon. Barrygray, UK. http://www.barrygraygillingham.com/Tutoring/BGasBal.html.

Gridling, G. and B. Weiss, 2007. Introduction to Microcontrollers. Vienna University of Technology, Vienna, Austria, Pages: 159.

Gunterus, F., 1997. Philosophy Basic Process Control System. Elex Media Komputindo Publishing Company, Jakarta, Indonesia.

Ogata, K., 2002. Modern Control Engineering. 4th Edn., Prentice Hall, New Jersey, USA., ISBN: 9780130609076, Pages: 964.

Richling, M., 2012. R/C control signal. Mitch Richling, Weston, Connecticut. http://www.mitchr.me/SS/batteriesRequired/RCcontrolTheory/.

Tjahyadi, C., 2015. H-bridge 4A dengan L298. Christianto Tjahyadi, Indonesia. http://christianto.tjahyadi.com/mikrokontroler/h-bridge-4a-dengan-l298.html.