Designing on-Board Data Handling for EDF (Electric Ducted Fan) Rocket

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Abstract. The EDF (Electric Ducted Fan) rocket to launch requires a system of monitoring, tracking and controlling to allow the rocket to glide properly. One of the important components in the rocket is OBDH (On-Board Data Handling) which serves as a medium to perform commands and data processing. However, TTC (Telemetry, Tracking, and Command) are required to communicate between GCS (Ground Control Station) and OBDH on EDF rockets. So the design control system of EDF rockets and GCS for telemetry and telecommand needs to be made. In the design of integrated OBDH controller uses a lot of electronics modules, to know the behavior of rocket used IMU sensor (Inertial Measurement Unit) in which consist of 3-axis gyroscope sensor and Accelerometer 3-axis. To do tracking using GPS, compass sensor as a determinant of the direction of the rocket as well as a reference point on the z-axis of gyroscope sensor processing and used barometer sensors to measure the height of the rocket at the time of glide. The data can be known in real-time by sending data through radio modules at 2.4 GHz frequency using XBee-Pro S2B to GCS. By using windows filter, noises can be reduced, and it used to guarantee monitoring and controlling system can work properly.

1. Introduction

Rocket and space technology is one of the leading technology targets for countries in the world to get the title as a developed country. No doubt, a country capable of mastering this technology will be respected in the world political arena. Indonesia as a large and vast archipelago country should have independence in the mastery of rocket and space technology. Therefore it is necessary to continue efforts to realize this independence, one of them through the effort to develop a love of aerospace technology, especially the technology of rocking from an early age. The importance of the development of rocket technology, then we must have the will and ability to examine the field of rocket technology, both rocket and rocket technology itself. Starting from designing, creating, functional testing to carry out flight test. Through understanding the behavior of rockets, both RUM rockets, and EDF rockets. Meanwhile, in this research will focus on making monitoring system, data processing of rocket behavior and Control of EDF Rocket by OBDH (On-Board Data Handling). OBDH has a function to perform commands and processing existing data on a rocket via TTC (Telemetry, Tracking, and Command) [1-4].

The purpose of making this EDF rocket is as follows, designing an OBDH system that contains a data measurement system (sensor), data processing (microprocessor), data communication (radio frequency), and power supply (battery). With OBDH intended to conduct telemetry, telecommand, and tracking [2-4]. Building Ground Control Station Software (GCS) using Microsoft Visual Studio application where should be able to:
• Communicate with OBDH system on EDF rocket.
• Display data of OBDH measurement results in numeric or graphic formats.

2. OBDH (On-Board Data Handling) and IMU Sensor

2.1. OBDH
OBDH is a microcontroller that has input, output, and sensors that are used to support OBDH function. OBDH also serves as an interface or link between other subsystems. Such as communication, and sensors that have been integrated with the microcontroller. The OBDH function has two main functions, the first function is to receive, validate, decode, and route commands to other rocket sub-systems. The second function is to collects, processes and manages the work and status of OBDH. In addition, OBDH generally has additional functions, such as timeliness, monitoring (watchdog), and security interfaces [1-3].

The size of the OBDH subsystem is usually directly proportional to the complexity and functionality of the system to be created. The more systems and functions you want to use, the more components you need in OBDH. In addition, to make the OBDH sub-system more reliable, OBDH sizes can be enlarged and added some peripherals that can support OBDH stability. To collect data, we use a lot sensor such as accelerometer, gyroscope, and magnetometer [4,5,7].

2.2. IMU Sensor

![Illustration of accelerometer sensor](image)

**Figure 1. Illustration of accelerometer sensor**

Captions of Figure 1:
• + 1g, the unidirectional position of the sensor in the vertical direction of the earth and facing upwards.
• 0g, the unidirectional position of the sensor in the direction of the horizontal earth. Accelerometer sensors can also be used to measure the angle of an object when in a static state [4-7]. The slope angle can be calculated by the acceleration using the following equation:

\[
x = \tan^{-1}\left(\frac{akskelerometer X}{akskelerometer Z}\right)
\] (1)

\[
\theta_y = \tan^{-1}\left(\frac{akskelerometer Y}{akskelerometer Z}\right)
\] (2)

The gyroscope is a device that serves to measure angular velocity or maintain rotational motion. The unit of angular velocity measured in degrees per second (°/s). By utilizing the angular velocity data can be known angle (roll, pitch, yaw) an object. To find the angle value, angular velocity data must be integrated [4-7]. The equation is the following:

\[
\theta_{(x,y,z)} = \int gyro (x,y,z) dt
\] (3)

\[
dt = T = t_n - t_{n-1}
\] (4)

where:
T = time sample
n = \{1,2,3,...\} values
gyro (x,y,z) = Gyroscope data (°/s)
For rocket attitude, we need to find it's position, included pitch, yaw, and roll. The mathematical equations applied to the microcontroller are as follows [4-7]:

\[ \theta(x,y,z)_t = \text{gyro}(x,y,z) \times T + \theta(x,y,z)_{t-1} \]  

(5)

A magnetometer is a useful electronic device for measuring the strength of a magnetic field. The existence of the earth's magnetic field originating from the north makes the magnetometer sensor can be used to measure the angle to the northern directions of the earth [5-7]. The equation to know the value of the compass is as follows:

\[ \text{Angle}(\theta) = \arctan\left(\frac{\text{Mag}Y}{\text{Mag}X}\right) \]  

(6)

Where:

- MagX = output value form magnetometer for X axis
- MagY = output value form magnetometer for Y axis
- Angle(\theta) = value which can be derived from magnetometer (angle)

A barometer is a sensor to measure air pressure with an output value of Pa (Pascal). By utilizing the air pressure, then this sensor can also measure the altitude (Altimeter) [5-7]. The equation measuring the altitude using a barometer sensor is as follows:

\[ \text{altitude} = 44330 \times \left[1 - \left(\frac{P}{P_0}\right)^{\frac{5.255}{29.6}}\right] \]  

(7)

Where:

- P = pressure(Pa)
- p0 = sea level standard atmospheric pressure (101325Pa)
- altitude = Altitude value (Meter above sea level)

3. OBDH Design

![Figure 2. OBDH block diagram](image)
Here is a list of a lot of component for OBDH:

- Teensy 3.1
  - A microcontroller to process a data from IMU sensor and also communicate with Ground Control Station
- XBee-PRO S2B
  - It is a radio modem for transmitting and receive data
- 10 DOF IMU
  - This a 10 DOF inertial measurement unit sensor for measure acceleration, angle, pressure, altitude of EDF Rocket
- GPS Ublox NEO-6
  - A GPS module for tracking.
- RC (Remote Control) receiver
  - Receiving signal and convert it into PPM (Pulse Position Modulation).
- Servo Motor
  - For trigger to open/close parachute
- ESC (Electronic Speed Control)
- ESC (Elektronic Speed Control) to control a speed of brushless motor.
- Brushless Motor
  - It is used as an actuator for EDF Rocket
- Power Supply
  - Based on DC power by using Lithium Polymer (LiPo) with 11.1 Volt and 1300 mAh.

Based on those part, here is a result of OBDH system for EDF Rocket

Figure 3. OBDH board top

Figure 4. OBDH board bottom
4. Ground Control Station

Ground Control Station (GCS) is used to telecommand, telemetry, tracking GPS, enable EDF motor and display sensor data in the form of numbers and graphics. All of the data as stored in databases system and it can be used for the further purpose [5-8].

5. Results and Discussion
Mechanical Filtering This window is applied to data acceleration and angular velocity only. The goal is that the noise from the acceleration data and the angular velocity that appears when the stationary device can be filtered [6-8].
Based on Figure 6 can be seen that by using the Mechanical Filtering Window can overcome the error data on the OBDH device in a state of silence (immobile) caused by very small vibration, mechanical noise or less precisely in determining the offset value [6-8].

![Graph of height sensor testing](image)

**Figure 7.** Altitude graph

The launch time of the rocket is 10 seconds and at 10 seconds the height of the rocket reaches 1076 meters above sea level or about 106 meters. Thus the altitude sensor can function properly.

6. **Conclusion**

On-Board Data Handling (OBDH) design results in power supply systems, sensors, microcontrollers and communications (radio frequency) have been successfully designed. And OBDH Hardware has successfully done telemetry, telecommand, and GPS tracking. This is based on the launch test results where data can be well received on GCS applications. Using the Mechanical Filtering Window can discriminate the small error value that arises when the object is idle. The error that appears when OBDH hardware is silent 99% successfully removed.

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