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Design And Development of Flight Controller For Quadcopter Drone Control

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ABSTRACT

UAV (Unmanned Aerial Vehicle), also commonly called drone, is a flying robot technology that can be controlled remotely and can also fly autonomously based on the mission given by the operator. Drones are usually used for various purposes such as package delivery, watering plants, land mapping, natural disaster monitoring, photography, videography and others. Drones have many types, one of which is a drone with four motors as the main drive, commonly called a quadcopter drone. Quadcopter drones have evolved a lot based on current needs. Although quadcopter drones have many uses, the development of quadcopter drone research in Indonesia is quite slow, one of the quadcopter drone components whose development is quite slow is the flight controller. Flight controller (FC) is a main controller brain in drones that has complex functions in quadcopter drone control. The function of the FC is to regulate motor speed, stabilize and maintain altitude. In this research, FC is designed to control the stability of quadcopter drones while flying. This FC was developed by applying LoRa technology as an internal receiver. LoRa technology is used to receive control data from the remote control (RC) and simultaneously send sensor data. The purpose of this research is to design FC to improve local products in the field of technology and participate in the development of flying robot technology, especially on quadcopter drones and to determine the performance of LoRa technology after being integrated as an internal transceiver in FC for remote control of quadcopter drones.

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1. INTRODUCTION

Unmanned Aerial Vehicle (UAV) is one type of drone that is growing rapidly until now so that it has a lot of potential that can be explored, both for personal purposes such as hobby toys to professional purposes such as tools for the military. One popular type of UAV is the quadcopter [1].

Quadcopter is a type of multirotor drone that uses four motors to fly. Two motors rotate clockwise and two other motors rotate counterclockwise equipped with a propeller to generate lift [2]. With four rotors, the quadcopter has the ability to maneuver in all directions flexibly. The ability of the quadcopter is utilized by humans to facilitate work in a fairly dangerous environment, such as observation of forest fires [3]. Quadcopters were originally developed in the military field, and can now be studied and developed into various fields such as agriculture, security, disaster areas, weather, and aerial photography [4].

In Indonesia, quadcopter drones are widely developed in agriculture. Drones used in agriculture are called drone sprayers. Sprayer drones are used to water plants or give fertilizer to plants and can also be used to monitor plant growth. With the development of quadcopter applications in various fields, students are expected to develop further with their creativity. One of the important aspects to be developed on the quadrotor is the position stability and balance control system during the hovering condition (hovering while maintaining the initial position point). The required control system must have a reliable and fast response to keep the quadrotor in a hovering condition at the same position point, even though it gets disturbed either naturally or with a physical push [5].

Quadcopter requires a component that can be used to control the movement and position of the quadcopter while flying in the air [6]. The component used to control movement, stability and balance while flying is called a flight controller (FC). Flight Controller is one of the important things in designing a quadcopter so that it can move according to the user's wishes. This component is a small circuit board that manages the functions of the quadcopter and is integrated by various types of sensors and actuators [6]. Until now, FC is only produced by foreign countries and has a price that is quite expensive for various groups, one of which is for students.

So this final project was made to design and develop a local flight controller that is cheap but feasible enough to be used to control drones specifically quadcopter drones which are later expected to become local products to meet the needs of the Indonesian people and can be utilized by other researchers to innovate in the development or research on drones both within Tanjungpura University and West Kalimantan and throughout Indonesia. Developed in this research is the control of hover position stability based on roll and pitch angles on quadcopter and remote control based on LoRa technology.

2. RELATED WORK

Based on research entitled " Analisa Rancangan Keseimbangan Menggunakan Sensor IMU Type MPU6050 Pada Quadcopter ". By Fadhli Palaha and friends in 2020. This research aims to achieve the balance value and reliability of the quadcopter during flight. The designed quadcopter is rotated by a BLDC motor controlled by Arduino. The output of the Arduino in the form of PWM becomes input for the motor drive, where the output speed of the motor will be detected by the MPU-6050 sensor. After that, the process will repeat, until the speed meets the set point value [4].

Based on research entitled "Perancangan Kendali *Quadcopter* Berbasis PID Menggunakan Arduino Uno". Zhuhriadi Abi Manyu and Mirza Zoni in 2021. In this research, it discusses how to control the speed of brushless motors on a quadcopter to achieve stability when flying in the air. The method used to solve this problem is the PID (Proportional Integral Derivative) control method using the Arduino Uno microcontroller as the main controller and using the MPU6050 as the sensor [7].

Based on research entitled "Evaluation of Unmanned Aerial Vehicle (UAV) Control Range System Using Lora-Based Communication System Using Path Loss". By Mokhammad Amin Hariyadi and Juniardi Nur Fadila in 2022. In this research, this research aims to evaluate the communication system between the ground control system and the Unmanned Aerial Vehicle (UAV) using the Lora communication system based on its Path Loss data. Lora itself is a 433 MHz-based communication system used for very long-distance communication [8].

Based on the research results from several journals above, researchers will make it a reference in this study. In this study, a flight controller with an internal transceiver using LoRa technology was designed for remote control of quadcopter drones and for monitoring sensor data on quadcopter drones. This research uses a close loop control system with the PID (Proportional Integral Derivative) method to maintain the stability of the quadcopter drone. The difference between this research and previous research is that the microcontroller used in this research uses an ESP32 microcontroller and the remote control system used in this research uses LoRa technology.

2.1. Quadcopter

Quadcopter is a type of multirotor drone that uses four motors to fly using the thrust generated from the rotation of its four rotors. The quadcopter is controlled by adjusting the angular velocity generated by the rotating rotors. To reduce movement due to the inertial effect on the quadcopter, adjacent motors must have different motor rotation directions, while opposite motors must have the same rotation direction. Two motors rotate clockwise and the other two motors rotate counterclockwise equipped with propellers to generate lift. Quadcopter is a type of multirotor drone that uses four motors to fly. Two motors rotate clockwise and two other motors rotate counterclockwise equipped with propellers to generate lift. generate lift. In a quadcopter there are two possible configurations used, namely the "+" configuration and the "x" configuration [2], [9].

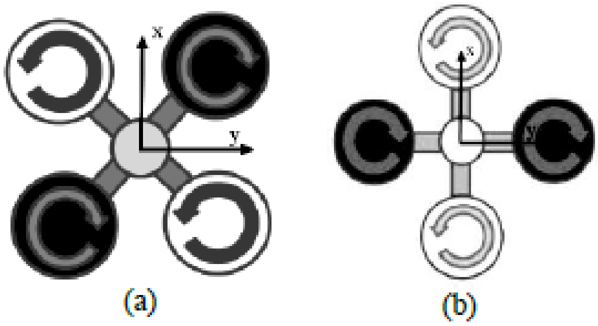

Figure 1 (a) "x" configuration and (b) "+" configuration

2.2. Quadcopter Basic Motion

Movements that can occur in a quadcopter are hovering, roll rotation, pitch rotation, and yaw rotation. rotation. These four movements are influenced by several parameters including: lift force on the motor and its direction, the rotational speed of the motor, and moment on the quadcopter wing. The following is an explanation of the movements that can occur in a quadcopter [2]:

1. Hovering or Throttle Control

The throttle is the quadcopter's movement for up and down. This is done by increasing or speed on all drive motors at the same the same target, resulting in a vertical force on the quadcopter [10].

2. Roll Control

Roll is the movement of the quadcopter to turn right and left. Turning to the right is done by slightly reducing the speed of the right motor and slightly adding the speed of the left motor. Turning to the left is done in the opposite way from the right, which is slightly adding the speed of the right motor and reducing the speed of the left motor slightly. The front and rear motors do not speed so that the Quadcopter position position remains hovering even though it is right and left[10].

3. Pitch Control

Pitch is the movement of the quadcopter to move forward and backward. Forward is done by slightly reducing the speed of the front motor and slightly adding the rear motor. Backing up is done by slightly adding the speed of the front motor and slightly reducing the speed of the rear motor. The right and left motors do not add speed so that the position of the Quadcopter position remains hovering even in a state of forward forward and backward [10].

4. Yaw Control

Yaw is the movement of the quadcopter to rotate to the right and left. Rotation to the left is done by slightly adding the speed of the front-rear motor and slightly reducing the speed of the right-left motor. A right turn is performed by slightly reducing the speed of the front-rear motor and slightly adding the speed of the right-left motor. left motor speed [10].

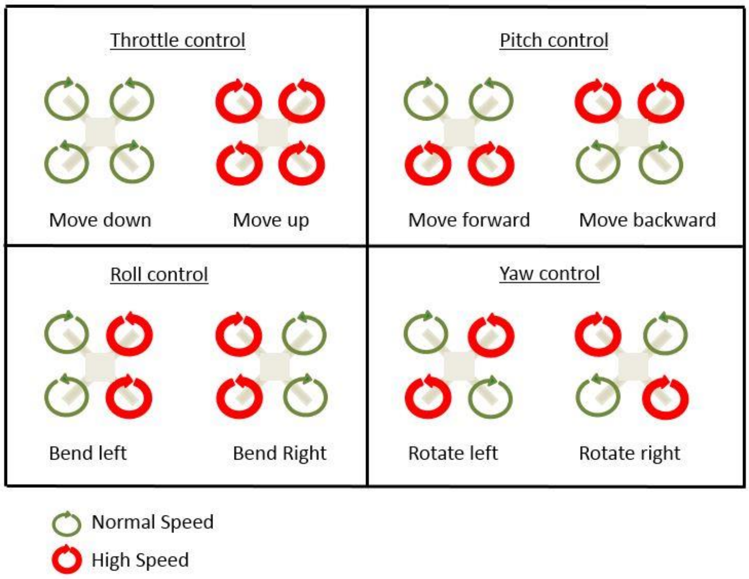

Figure 2 Maneuvering movement on a quadcopter drone

2.3. Quadcopter components

The following are the components contained in the quadcopter drone which consists of a flight controller, electronic speed controller, BLDC motor reciever and propeller.

1. Flight Controller

The brain of the quadcopter is an important component of the quadcopter and determines what the features of the quadcopter are. The Flight Controller is the nerve center of the drone. The flight control systems of these unmanned aircraft are many and varied. From GPS enabled autopilot systems and flown by means of telemetry links to basic stabilization systems using radio control class hardware, and there is an opensource program. The flight controller is also connected to, radio module, GPS, gyroscope, plus accelerometer, radio receiver module, battery, electronic speed controller and gimbal. speed controller and gimbal [11]. The flight controller system consists of several components such as accelerometer, gyroscope, barometer, compass and others. Flight controller is useful for controlling the stability and balance of the drone to be controlled by controlling the speed of the motor.

2. Electronic Speed Control

   ESC stands for Electronic Speed Controller which functions as a controller of the rotation and direction of rotation of the motor. In general, for the motor to rotate, the remote control (RC) gives a signal pulse of 1000µS min and at full speed of 2000µS [12].

   To determine the ESC to be used it is very important to know the power (peak current) of the motor. The power of the ESC used should exceed the power of the of the motor. For example, from the data obtained the power of the motor is 12A (according to the motor datasheet) when the throttle is fully open. The ESC to be used should be an ESC with a power of 18A or 20A. If forced using a 10A ESC, it is likely that when the throttle is throttle is fully opened, the ESC will heat up and even catch fire [12].
3. Motor BLDC

   Brushless direct current (BLDC) is a three-phase brushless synchronous electric motor. As the name implies, BLDC motors do not use brushes or brushes for magnetic commutation contact (communication) but are electronically commutated. The use of BLDC motors has many advantages over DC motors and other induction motors. Brushless motors or brushless motors have high-speed operation that uses coils as a stator as a 3-phase voltage input while magnets as a rotor with an electrical diagram [12], [13].
4. Propeller

   The propeller is the counterpart to the motor. For Hexacopter, there are two types of propellers used, namely Clock Wise (CW) / Clockwise and Counter Clock Wise (CCW) / Counterclockwise. Figure 3 shows an example of a 1 pair CW and 1 pair CCW propeller [12].
5. LiPo Battery

   LiPo battery use dry polymer electrolytes which have a film-like shape with a layered arrangement between the anode and cathode which can result in ion exchange. Li-Po batteries also have the main advantage of the power to weight ratio [14].

2.4. Inertial Measurement Unit

IMU (Inertial Measurement Unit) is a unit in an electronic module that collects angular velocity and linear acceleration data which is then sent to the Central Processing Unit (CPU) to obtain data on the presence and movement of an object [4]. The IMU incorporates an accelerometer, gyroscope and magnetometer. The Attitude and Heading Reference System (AHRS), also called IMU, adds a central processing unit (CPU) that embeds an Extended Kalman Filter to calculate the attitude with direction relative to magnetic north.

1. Accelerometer

   Accelerometers are sensors used to measure acceleration or changes in velocity over time. This sensor is installed with the object to be measured for acceleration, such as measuring changes in the speed of a rocket launching or used for vibration analysis on machines, as well as used to detect motion and tilt on smart phones. Acceleration is a state of change in velocity over time. The increase in speed over a period of time is called acceleration. But if the speed is getting less than the previous speed, it is called deceleration [4].
2. Gyroscope

   Gyroscope sensors are devices used to measure or maintain orientation, which is based on the principles of angular momentum mechanically. Basically a mechanical gyroscope is shaped like a rotating wheel or disk where the shaft is free to take any orientation such as [4].
3. Magnetometer

   The magnetometer sensor functions as a measure of the strength and direction of the magnetic field around the device. Magnetometers are divided into two types, namely scalar and vector types. The vector magnetometer is the type used in this research and serves to measure the direction of the magnetic field in all three axes (X, Y, Z) with units of micro tesla (µT) [15].
4. Kalman Filter

   Kalman filter is a minimum variance estimation algorithm for dynamic systems to obtain the optimal state. The Kalman filter is grouped into two parts, namely, the time update equation as the prediction equation and the measurement update equation as the correction equation. The work cycle of the discrete Kalman filter is the time update makes a prediction of the state value. Measurement update adjusts the predicted value to the actual measured value [16].

2.5. LoRa Technology

LoRa stands for long range which means long distance. LoRa devices communicate wirelessly by utilizing frequency as an intermediary medium to transmit data. LoRa devices are one of the transceiver devices that excel in wide coverage distance, low power consumption, and resistance to intervention. Currently, LoRa technology technology has been used in IoT networks around the world. device LoRa devices have been widely used in smart cities, agriculture, smart home, smart metering, and so on [17].

2.5.1. RSSI

RSSI is a measurement of the power received by a wireless device. Measurements are made based on the Signal Strength received. This aims to determine the level of accuracy of measurements and calculations using Wireless [18].

Table 1 Signal Strength Standard according to TIPHON

Category	Signal Strength (dBm)
Outstanding	> -70
Excellent	-70 s/d -85
Fair	-86 s/d -100
Bad	< -100

2.5.2. SNR

Signal To Noise Ratio (SNR) is a comparison between signal strength and noise level, the greater the SNR value, the higher the network quality and the unit of measure of SNR is decibel (dB). SNR is a parameter that must be considered and used to show how much noise interferes with the transmitted signal [18].

Table 2 Signal to Noise Ratio standard according to TIPHON

Category	SNR (dB)
Outstanding	> 29
Excellent	20.0 s/d 28.9
Good	11.0 s/d 19.9
Fair	7.0 s/d 10.9
Bad	< 6.9

2.6. PID Control

PID (Proportional, Integral, Derivative) control is a controller system that is used to determine the precision of a system with feedback from the system. precision of a system with feedback on the system system. PID components include proportional, integral, and derivative. The elements P, I, and D, aim to speed up the response of a system, eliminate latency, and produce large initial changes. The characteristics of PID control are strongly influenced by the three elements P, I, and D elements [6].

The PID control equation in the time domain (t) is:

$$u(t) = Kp \times e(t) + Ki \times \int_0^t e(t)dt + Kd \times \frac{de(t)}{dt} \quad (1)$$

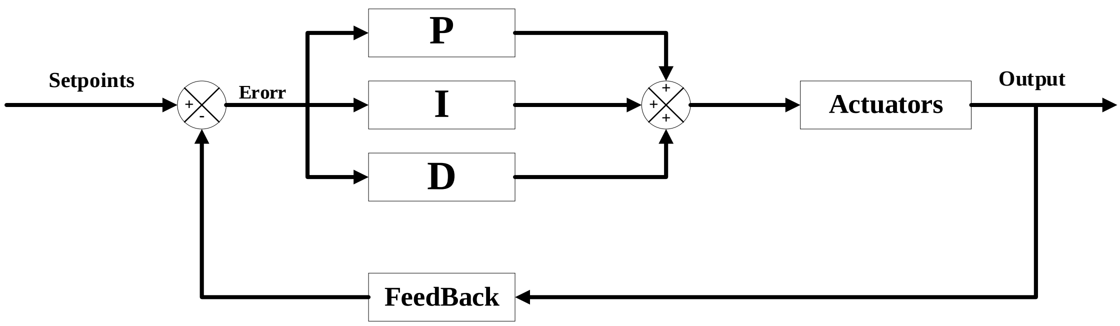

Figure 3 Close Loop PID Controller

The PID controller compares the set point value with the error reading value of the plant/process, then by using the right PID value, the controller will provide action on the system to produce an output whose value is not far or even in accordance with the given set point value. in accordance with the given set point value. The PID control process will continue as long as the system is still running, because PID is a closed-loop control system. control system. The process of finding the PID value is called the tuning process, the way to do PID tuning manually is by looking at the look at the PID parameter table and then analyze the response resulting from the value entered into the PID parameter [19].

3. METHOD

3.1. Research Methods

Literature study is a method of collecting information and studying supporting theories from various sources of information both obtained offline and online. Data can be found from various sources, namely articles, journals, datasheets, web pages (verified), and books.

The experimental method is one of the quantitative studies where researchers manipulate one or more independent variables, control other relevant variables, and observe the effect of manipulation on the dependent variable. Important requirements for experimental research are control, manipulation of independent variables, observation, control measurement, careful observation and measurement [15].

Literature studies and experiments related to this writing, which can later be used in the guidelines for making research reports. The following is an image of the flow chart below.

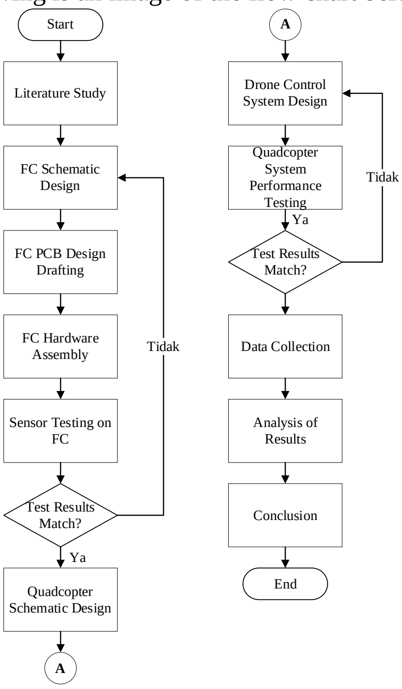

Figure 4 Research flow chart

Based on Figure 4 Research Flowchart, there are stages carried out in this study. In the first stage, information collection will be carried out using the literature study method. Furthermore, FC schematic design and FC PCB. In the next stage, FC device assembly and sensor performance testing. The next stage is quadcopter schematic design and quadcopter control system design. Furthermore, testing the entire quadcopter system. If the test is successful, data collection and analysis of the data obtained will be carried out. Finally make conclusions from the results of research that has been done based on the data obtained.

3.2. PCB Design Flight Controller

Figure 5 shows the PCB design of the flight controller which was designed using EasyEDA software. In Figure 5, we can see the components contained in the FC, namely the ESP32 microcontroller, LoRa Ra-02, MPU6050, QMC5883L, BMP280, LDO regulator AP2112 and several other supporting components. The sensors contained in this FC consist of a 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer and barometer. This FC also has outputs in the form of LEDs for power indicators and a connector for GPS, although in this study GPS will not be discussed. This FC is designed with PCB size (P x L x T): 52 x 57 x 0.8 mm.

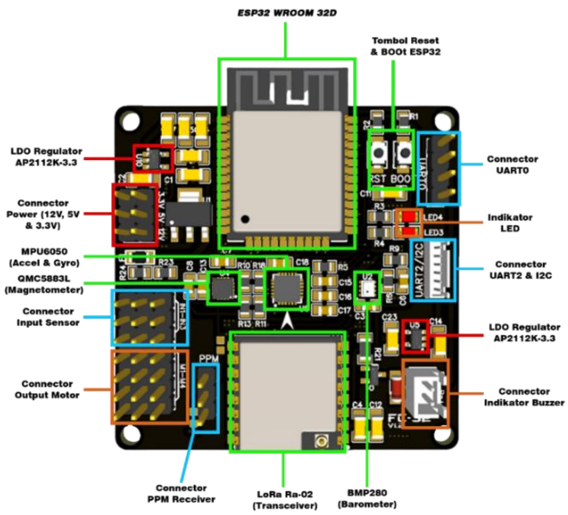

Figure 5 3D Design PCB flight controller

3.3. System Model of LoRa Protocol

The following is a depiction of the LoRa protocol system used in this research. In this research, the LoRa communication protocol used consists of three, namely header, payload and sum. The header functions as an upper barrier to filter out inappropriate messages. Payload contains data in the form of messages to be sent. While the sum is a lower limiter that is useful for filtering out corrupted message data. The LoRa communication protocol format used can be seen in Figure 6.

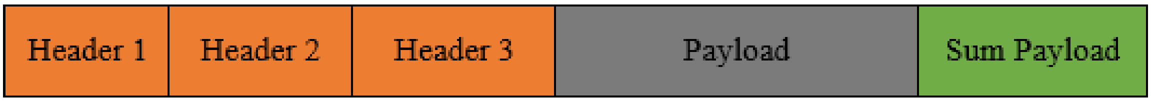

Figure 6 Protocol LoRa

Keterangan:

- Header 1 is the sender address.
- Header 2 is the recipient address
- Header 3 is the payload address
- Payload is the data sent
- Sum is the amount of data sent after summing up

3.4. Quadcopter System Design

The quadcopter drone will be illustrated in the form of 2D images, these 2D images have nothing to do with the original design of the quadcopter drone in this study. Figure 7 illustrates the component positioning and illustrates the quadcopter drone remote communication system. The first is the flight controller section which functions to control and calculate the stability of the quadcopter. Second is the electronic speed controller (ESC) which functions to regulate the speed of the BLDC motor based on commands from the flight controller. Third is the engine part in the form of BLDC motors consisting of 4 motors on each quadcopter arm. Fourth is the wing part in the form of a propeller.

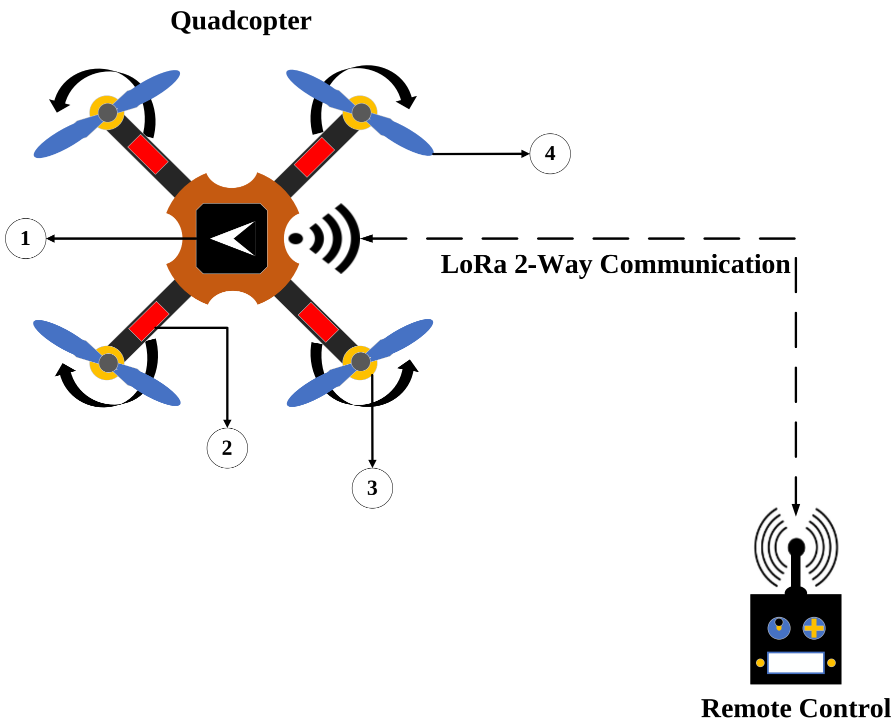

Figure 7 Illustrated drone quadcopter system

3.5. Quadcopter PID Control System

The quadcopter has six states that grouped into two parts, including position (x, y, z) and attitude (roll, pitch, yaw). At this Final Project research uses a PID control system to stabilize the quadcopter during hovering. when flying hovering. System block diagram PID control system on the quadcopter can be seen in Figure 7 [20].

Figure 8 shows the close loop control system of both PID drone quadcopter there are three angle controls namely roll, pitch and yaw. PID roll control serves to stabilize the left and right parts of the quadcopter.

Pitch PID control serves to stabilize the front and rear of the quadcopter. As for the yaw PID control to stabilize the position on the left and right rotation. The PID roll, pitch and yaw output values will be converted in the form of PWM signals in the range of 1000-2000 ms. This PWM signal will be input into the ESC to be able to control the motor speed so that the quadcopter reaches stability

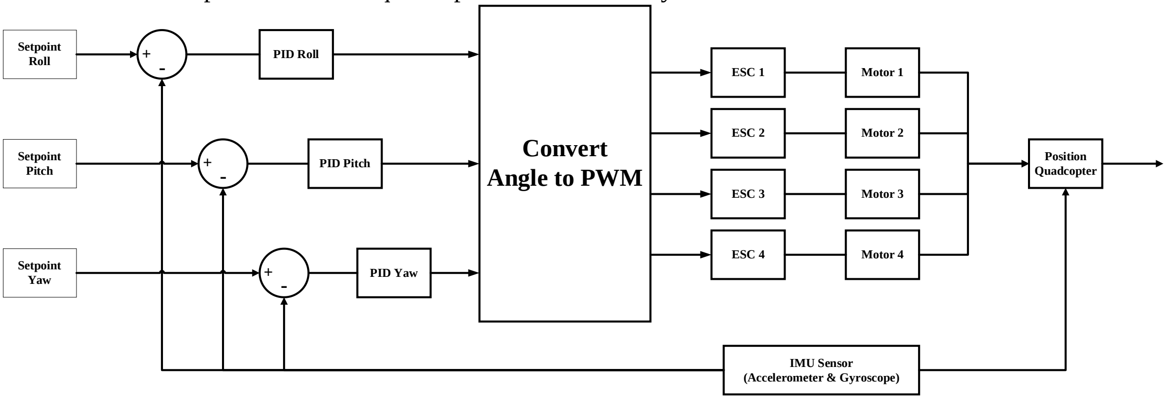

Figure 8 Quadcopter PID System

4. RESULTS AND DISCUSSION

4.1. Roll Angle Testing Steady State

After testing the roll angle measurement by doing 10 trials, the roll angle measurement data can be seen in Table 3 below. Based on the calculation data contained in Table 3, the average value of the roll angle is 0.4^o with the lowest error rate of 0^o and the highest error of 2^o. From the calculation of the percentage error in roll angle measurement, the average percentage error is 0.53% with the lowest error of 0% and the highest error of 3.33%.

Table 3 Roll angle test results

No.	Roll Angle (^{o})		Errors (^{o})	Error Percentage (%)
	Measurement Tools	FC Created		
1	0	0	0	0
2	-30	-29	1	3.33
3	-60	-60	0	0
4	-90	-90	0	0
5	-179	-177	2	1.12
6	30	30	0	0
7	45	45	0	0
8	60	60	0	0
9	90	90	0	0
10	115	116	1	0.87
Average			**0.4**	**0.53**

4.2. Pitch Angle Testing Steady State

After testing the pitch angle measurement by doing 10 trials, the pitch angle measurement data can be seen in Table 4 below. Based on the data in Table 4, the average error value of the pitch angle is 1^o with the lowest error rate of 0^o and the highest error rate of 2^o. From the calculation analysis of the accuracy of the pitch angle measurement, an average percentage error of 1.28% is obtained with the lowest error of 0% and the highest error of 3.33%.

Table 4 Pitch angle test result

No.	Pitch Angle (^{o})		Errors (^{o})	Error Percentage (%)
	Measurement Tools	FC Created		
1	0	0	0	0
2	30	30	0	0
3	45	44	1	2.22
4	90	88	2	2.22
5	177	179	2	1.13
6	-30	-31	1	3.33
7	-45	-45	0	0
8	-86	-88	2	2.33
9	-126	-127	1	0.79
10	-137	-138	1	0.73
Average			**1**	**1.28**

4.3. Yaw Angle Testing Steady State

After testing the yaw angle measurement by doing 10 trials, the yaw angle measurement data can be seen in Table 5 below. Based on the data in Table 5, the average error value of the yaw angle is 4.8° with the lowest error level of 0° and the highest error of 12°. From the analysis of the calculation of the percentage of error in the measurement of the yaw angle, an average percentage error of 10.96% is obtained with the lowest error of 0% and the highest error of 60%.

Table 5 Yaw angle test result

No.	Yaw Angle (°)		Errors (°)	Error Percentage (%)
	Measurement Tools	FC Created		
1	0	0	0	0
2	45	37	8	17.78
3	60	58	2	3.33
4	90	85	5	5.56
5	135	125	10	7.41
6	179	177	2	1.12
7	-135	-132	3	2.22
8	-90	-89	1	1.11
9	-45	-40	5	11.11
10	-20	-8	12	60
Average			**4.8**	**10.96**

4.4. Quadcopter Flight Condition Testing

The quadcopter drone flight testing process was carried out in the Tanjungpura University ball field. This test was conducted to determine the level of stability control of the quadcopter drone while flying. In this study using the basic PID method as a quadcopter drone stability control. In this test, the initial PID setting values have been determined, namely KP, KI, and KD from the roll and pitch angles. The roll and pitch PID setting values are KP = 2.3, KI = 0.0, and KD = 0.25. The roll and pitch angle data collection process will be carried out simultaneously.

4.4.1. Roll Kontrol

Roll angle control measurement testing is done to determine the error rate in roll angle control on the quadcopter by taking 16 data in some time. The roll angle measurement data can be seen in Table 6 below. It can be seen from the measurement and calculation data in Table 6 that the average value of roll angle measurement is 1.49° with the lowest error rate of 0.03° and the highest error of 3.83°. From the analysis of the calculation of the percentage error in roll angle measurements, an average error of 0.83% is obtained with the lowest error percentage of 0.02% and the highest error of 2.13%.

Table 6 Roll Control Measurement

No.	Setpoint (°)	Roll (°)	Errors (°)	Error Percentage (%)
1	0	2.88	2.88	1.60
2	0	2.87	2.87	1.59
3	0	2.5	2.5	1.39
4	0	1.39	1.39	0.77
5	0	-0.03	0.03	0.02
6	0	-0.03	0.03	0.02
7	0	1.99	1.99	1.11
8	0	-0.19	0.19	0.11
9	0	0.23	0.23	0.13
10	0	0.07	0.07	0.04
11	0	0.29	0.29	0.16
12	0	0.69	0.69	0.38
13	0	0.33	0.33	0.18
14	0	3.83	3.83	2.13
15	0	-3.11	3.11	1.73
16	0	-3.36	3.36	1.87
Average		**0.65**	**1.49**	**0.83**

4.4.2. Pitch Kontrol

Pitch angle control measurement testing is done to determine the error rate in roll angle control on the quadcopter by taking 16 data in some time. The pitch angle measurement data can be seen in Table 7 below. It can be seen that the measurement and calculation pitch angle data in Table 7 obtained the average value of the pitch angle error measurement is 2.12° with the lowest error rate of 0.14° and the highest error of 4.46°. From the calculation analysis, the average percentage of pitch angle error data is 1.18% with the lowest error percentage of 0.08% and the highest error of 2.48%.

Table 7 Pitch Control Measurement

No.	Setpoint (º)	Pitch (º)	Errors (º)	Error Percentage (%)
1	0	0.35	0.35	0.19
2	0	-4.09	4.09	2.27
3	0	-1.49	1.49	0.83
4	0	-4.17	4.17	2.32
5	0	0.46	0.46	0.26
6	0	0.46	0.46	0.26
7	0	-0.14	0.14	0.08
8	0	-3.35	3.35	1.86
9	0	-4.46	4.46	2.48
10	0	-2.08	2.08	1.16
11	0	-0.85	0.85	0.47
12	0	-4.39	4.39	2.44
13	0	-3.12	3.12	1.73
14	0	-0.51	0.51	0.28
15	0	1.38	1.38	0.77
16	0	2.56	2.56	1.42
Average		**-1.47**	**2.12**	**1.18**

4.5. LoRa Performance Testing for Quadcopter Remote Control

This distance test is conducted to determine the performance of LoRa when implemented with a quadcopter drone. The research location was carried out at the Tanjungpura University soccer field. Testing was carried out with LOS (line of sight) field conditions with a testing distance of 0-140 meters and a height of 0-10 meters.

Data collection was carried out as much as 16 test data by measuring RSSI and SNR values at a distance and height position or based on a reference position where LoRa was placed at a certain distance and height. In measuring the RSSI signal, the signal will be categorized as good if the value is getting closer to the value of 0, while for the SNR signal it will be categorized as good if the value is getting bigger, the explanation of the strength of the SNR and RSSI signals is based on references Table 1 and Table 2. In testing, the initial setting of LoRa parameters will be carried out, which in this research the LoRa parameters that have been determined are Fq = 425 MHz, BW = 250 KHz, SF = 8, CR = 4/8, and TX Power = 20 dB.

Table 8 shows the results of LoRa signal measurements at a height of 0 meters resulting in the highest RSSI signal strength of -44 dBm at a distance of 0 meters and the lowest RSSI signal of -106 dBm at a distance of 120 meters. While the highest SNR signal strength is 12.63 dB at a distance of 0 meters and the lowest is 3.15 dB at a distance of 100 meters. Based on the data analysis in Table 8 in this measurement from a distance range of 80-140 meters the RSSI and SNR signal quality is "Bad".

Table 8 Measurement Results at a Height of 0 meters

No.	Distance	Measurement at a height of 0 meters			
		RSSI (dBm)	RSSI Status	SNR (dB)	SNR Status
1	0	-44	Outstanding	12.63	Good
2	10	-95	Fair	11.53	Good
3	20	-94	Fair	10.73	Fair
4	30	-93	Fair	10.13	Fair
5	40	-94	Fair	9.25	Fair
6	50	-100	Fair	8.43	Fair
7	60	-95	Fair	10.80	Fair
8	70	-97	Fair	7.18	Fair
9	80	-100	Bad	6.00	Bad
10	90	-103	Bad	5.70	Bad
11	100	-104	Bad	3.15	Bad
12	110	-105	Bad	4.00	Bad
13	120	-106	Bad	3.78	Bad
14	130	-104	Bad	5.18	Bad
15	140	-105	Bad	3.33	Bad
Average		**-96**	**Fair**	**7.45**	**Fair**

Table 9 shows the results of LoRa signal measurements at a height of 5 meters resulting in the highest RSSI signal strength of -77 dBm at a distance of 0, 50 and 70 meters and the lowest RSSI signal of -95 dBm at a distance of 120 meters. While the highest SNR signal strength is 12.63 dB at a distance of 70 meters and the lowest is 11.05 dB at a distance of 120 meters. Based on data analysis in Table 9 at a height of 5 meters the RSSI signal quality generated by LoRa is "Excellent", then the SNR signal quality generated by LoRa is "Good".

Table 9 Measurement Results at a Height of 5 meters

No.	Distance	Measurement at a height of 5 meters			
		RSSI (dBm)	RSSI Status	SNR (dB)	SNR Status
1	0	-77	Excellent	12.58	Good
2	10	-89	Fair	12.45	Good
3	20	-81	Excellent	12.45	Good
4	30	-83	Excellent	12.38	Good
5	40	-78	Excellent	12.40	Good
6	50	-77	Excellent	12.58	Good
7	60	-80	Excellent	12.43	Good
8	70	-77	Excellent	12.63	Good
9	80	-80	Excellent	12.28	Good
10	90	-89	Fair	12.18	Good
11	100	-90	Fair	12.25	Good
12	110	-88	Fair	12.33	Good
13	120	-95	Fair	11.05	Good
14	130	-88	Fair	12.38	Good
15	140	-91	Fair	11.65	Good
Average		**-84**	**Excellent**	**12.27**	**Good**

Table 10 shows the results of LoRa signal measurements at a height of 10 meters resulting in the highest RSSI signal strength of -66 dBm at a distance of 20 meters and the lowest RSSI signal of -90 dBm at a distance of 120 meters. While the highest SNR signal strength is 12.63 dB at a distance of 0 meters and the lowest is 12.18 dB at a distance of 110 meters. Based on data analysis in Table 10 at a height of 10 meters the RSSI signal quality generated by LoRa is "Excellent", then the SNR signal quality generated by LoRa is "Good".

Table 10 Measurement Results at a Height of 10 meters

No.	Distance	Measurement at a height of 10 meters			
		RSSI (dBm)	RSSI Status	SNR (dB)	SNR Status
1	0	-86	Fair	12.63	Good
2	10	-67	Outstanding	12.58	Good
3	20	-66	Outstanding	12.60	Good
4	30	-74	Excellent	12.23	Good
5	40	-84	Excellent	12.35	Good
6	50	-84	Excellent	12.35	Good
7	60	-84	Excellent	12.35	Good
8	70	-76	Excellent	12.43	Good
9	80	-77	Excellent	12.53	Good
10	90	-85	Excellent	12.40	Good
11	100	-84	Excellent	12.35	Good
12	110	-81	Excellent	12.18	Good
13	120	-90	Fair	12.23	Good
14	130	-80	Excellent	12.23	Good
15	140	-83	Excellent	12.53	Good
Average		**-80**	**Excellent**	**12.40**	**Good**

5. CONCLUSION

Based on the measurement of the quadcopter in a stationary condition, the average percentage of roll, pitch and yaw angle measurements is obtained. The roll angle has an average percentage error of 0.53%. The pitch angle has an average percentage error of 1.28%. While the yaw angle has a percentage error of 10.96%. On quadcopter stability measurements managed to fly stable with an average percentage error roll of 0.83%, while the average percentage error pitch of 1.18%. From the measurement results, it is known that the average RSSI LoRa signal quality generated at a height of 0 meters is "Fair" and for heights of 5 and 10 meters is "Excellent". While the average SNR LoRa signal quality generated at a height of 0 meters is "Fair" and a height of 5 and 10 meters is "Good".

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REFERENCES

[1] T. V. Kashira, E. Setiawan, M. Hannats, and H. Ichsan, "Simulasi Kendali Altitude Quadcopter Parrot Mambo menggunakan Linearisasi Fungsi Alih dan PID," 2021. [Online]. Available: http://j-ptiik.ub.ac.id

[2] A. K. Rahman, H. Supriyanto, and T. Meizinta, "Rancang Bangun Dan Implementasi Sistem Kendali Quadcopter Melalui Jaringan Internet Berbasis Lokasi Menggunakan Smartphone Android," *Seminar Nasional Instrumentasi, Kontrol dan Otomasi (SNIKO)*, 2018.

[3] E. Roscitra Oktaria, G. E. Setyawan, and W. Kurniawan, "Sistem Kendali Jarak Tempuh Quadcopter Menggunakan Metode Proportional Integral Derivative," 2019. [Online]. Available: http://j-ptiik.ub.ac.id

[4] F. Palaha, J. Teles, and Yolnasdi, "Analisa Rancangan Keseimbangan Menggunakan Sensor IMU Type–MPU6050 Pada Quadcopter," *SAINSTEK*, vol. 8, no. 2, pp. 97–104, 2020.

[5] S. Sumardi, H. Afrisal, and W. Dyan Nugroho, "Sistem Kendali Kestabilan Attitude Quadrotor Dengan Metode Self-Tuning Fuzzy-PD," *Jurnal Teknologi dan Sistem Komputer*, vol. 8, no. 2, pp. 164–170, Apr. 2020, doi: 10.14710/jtsiskom.8.2.2020.164-170.

[6] F. G. Mahardika, M. R. Rosa, and M. Z. Romdlony, "Desain dan Implementasi Kendali Posisi pada Quadcopter," 2021. [Online]. Available: https://www.mydronelab.com/accessories/quadcopter-

[7] Z. Abi Manyu and M. Zoni, "Perancangan Kendali Quadcopter Berbasis Pid Menggunakan Arduino Uno," vol. 18, no. 1, Nov. 2021.

[8] M. A. Hariyadi and J. N. Fadila, "Evaluation of Unmanned Aerial Vehicle (UAV) Control Range System using Lora-Based Communication System using Path Loss," *Fountain of Informatics Journal*, vol. 7, no. 2, pp. 57–63, Nov. 2022, doi: 10.21111/fij.v7i2.7571.

[9] A. A. G. J. Putra, P. Pangaribuan, and A. S. Wibowo, "Implementasi Metode Kendali Fuzzy Logic Untuk Kestabilan Sikap Quadcopter Terhadap Sumbu Roll Dan Sumbu Pitch," *Jurnal TEKTRIKA*, vol. 4, no. 2, pp. 46–53, Jul. 2019.

[10] A. P. Pratiwi, A. Wajiansyah, A. Fanany, and O. Gaffar, "Optimasi Manuver Lepas Landas Pada Quadcopter Menggunakan Jaringan Syaraf Tiruan Propagasi Balik," *Prosiding Seminar Ilmu Komputer dan Teknologi Informasi*, vol. 3, no. 1, 2018.

[11] I. Ruanagara, A. S. Wibowo, and A. Rizal, "Stabilisasi Kendaraan Tanpa Awak Menggunakan 4 Propeller Dengan Metode Pengontrol Derivatif Integral," vol. 9, no. 5, pp. 2550–2558, Oct. 2022.

[12] R. Hidayat, Muhaimin, and A. Finawan, "Rancang Bangun Prototype Drone Penyemprot Pestisida Untuk Pertanian Padi Secara Otomatis," *JURNAL TEKTRO*, vol. 3, no. 2, pp. 86–94, 2019.

[13] A. Prianto, A. Rahman, A. Mufti, and A. Bahri, "Rancang Bangun Sistem Kendali Attitude Hold Satu Derajat Kebebasan Berbasis Metode Pid Untuk Penggerak Dua Rotor," *Jurnal Komputer, Teknologi Informasi, dan Elektro*, vol. 6, no. 1, pp. 32–37, 2021.

[14] A. Muhammad Saiful Islam, M. Rafsanjani Husain, N. K, M. Nur, and Fauziah, "Rancang Bangun Quadcopter Sebagai Alat Bantu Penyemprot Pestisida Pada Lahan Persawahan," 2021.

[15] R. R. G. Eunike, H. Maclaurin, and H. S. Imanta, "Aplikasi Sensor Fusion untuk Mendeteksi Posisi dan Arah Pergerakan Ponsel Pintar di Dalam Ruangan," *Jurnal Telematika*, vol. 14, no. 1, pp. 19–26, 2019.

[16] M. J. Caesariano, E. Setiawan, and H. Fitriyah, "Sistem Kendali Pitch, Roll dan Ketinggian Quadcopter dengan Isyarat Tangan menggunakan Kalman Filter," 2022. [Online]. Available: http://j-ptiik.ub.ac.id

[17] A. Pratama, A. A. N. Amrita, and D. C. Khrisne, "Rancang Bangun Sistem Monitoring Listrik Tiga Fasa Berbasis Wireless Sensor Network Menggunakan LoRa Ra-02 SX1278," *Majalah Ilmiah Teknologi Elektro*, vol. 20, no. 2, p. 351, Dec. 2021, doi: 10.24843/mite.2021.v20i02.p20.

[18] T. S. J. Putra and I. R. Widiasari, "Analisis Kualitas Signal Wireless Berdasarkan Received Signal Strength Indicator (RSSI) pada Universitas Kristen Satya Wacana," 2019.

[19] A. Haniffullah, I. Abdi Bangsa, and A. Stefanie, "Implementasi Quadcopter Pembawa Arm Robot Pembersih Kaca Jendela Gedung Bertingkat," *Edu Elektrika Journal*, vol. 9, no. 2, pp. 36–42, 2020.

[20] P. Sukabumi, S. Saffanah, K. Wijayanto, A. Rafi, and A. Tahtawi, "Sistem Kendali Kestabilan Quadcopter dengan Navigasi Manual Berbasis Pengendali PID," Oct. 2020.

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