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Arduino-Based Real-Time Drone Performance Monitoring with MEMS Sensor Application

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Abstract

This paper presents the design and implementation of a real-time drone performance monitoring system using MEMS sensor applications. The system employs MPU6050 gyroscope and accelerometer modules to collect key parameters such as orientation and stability. It also integrates voltage and current sensors (SIMPLE B25, ACS712, INA219) for energy monitoring. Data are processed via Arduino UNO and ESP32 microcontrollers and displayed using Arduino IDE and ThingSpeak cloud. This setup enables real-time tracking and enhances operational efficiency, making it suitable for applications like autonomous navigation and aerial surveillance. Results obtained shows the prototype operated efficiently and works as intended. In conclusion, the proposed system demonstrates the ability of MEMS sensors working in tight structure of a drone.

1. Introduction

Real-time monitoring of the performance of drones is necessary for maximum operational efficiency and safety in different applications. The combination of Arduino and MEMS sensors like gyroscopes and accelerometers have become essential parts of today's drones. The sensors provide accurate measurements of angular velocity, acceleration, and orientation for controlled and stable flights [1]. Integration of MEMS sensors with machine learning algorithms also improves the sensor's performance, allowing for high-level applications such as virtual reality-based drone control [1-3].

Low-cost MEMS inertial sensors have been effective in precise attitude determination for UAVs. The sensors offer strong attitude estimation using methods such as the Kalman filter, even in adverse conditions. Compactness and low cost qualify them for consumer and industrial UAV applications. Compensation of sensor shortcomings such as noise and drift remains an important part of delivering high accuracy to navigation and orientation control [4-6].

Moreover, the low-cost MEMS sensors and nonlinear filtering approaches offer a low-cost yet reliable attitude estimation solution for UAVs. The approach ensures high reliability at low cost, and therefore, it is set to be adopted in numerous fields. Utilization of nonlinear filters effectively removes sensor noise impacts and improves the accuracy of attitude estimation in drones [7-10].

Thus, MEMS sensor technology is the fulcrum of real-time drone performance monitoring innovation. When combined with machine learning and smart filtering algorithms, it greatly enhances navigation accuracy and stability to meet expanding needs of commercial and industrial drone applications [11-13].

1.1 Problem Statement

With drones being applied to a variety of settings, this necessitates the having systems that provide real-time performance tracking. The requirements to maintain stability and orientation while ensuring operational outputs with an aerial platform can be impacted due to the variety of dynamic tasks [14]. Current monitoring systems do not have the capacity to provide real-time feedback, resulting in inconsistencies during critical performance measures. Utilising MEMS state sensors, the proposed system will provide real-time monitoring and allow drones to collect real-time data on angular velocity, orientation and acceleration to provide a drone with an efficient and consistent basis of operation especially for beginners [15].

Using MEMS sensors for real-time detection and monitoring by integrating MEMS sensors into drone system for real-time reporting and Arduino for performance monitoring, the user will be able to capture deviations or irregularities quickly and potentially remedy them immediately. This type of mechanism improves the drone's ability to cope with change in a dynamic environment and maintain that record over time with predictability and accuracy [16]. The live performance reporting gives a direct understanding of the drone's performance metrics, while maintaining a baseline to improve upon for operating portrait for normal interventions. Real-time performance monitoring will solve the operational criteria currently limiting drone capabilities, as well as develop opportunities to maximize drone capabilities in an expanding sector in the economy.

2. Methodology

This chapter outlines the methodology employed for the development of the Arduino-Based Real-Time Drone Performance Monitoring System utilizing MEMS sensors. The methodology is structured in phases to ensure a systematic approach, starting from hardware design and integration to data acquisition and analysis. Each phase is described in detail, focusing on the processes, parameters, and variables involved, as well as the testing procedures to validate the system's functionality and performance. A clear project flowchart is provided to illustrate the step-by-step process, ensuring all components work seamlessly to achieve the intended objectives. This methodology emphasizes iterative testing and optimization to enhance the system's efficiency and reliability. By following this approach, the project aims to deliver a robust monitoring system that meets the requirements for real-time drone.

2.1 Overview of the System

The drone system integrates MEMS sensors, communication modules, and a microcontroller to monitor performance metrics like orientation and acceleration in real time. It uses MPU6050 for precise data collection and the ESP32 module for Bluetooth and Wi-Fi communication. Power management is ensured using INA219 power sensors to track voltage and current during flight. The system, programmed via Arduino IDE, ensures efficient data acquisition and transmission while maintaining reliability. Fig. 1 shows the mechanism for the system.

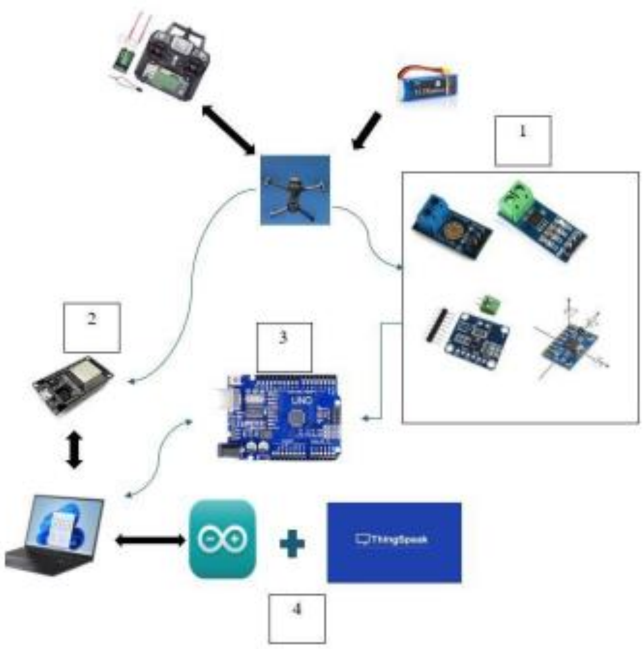

Fig. 1 *Drone system overview*

Based on the system overview in Fig. 1, the functions of each component are as follows:

1. MPU6050: Used for detecting orientation and motion, B25 Module: Used to measure voltage, ACS712 Module: Measures the current flowing through the system., INA219 Sensor: Measures overall power consumption.

2. ESP32: Acts as the communication module, enabling wireless connectivity and corresponding with the software platform.
3. Arduino Uno: Serves as the primary controller for acquiring and processing data from the connected sensors.
4. Arduino IDE and ThingSpeak: Used as the user interface for real-time visualization and monitoring of collected data.

2.2 Prototype Development

The methodology for the Arduino- Based Real-Time Drone Performance Monitoring with MEMS Sensor Application project follows a systematic approach to ensure the design, implementation, and evaluation of the drone monitoring system. The process to involves sensor integration, data collection, data analysis, and display through a user interface, which aims to monitor real-time drone performance. Fig. 2 illustrates the block diagram of the proposed system.

A system that provides an overview of the operational idea must be made prior to system construction. To ensure that the system will provide sufficient performance to achieve the project's goals, the systematic system is essential. Additionally, this guarantees that time are saved by carefully to the project's building approach. The effectiveness of the project's completion will be determined by this process. Fig. 3 shows the prototype of the proposed system.

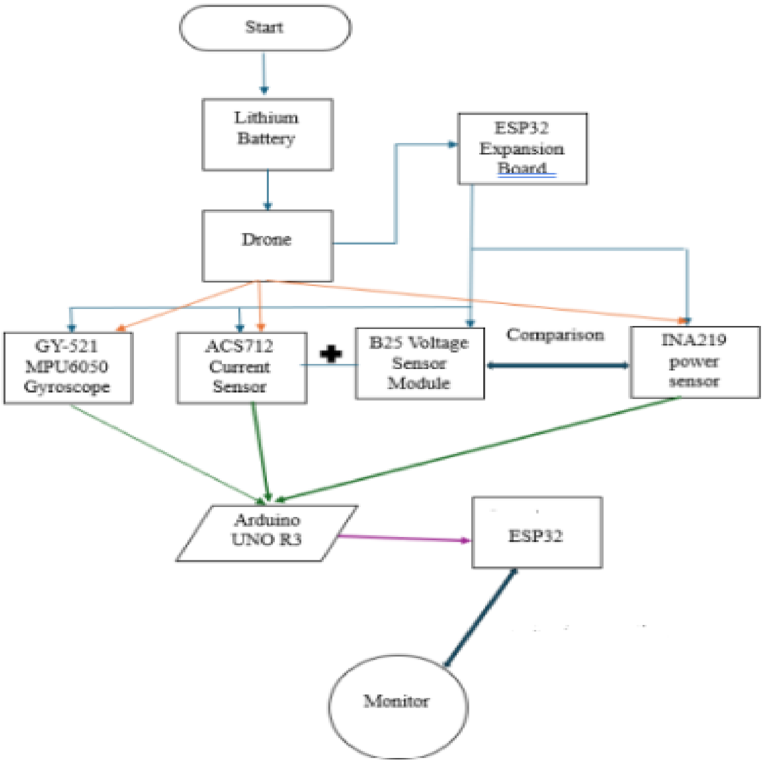

Fig. 2 *Block diagram*

Fig. 3 *Drone prototype*

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3. Result

Initial tests also show the potential of MEMS-based vibration sensors in detecting mechanical anomalies, enabling early identification of potential failures. The integration of MEMS sensors with advanced and enhanced the accuracy of the drone's positioning, contributing to precise navigation and improved environmental interaction.

3.1 Voltage Monitoring

Voltage monitoring is a critical component of the real-time performance monitoring system for drones. By measuring the voltage of the drone's power source, typically a LiPo battery, the system can provide important insights into the drone's operational status. Monitoring voltage helps ensure that the battery remains within a safe operational range and provides early warnings if the power supply is dropping or unstable.

Fig. 4 shows the voltage readings from simulated or sensor data, screenshot from *ThingSpeak* and graph of battery voltage against time. These data are obtained directly from the actual experiment using the prototype.

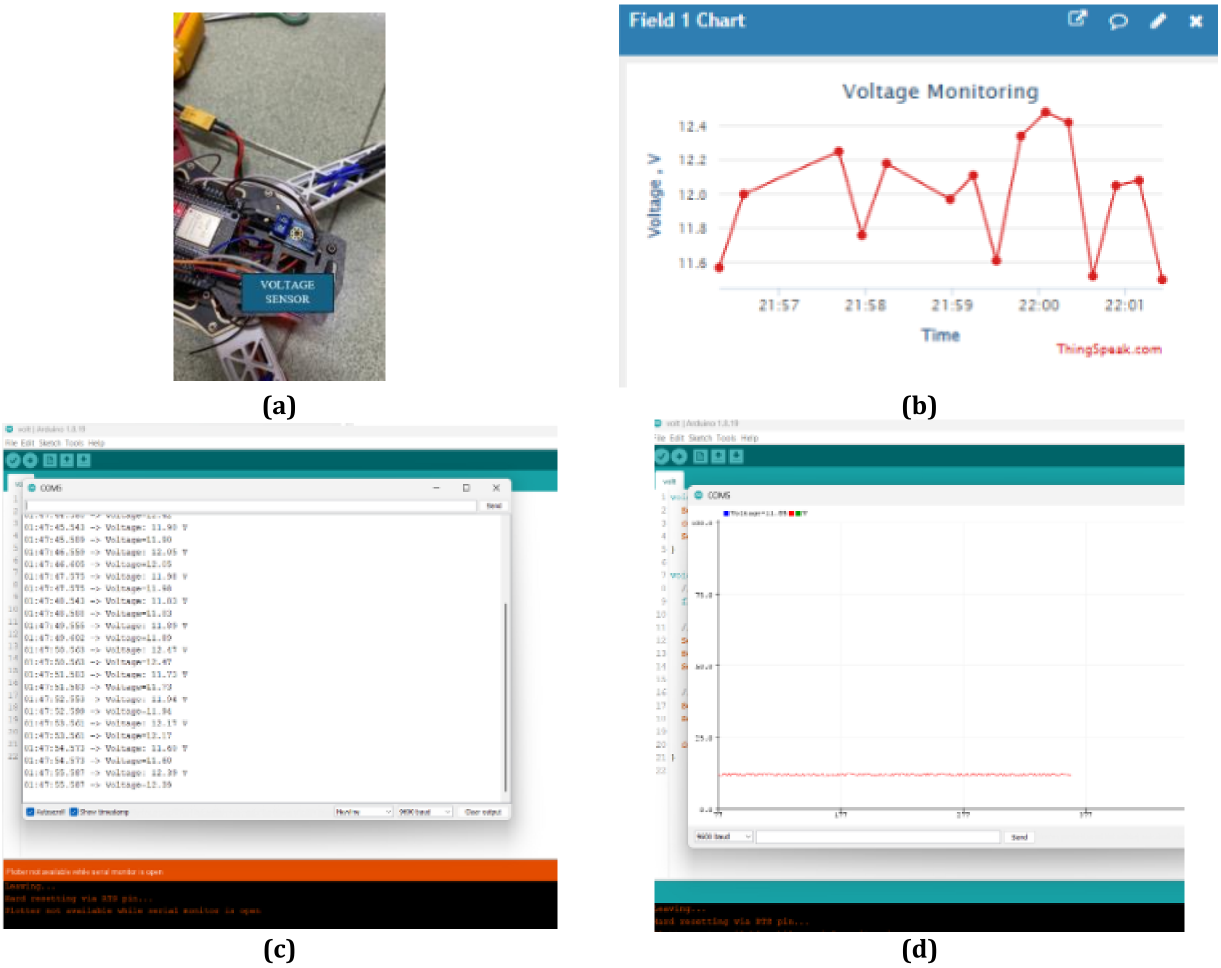


Fig. 4 *(a) Voltage Sensor (b) Thingspeak Voltage graph (c) Serial Monitor Arduino IDE Voltage value (d) Serial Plotter Arduino IDE Voltage Value*

3.2 Current Monitoring

Current monitoring is essential in ensuring that the drone operates within safe electrical parameters. By using a current sensor, such as the ACS712, the system can measure the amount of current drawn by the drone's motors or other electrical components. Monitoring the current helps in identifying any electrical overload or inefficiencies, which is vital for both performance and safety. The sensor outputs a voltage corresponding to the current, and this data can be processed to determine the actual current value, which is then displayed and used for operational insights.

Fig. 5 depicts the current reading obtained from the prototype, *Thingspeak* current graph, serial monitor Arduino IDE current and serial plotter Arduino IDE current. Similar to voltage monitoring, these data are obtained directly from the actual experiment using the prototype.

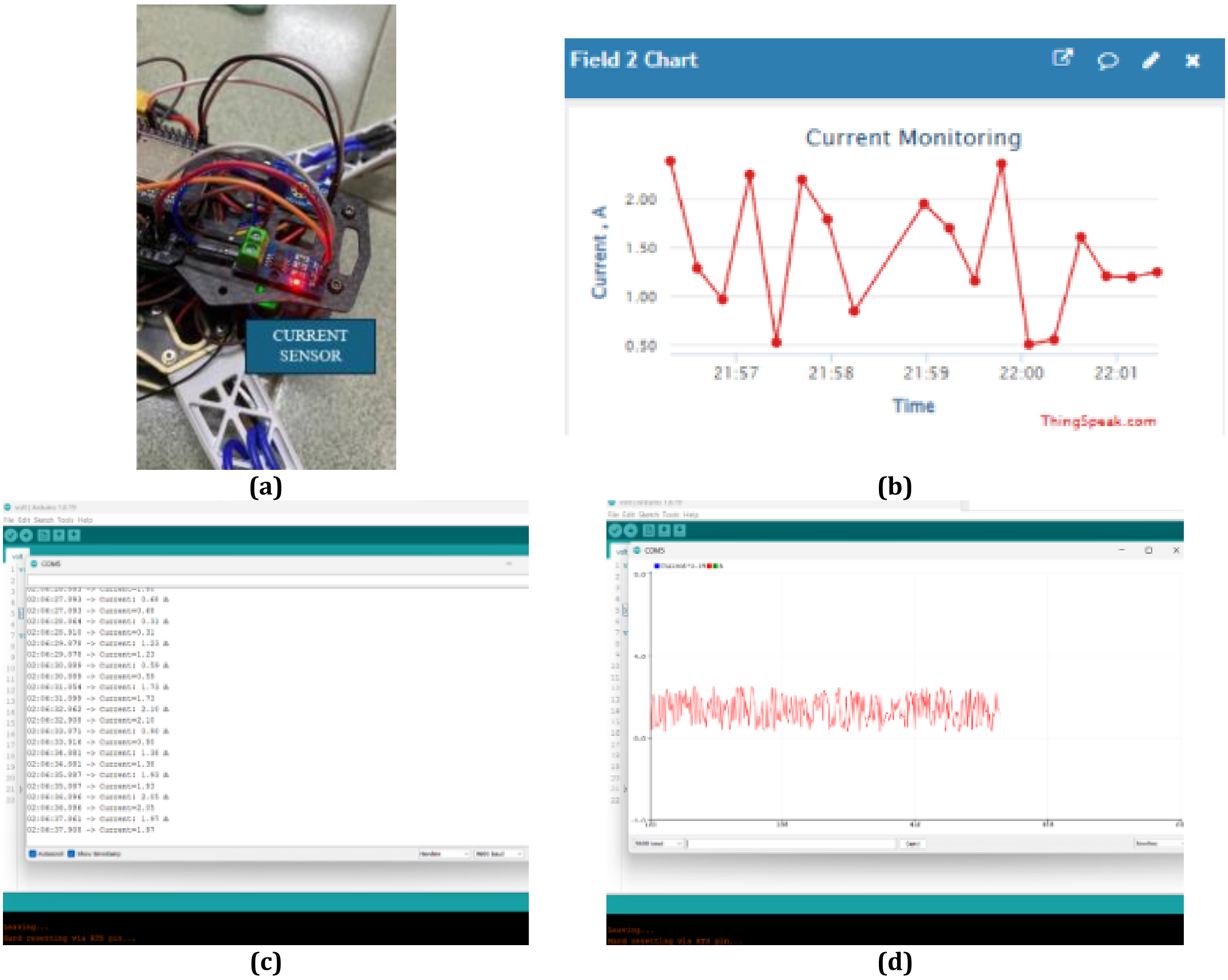
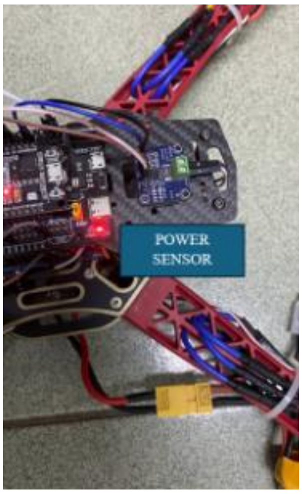


Fig. 5 *(a) Current Sensor (b) Thingspeak Current graph (c) Serial Monitor Arduino IDE Current value (d) Serial Plotter Arduino IDE Current Value*

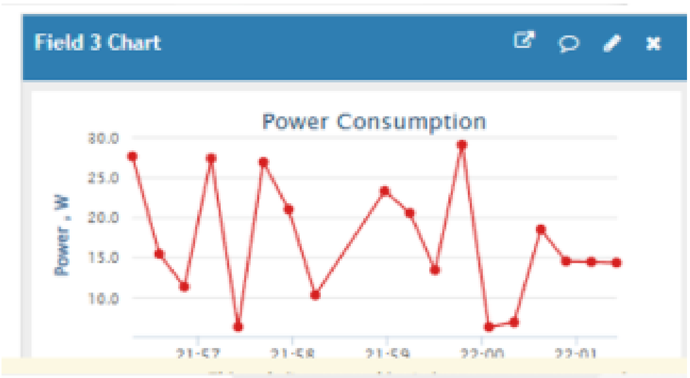
3.3 Power Consumption Monitoring

Power consumption monitoring plays a crucial role in understanding and optimizing the energy efficiency of a drone. By using sensors like the INA219, which measures both the bus voltage and the current, the system can calculate the power consumption in real-time. This is vital for determining the overall efficiency and operational status of the drone, allowing for adjustments or optimizations to extend battery life and prevent power-related failures.

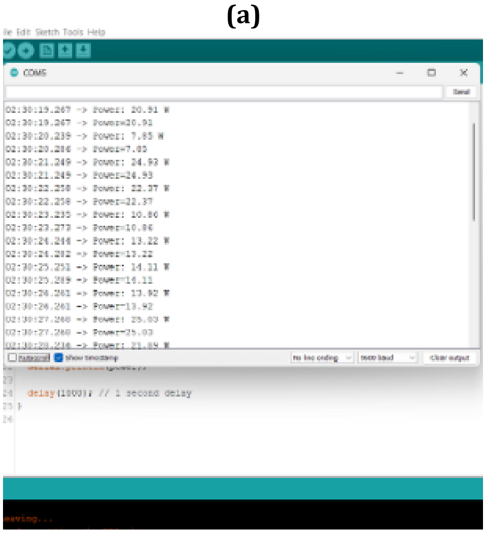
Fig. 6 shows power sensor installed in the prototype, *Thingspeak* power consumption graph, serial monitor Arduino IDE power consumption value and serial plotter Arduino IDE power consumption value. Similar to both current and voltage monitoring, these data are obtained directly from the actual experiment using the prototype.



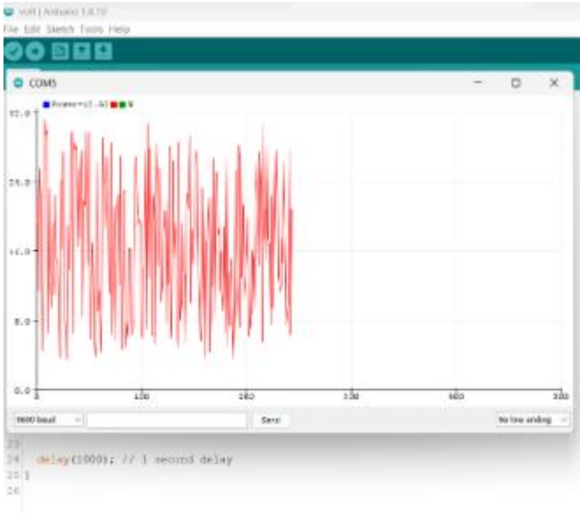
(a)



(b)



(c)



(d)

Fig. 6 *(a) Power Sensor (b) Thingspeak Power Consumption graph (c) Serial Monitor Arduino IDE Power Consumption value (d) Serial Plotter Arduino IDE Power Consumption Value*

3.4 Movement & Orientation Monitoring

The MPU6050 is a popular sensor used for monitoring the movement and orientation of a device, such as a drone or robotic system. It combines a 3-axis accelerometer and a 3-axis gyroscope, allowing for precise measurement of acceleration, rotational velocity, and orientation. The sensor's data is essential for understanding the device's motion, maintaining balance, and making real-time adjustments to its control system. By detecting the angles along the X, Y, and Z axes, the MPU6050 provides orientation feedback that can be used for various applications such as navigation, stabilization, and motion detection.

Fig. 7 shows gyroscope sensor installed in the prototype, *Thingspeak* angle graph, serial monitor Arduino IDE angle value and serial plotter Arduino IDE angle value. Similar to previous data monitoring, these angle data are obtained directly from the actual experiment using the prototype.

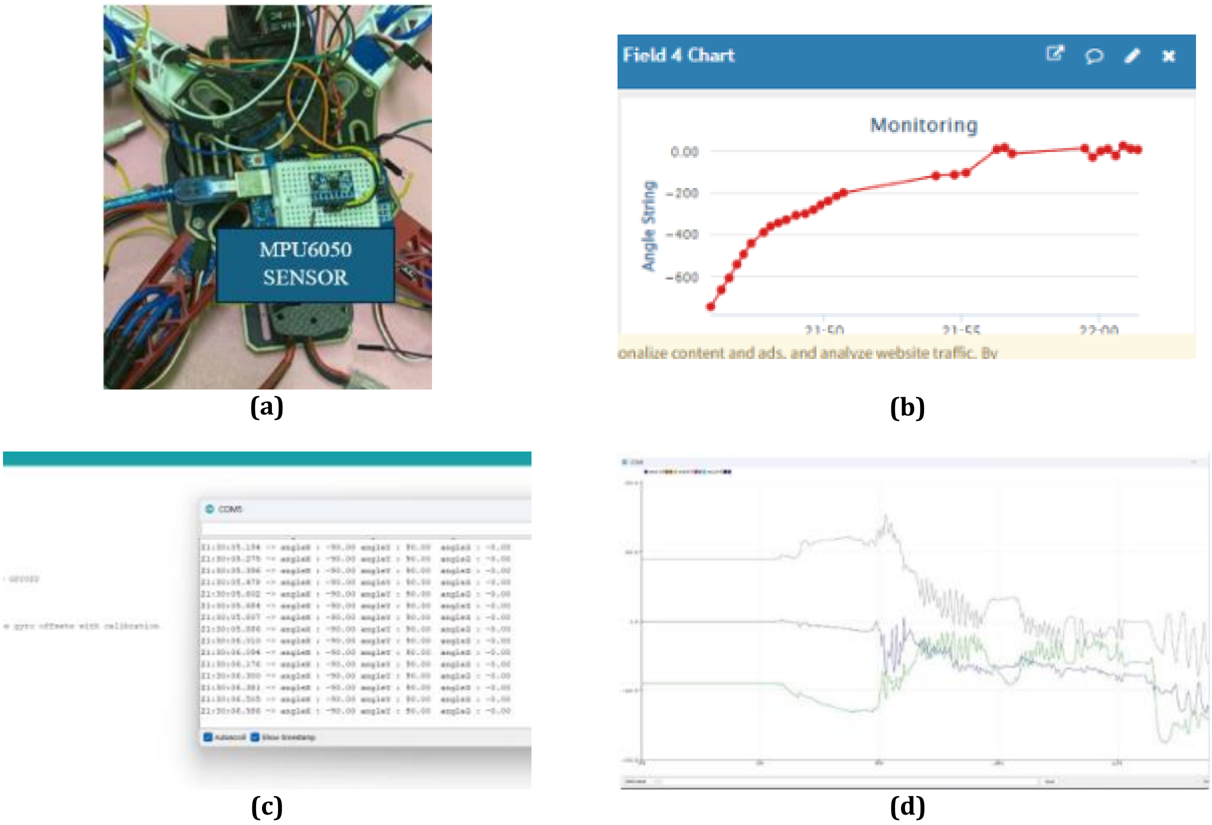


Fig. 7 *(a) Gyroscope Sensor (b) Thingspeak Angle graph (c) Serial Monitor Arduino IDE Angle value (d) Serial Plotter Arduino IDE Angle Value*

4. Conclusion

In this project, *ThingSpeak* integration plays a crucial role in enhancing monitoring systems. All intended data of the prototype are sent at regular intervals efficiently, ensuring continuous updates and long-term tracking for performance optimization. The *ThingSpeak* integration adds convenience by enabling remote access to the drone's status and providing reliable cloud-based data storage and analysis.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution

The authors confirm contributions to the paper as follows: ***study conception and design:*** *Megat Najmudin Jaaffar, Mohd Jais Che Soh;* ***data collection:*** *Megat Najmudin Jaaffar;* ***analysis and interpretation of results:*** *Megat Najmudin Jaaffar, Mohd Jais Che Soh;* ***draft manuscript preparation:*** *Megat Najmudin Jaaffar, Mohd Jais Che Soh. All authors reviewed the results and approved the final version of the manuscript.*

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