International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

ESP8266-Based Flight Controller and Drone

[1]Ashwini Patidar, [2]Arjun Sonil Sharma, [3]Aditya Raj Singh Rathor, [4]Archie Malviya,
[5]Akshay Kumar Singh, [6]Dr. Shravan Sable
Dept. of ECE Lakshmi Narain College of Technology, Bhopal (M.P.), India

ABSTRACT

This paper presents the design, implementation, and experimental evaluation of a low-cost quadrotor drone whose flight controller is centred on the ESP8266 Wi-Fi microcontroller. The system integrates a PID-based attitude stabilisation algorithm with real-time orientation feedback from an MPU6050 Inertial Measurement Unit (IMU), supplying three-axis gyroscope and accelerometer data over I2C. Motor speed is regulated through a discrete transistor-MOSFET driver circuit comprising 2N2222 BJT transistors and IRFZ44N MOSFETs, powering four small brushed DC motors. Wireless pilot commands are transmitted via a 433 MHz RF transceiver module over a reliable range of 50 to 100 metres. The frame is constructed on a zero PCB, keeping the design lightweight, compact, and reproducible at minimal cost. Calibration offsets and PID tuning parameters are stored in EEPROM, ensuring consistent flight behaviour across power cycles. Experimental results confirm stable hover, responsive roll/pitch/yaw control, a motor driver current of 1.5 A, flight endurance of 12 to 15 minutes, and payload capacity of 180 g. The platform is readily extensible for IoT integration, autonomous navigation, environmental monitoring, and delivery.

Keywords—ESP8266, ESP32, Drone, Flight Controller, PID Control, MPU6050, IMU, Brushed DC Motor, PWM, 433 MHz RF Transceiver, Arduino UNO, Embedded Systems, EEPROM.

I INTRODUCTION

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have evolved rapidly from niche research instruments into versatile platforms spanning agriculture, logistics, disaster response, and environmental monitoring. A persistent barrier to broader adoption is the cost and complexity of commercial flight controllers, which typically rely on proprietary firmware and specialised hardware that place them beyond the reach of students, hobbyists, and small research groups.

This paper addresses that barrier by presenting a fully open, reproducible quadrotor built around the ESP8266 system-on-chip. Although the ESP8266 is best known as a Wi-Fi connectivity module, its 80/160 MHz Tensilica L106 core provides ample computational headroom for real-time PID control, sensor fusion, and wireless command decoding simultaneously.

The key design objectives are: (i) stable autonomous attitude control using commodity components; (ii) a discrete BJT-MOSFET motor driver in place of costly ESCs; (iii) long-range pilot command reception via 433 MHz RF; and (iv) a zero-PCB mechanical frame to maximise affordability and repairability. The paper reports full experimental characterisation of the achieved system performance against design targets.

II LITERATURE REVIEW

Research in low-cost quadrotor platforms has expanded alongside hobbyist microcontroller ecosystems. Mahony et al. [1] established a seminal nonlinear complementary filter on SO (3) for IMU-based attitude estimation, forming the theoretical backbone of many open-source autopilots. Bouabdallah et al. [2] systematically compared PID and LQ control for miniature quadrotors, showing that well-tuned PID controllers achieve adequate stability for lightweight platforms.

Caballero et al. [3] demonstrated that Arduino-class 8-bit AVR processors can sustain the required control loop rates for flight stabilisation. The subsequent introduction of the ESP8266 by Espressif Systems [4] extended this further by integrating Wi-Fi at sub-dollar cost. MOSFET-based brushed motor drivers [5] offer low on-resistance and fast switching critical for smooth PWM control. The MPU6050 has been validated for small-UAV attitude sensing [6], and 433 MHz RF links offer superior range and obstacle penetration in cluttered environments [7].

III SYSTEM ARCHITECTURE & HARDWARE DESIGN

A. System Overview

The system comprises two subsystems: a ground-side transmitter and an airborne flight controller. The transmitter, built on an Arduino UNO with a joystick shield, reads four analogue control axes (throttle, pitch, roll, yaw), encodes them as serial command frames, and broadcasts at 10 Hz via a 433 MHz TX module. The flight controller, hosted on the ESP8266, receives frames, reads the MPU6050 IMU over I2C, executes three PID controllers, and drives four brushed motors through the motor-driver circuit. The control loop runs at approximately 250 Hz.

Remote Controller	**RF Link**	**ESP8266 Flight Ctrl**
Arduino UNO + Joystick Shield	433 MHz Transceiver	MPU6050 → PID → Motor Driver → Motors

Fig. 1. System block diagram

A. Component Descriptions

- ESP8266 NodeMCU: Core flight-controller SoC (80 MHz). Interfaces MPU6050 via I2C, decodes RF frames via UART, generates four PWM outputs, and stores PID gains in EEPROM.
- MPU6050 IMU: Six-axis MEMS device (3-axis gyro + 3-axis accelerometer). Provides real-time pitch, roll, and yaw data as PID feedback over I2C at 400 kHz.
- **Arduino UNO (Transmitter):** Reads four analogue joystick axes (0–1023 ADC), maps to command bytes (0–255), appends a checksum, and transmits 5-byte serial frames to the 433 MHz TX module at 10 Hz.
- **433 MHz RF Transceiver:** Sub-GHz ISM-band link. Provides 50–100 m range with improved obstacle penetration versus 2.4 GHz alternatives. Checksum byte enables frame-level error detection.
- **2N2222 BJT (×4):** Buffer stage between the 3.3 V ESP8266 GPIO and the IRFZ44N MOSFET gate. A 1 k□ base resistor limits base current.
- **IRFZ44N MOSFET (×4):** N-channel MOSFET with R

□ 17 m□ DS(on) and yaw (□). Each controller computes: Handles up to 1.5 A per motor under PWM control.
Flyback diodes suppress inductive spikes.

- Brushed DC Motors (×4, 3.7 V): Lightweight coreless motors generating quadrotor thrust. Speed modulated by PWM duty cycle from the motor-driver circuit.
- Zero PCB Frame: Lightweight rigid chassis mounting all electronics. Minimises overall drone mass while remaining easily repairable and reproducible.
- 7.4 V Li-Po Battery: Powers the motor-driver circuit directly. An onboard LDO regulator supplies regulated 5 V for the microcontroller and sensor rails.

B. Circuit Design

Main Control Circuit: The ESP8266 connects to the MPU6050 via I2C (SDA/SCL at 400 kHz), to the 433 MHz receiver via UART (9600 baud), and exports four PWM signals on GPIO 4, 5, 12, and 13 to the motor-driver circuit.

Motor Driver Circuit: Each of four identical stages uses a 1 k□ resistor at the BJT base, a 3.3 k□/6.6 k□ gate divider, and a 10 k□ pull-down to prevent floating-gate shoot-through at startup. 1N4007 flyback diodes are placed anti-parallel across each motor winding.

IV. METHODOLOGY & FIRMWARE

A. Sensor Fusion — Complementary Filter

Raw MPU6050 data are fused using a complementary filter combining gyroscope integration (accurate at high frequency, prone to drift) with accelerometer tilt estimation (accurate at low frequency, noisy at high frequency):

angle = □ × (angle + □ × □t) + (1□□) × □acc

where □ = 0.98, □ is the gyro angular rate, □t = 4 ms (250 Hz loop rate), and □acc is the accelerometer-derived tilt angle.

B. PID Attitude Controller

Three independent PID controllers handle roll (□), pitch (□),

u(t) = Kp·e(t) + Ki·□e(t)dt + Kd·de(t)/dt

where e(t) is the error between the desired and measured angle.

Gains Kp, Ki, Kd are stored in EEPROM and adjustable in-field without reflashing. Integral windup is clamped to prevent actuator saturation during aggressive manoeuvres.

C. Motor Mixing (X-Configuration)

PID outputs are combined with the throttle command to generate four individual PWM values per the X-configuration mixing logic shown in Table I. FL=Front-Left, FR=Front-Right, RL=Rear-Left, RR=Rear-Right, CW=Clockwise.

TABLE I — MOTOR MIXING LOGIC (X-CONFIGURATION)

Manoeuvre	M1 FL	M2 FR	M3 RL	M4 RR
Throttle ↑	↑	↑	↑	↑
Roll Right	↑	↓	↑	↓
Pitch Fwd	↑	↑	↓	↓
Yaw CW	↑	↓	↓	↑

D. Firmware Architecture

Transmitter (Arduino UNO): Reads two joystick analogue axes, maps to four command bytes, appends a checksum, and transmits 5-byte frames at 10 Hz over the 433 MHz link.

Flight Controller (ESP8266): On each 4 ms iteration: (i) reads MPU6050 via I2C; (ii) applies complementary filter; (iii) decodes any new RF command frame; (iv) runs three PID controllers; (v) applies motor mixing; (vi) writes four PWM duty cycles to GPIO outputs. EEPROM routines persist PID gains and IMU offsets across power cycles.

V PROJECT SPECIFICATIONS

Table II summarises the hardware design parameters and their specified operating values as characterised during bench testing.

TABLE II — DESIGN SPECIFICATIONS

S. No.	Parameter	Specification
1	Input Voltage	7.4 V – 12 V
2	Motor Drive Current	0.5 – 1.5 A
3	No. of Motors	4 (Brushed DC)
4	Max. Payload	200 g
5	Control Range	50 – 100 m
6	Flight Time	15 – 20 min
7	PID Parameters	Adjustable / EEPROM
8	Comm. Frequency	433 MHz RF
9	Axis Rotation	90° (stability)

VI RESULTS & PERFORMANCE EVALUATION

The assembled drone was tested under controlled indoor conditions across multiple flight sessions. Table III compares design targets against experimentally achieved performance metrics.

TABLE III — EXPECTATIONS vs. ACHIEVEMENTS

S.No.	Parameter	Expected	Achieved
1	Motor Driver Current	1 – 2 A	1.5 A
2	Response Time	Immediate	5 – 10 ms lag
3	Battery Life	15 – 20 min	12 – 15 min
4	Flight Range	100 m	~80 m
5	Control Response	Immediate	Minor delay
6	Payload Capacity	200 g	180 g

Stable hover was achieved within a few seconds of takeoff after iterative PID tuning. Roll and pitch response was smooth with oscillations damping rapidly. The measured control range (~80 m) fell slightly short of the 100 m target due to RF reflections in the indoor test environment; outdoor tests showed improved range. Flight endurance of 12–15 min was marginally below target owing to additional quiescent current drawn by the ESP8266 Wi-Fi subsystem (partially mitigated by disabling Wi-Fi during flight). A control loop latency of 5–

10ms arose from I2C readout and UART frame-decode overhead but did not perceptibly affect flight stability.

The work demonstrates that the ESP8266, typically deployed as a Wi-Fi peripheral, is fully capable of serving as the primary processing core of a real-time flight controller, making it an ideal, low-cost foundation for further research in autonomous UAVs, IoT-connected drones, and accessible drone education.

VII CHALLENGES & LIMITATIONS

- **PID Tuning Complexity:** Manual iterative tuning of K, K, p i to RF environment and Wi-Fi power draw, and are readily
- Kd for all three axes is time-consuming. An auto-tuning routine would reduce commissioning time.
- Brushed Motor EMI: Brush arcing generates interference that couples into the MPU6050 I2C bus. Decoupling capacitors (100 nF ceramic) at each motor terminal partially mitigate this; brushless motors would eliminate it.
- RF Interference: Other 433 MHz emitters reduce reliable control range. Forward-error-correction coding would improve link robustness in congested RF environments.
- Power Budget: The ESP8266 Wi-Fi radio draws peak currents stressing the 5 V regulator and reducing flight endurance. Disabling Wi-Fi during flight partially restores this.
- Frame Flex: The zero PCB frame exhibits minor vibration-induced flex at high throttle. A carbon-fibre or 3D-printed frame would improve structural stiffness.

VIII FUTURE SCOPE & APPLICATIONS

A. Technical Enhancements

Planned upgrades include migration to brushless motors with dedicated ESCs for improved efficiency and reduced EMI. Integration of a BMP280 barometric sensor and GPS module would enable altitude-hold and waypoint navigation. A Kalman filter could replace the complementary filter for more accurate attitude estimation. The native Wi-Fi of the ESP8266 provides a direct path to OTA firmware updates, real-time telemetry dashboards on cloud platforms, and mobile-app-based control.

B. Application Domains

- Precision Agriculture: Multispectral cameras and spray nozzles enable crop health monitoring and targeted pesticide application, reducing chemical use and improving yield.
- Search and Rescue: Thermal imaging and GPS allow the drone to assist in locating missing persons in disaster zones or dense forest areas inaccessible to ground teams.
- Last-Mile Delivery: With enhanced payload capacity, the platform can support lightweight parcel or medical-supply delivery in urban and rural areas.
- Environmental Monitoring: Onboard air-quality and pollution sensors can collect spatially distributed data in areas difficult to reach by ground vehicles.
- Surveillance & Security: Real-time aerial video supplements ground-based security systems for monitoring large public events or critical infrastructure.

IX CONCLUSION

This paper has presented the complete design, implementation, and experimental evaluation of a low-cost quadrotor drone controlled by the ESP8266 microcontroller. The system achieves real-time PID-based attitude stabilisation through MPU6050 IMU feedback, reliable pilot-command reception via a 433 MHz RF link, and independent motor speed regulation through a discrete 2N2222/IRFZ44N driver circuit, all assembled on a zero PCB frame at minimal cost.

Experimental evaluation confirmed stable hover, responsive attitude control, a motor-driver current of 1.5 A, flight endurance of 12–15 minutes, and payload capacity of 180 g. Observed shortfalls in range and endurance relative to targets are attributable

REFERENCES

1. Arduino, "Arduino UNO R3 Datasheet," Arduino.cc, 2022. [Online]. Available: https://www.arduino.cc
2. Espressif Systems, ESP8266 Technical Reference, ver. 1.7, Shanghai, China, 2020. [Online]. Available: https://www.espressif.com
3. F. Caballero, L. Merino, J. Ferruz, and A. Ollero, "Vision-based odometry and SLAM for medium and high altitude flying UAVs," J. Intell. Robot. Syst., vol. 54, no. 1–3, pp. 137–161, 2009.
4. H. Meyr and G. Ascheid, Synchronization in Digital Communications. New York, NY: Wiley, 1990.
5. InvenSense Inc., MPU-6050 Product Specification Rev. 3.4,
6. P. Corke, Robotics, Vision and Control, 2nd ed. Springer, 2017.
7. R. Mahony, T. Hamel, and J.-M. Pflimlin, "Nonlinear complementary filters on the special orthogonal group," IEEE Trans. Autom. Control, vol. 53, no. 5, pp. 1203–1218, Jun. 2008.
8. S. Bouabdallah, A. Noth, and R. Siegwart, "PID vs LQ control techniques applied to an indoor micro quadrotor," in Proc. IEEE/RSJ IROS, Sendai, Japan, 2004, pp. 2451–2456.
9. Sunnyvale, CA, 2013. [Online]. Available: https://invensense.tdk.com
10. T. L. Floyd, Electronic Devices: Conventional Current Version, 10th ed. Pearson Education, 2018.