Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 2, No.1, February : 2025

DC MOTOR SPEED CONTROL USING ESP32

Dr.O.P.Suresh, Professor, Department of Electrical and Electronics Engineering, Hyderabad Institute of Technology and Management, india : eee.hod@hitam.org.
N.Avanthika, UG Scholar ,Department of Electrical and Electronics Engineering, Hyderabad Institute of Technology and Management, India: avanthikanilli@gmail.com.
Ch.Rajesh, UG Scholar, Department of Electrical and Electronics Engineering, Hyderabad institute of technology and management, India: raajeshch123@gmail.com.
N.Pranay, UG Scholar, Department of Electrical and Electronics Engineering, Hyderabad institute of technology and management, India: neeradipranay@gmail.com.
V.Rupesh Reddy, UG Scholar, Department of Electrical and Electronics Engineering,Hyderabad institute of technology and management, India: rupeshreddy0987@gmail.com.

ABSTRACT :
This paper presents a precise and efficient method for speed control of DC motors using the ESP32 microcontroller. By leveraging Pulse Width Modulation (PWM), the system modulates voltage duty cycles to regulate motor speed. The ESP32's advanced capabilities, including integrated Wi-Fi and Bluetooth, facilitate manual and remote control via potentiometers, smartphones, or web interfaces. Real-time feedback mechanisms ensure speed stability under varying loads, making this approach ideal for applications in robotics, conveyor belts, and Io based systems. The proposed system demonstrates cost-effectiveness, scalability, and versatility for modern motor control requirements.
Keywords: ESP32, DC Motor Control, PWM, IoT, Potentiometer & Microcontroller.

INTRODUCTION :
Introduction proposes a scalable, solar-powered DC motor control system leveraging ESP32, PWM precision, IoT integration, and adaptive energy management for efficient renewable energy applications.

The rapid advancements in renewable energy technologies have significantly impacted various sectors, with solar energy emerging as a clean and sustainable resource offering immense potential for diverse applications. Solar-powered systems provide an eco-friendly and cost-effective solution for powering electrical devices and systems, making them a preferred choice for modern energy solutions. Integrating solar charging systems with efficient motor control mechanisms ensures optimal energy utilization while addressing environmental concerns. The methods used in referred papers contribute in improved control and precision, efficient energy consumption, reduced commutation ripple and automation.

This study focuses on designing and implementing a solar-powered speed control system for a DC motor, leveraging the capabilities of the ESP32 microcontroller. The proposed system employs advanced features such as Pulse Width Modulation (PWM) for precise motor speed control and IoT integration for enhanced functionality. The ESP32's built-in wireless communication capabilities, including Wi-Fi and Bluetooth, facilitate remote monitoring and control, offering scalability and convenience. Similar approaches in IoT-based motor control have demonstrated the effectiveness of such systems in optimizing performance and energy efficiency [1], [2], [4]. The paper also addresses critical challenges in solar energy applications such as managing variable solar irradiance and ensuring system stability under dynamic load conditions. Adaptive energy management techniques, as explored in previous research, form the foundation of this system's design to ensure reliable and efficient operation [3], [5].

Furthermore, the modular nature of the proposed solution allows it to be tailored for various applications requiring precise and dynamic control of DC motors.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 2, No.1, February : 2025

The main disadvantages of abovementioned methods are cost, complexity, inconsistent performance, overheating risks, limited control, maintenance, increased computational demands. The proposed solution provides speed control with advantages such as cost effective, simple setup, simple integration, real time feedback, flexibility, efficient energy consumption.
Section II shows block diagram and circuit diagram, section III shows the methodology and components used, Section IV shows the Experimental setup and section V shows the Results and Discussions.

BLOCK DIAGRAM :

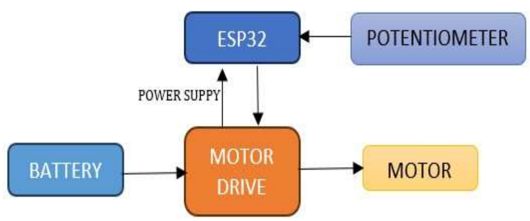


Fig 1: Block Diagram of DC motor speed control using ESP32.
The provided block diagram illustrates the interaction between the key components of a DC motor speed control system using an ESP32 microcontroller. At the core of the system is the ESP32, which serves as the central control unit, generating Pulse Width Modulation (PWM) signals to regulate the motor's speed and direction. A potentiometer is connected to the ESP32, acting as an input device that allows the user to manually adjust the motor speed by modifying the PWM duty cycle. The motor driver, such as the L298N, acts as an intermediary between the ESP32 and the DC motor. Motor driver translates the control signals from the ESP32 into actionable outputs that regulate the power and direction of the motor. A battery serves as the power source for the motor driver and motor, ensuring an independent and portable power supply. The DC motor executes the mechanical motion, with its speed and direction adjusted according to the input signals from the motor driver. This design demonstrates a seamless flow of power and signals, with the ESP32 coordinating the interaction between user input, motor control and power regulation, making it efficient and flexible solution for motor speed control applications.

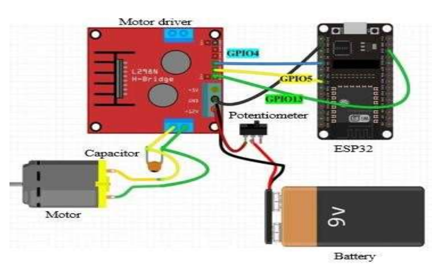


Fig 2: Circuit Diagram of DC motor speed control using ESP32.
To control the DC motor, we use motor output pins on the driver, with ENA setting speed and IN1/IN2 are the input pins are used for controlling the direction. For ESP32, GPIO13 connects to ENA, while GPIO5 and GPIO4 connect to IN1 and IN2, respectively. The 6-12V motor, requiring high starting current, is powered by an external 9V battery, though any 6-12V source is suitable. A slider switch is added for convenient power control, and a capacitor across the motor terminals

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 2, No.1, February : 2025
mitigates voltage spikes. While the switch and capacitor are optional, they enhance the project's functionality.

METHODOLOGY :

Methodology of DC motor speed control using ESP32 employs an ESP32 microcontroller, L298N motor driver, and PWM signals for precise speed and direction control. Sensor-driven feedback enables consistent performance with a closed-loop system. The modular design supports scalability for various applications.

DC motor speed control using ESP32 involves hardware and software to work together. The hardware configuration includes an ESP32 microcontroller as the central controller, an L298N motor driver module to interact with the DC motors, and additional devices such as potentiometers, 9V batteries, and capacitors for power control and safety. The system is programmed using Arduino IDE, where the PWM signal generated by the ESP32 is used to control the motor and direction. This circuit design provides seamless communication between the ESP32 and the driver, and has dedicated GPIO pins are used for speed control. The instant sensor-driven feedback mechanism allows closed-loop control to maintain consistent motor performance under various conditions. This modular and flexible approach enables scalability across multiple drivers and applications.

The following components are used in this:

ESP32 Microcontroller: The ESP32 has multiple GPIO pins, ADCs, DACs, and PWM channels, allowing it to interface with a wide variety of sensors, actuators, and peripheral devices. Its compact size and power efficiency make it suitable for battery-operated systems.

L298N Motor Driver Module: The L298N motor driver module is an essential component for controlling the speed and direction of DC motors. It uses a dual H-bridge driver IC capable of handling up to 46V and 2A per channel, making it suitable for medium-sized motors. The module includes ENA and ENB pins for PWM-based speed control and IN1, IN2, IN3, and IN4 pins for directional control as given in Table 1. An onboard voltage regulator ensures consistent operation, while a built-in heat sink prevents overheating during extended use. The module is versatile and widely used in robotics and automation projects.

DC Motor: The DC motor is a widely used electromechanical device that converts electrical energy into mechanical motion. For this project, a 6-12V brushed DC motor is employed, capable of delivering reliable performance across a range of speeds. Its specifications include a no-load speed of up to 3800 RPM and a rated load speed of around 3200 RPM, making it suitable for precision applications like robotics and conveyor systems. The motor’s compact design and robust construction ensure durability and ease of integration.

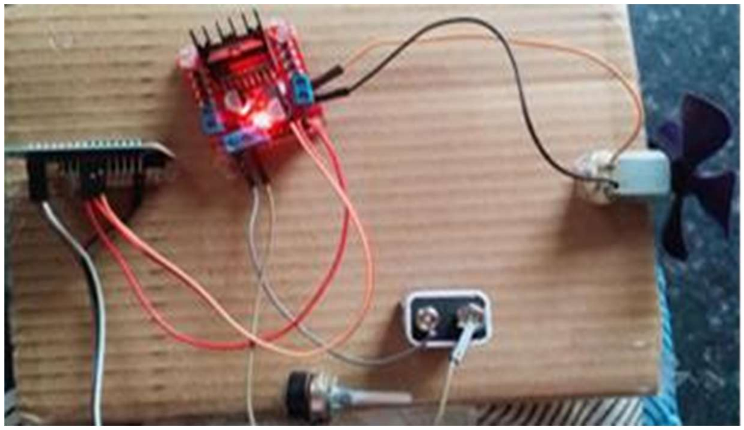
Power Supply (9V Battery): A 9V battery serves as the primary power source for the motor. It provides sufficient voltage and current for stable motor operation while maintaining portability. The battery's compact size and availability make it a practical choice for prototyping and testing.

Capacitors: Capacitors are included in the system to stabilize voltage levels and suppress electrical noise. A 0.1 µF capacitor is connected across the motor terminals to filter out high frequency interference and protect the motor driver from voltage spikes. This ensures smoother motor operation and reduces wear on electronic components.

Potentiometer: A potentiometer is used for manual speed control. It acts as an input device, allowing users to adjust the motor’s speed by varying the resistance and, consequently, the PWM duty cycle sent to the motor driver. Potentiometer Input: The potentiometer's analog signal is read using analogRead (POT_PIN). The ESP32 ADC reads values between 0 and 4095. The potentiometer's range (0-4095) is mapped to the motor speed range (0-255) using the map () function. The mapped value is used as the PWM duty cycle for the ENA pin to control the motor speed. The motor's direction is set to forward (IN1 = HIGH, IN2 = LOW). You can modify this logic to include reverse direction based on additional controls.

EXPERIMENTAL SETUP :

The implementation of the ESP32-based motor speed control system demonstrates an effective



approach for dynamically adjusting the speed of a DC motor using a potentiometer. The system utilizes the analog-to-digital conversion capabilities of the ESP32 to read the potentiometer's input voltage, which is mapped to a PWM signal for motor speed regulation through the L298N motor driver. Experimental results validate the smooth and precise speed control across the full operational range, with motor speed varying proportionally to the potentiometer's rotation. The forward direction of the motor is achieved using predefined logic on the control pins of the motor driver. This system ensures real-time responsiveness with minimal latency and provides a user-friendly interface for manual motor speed adjustment. The approach is scalable for integration into applications such as robotic systems, electric vehicles, or solar-powered tricycles, where efficient and precise motor control is essential.

Fig 3: Prototype of DC motor speed control using ESP32.

RESULTS AND DISCUSSIONS :

The motor is controlled using the ESP32 or ESP8266 microcontroller, where a potentiometer connected to an analog input pin adjusts the PWM signal sent to the ENA pin of the L298N motor driver, allowing for precise speed control. The IN1 and IN2 pins receive HIGH/LOW signals from the microcontroller to determine the motor's direction. The motor is powered by an external 9V battery, with a capacitor across its terminals to stabilize voltage spikes, ensuring smooth operation. This setup, combined with the potentiometer, provides user adjustable speed and direction control.

By adjusting the potentiometer, its analog output is read by the ESP32 through an analog input pin. The ESP32 processes this input to determine the desired speed and generates a corresponding PWM signal, which is sent to the ENA pin of the L298N motor driver. This dynamically adjusts the motor's speed based on the potentiometer's position,

Potentiometer Input	Motor Output (RPM)
25%	625
50%	1450
75%	1875
1000%	2500

When the potentiometer rotates manually at 25% the motor will rotate at the speed of 625 RPM. At 50% the motor will rotate at the speed of 1450 RPM. At 75% the motor will rotate at the speed of 1875 RPM. At 100% the motor will rotate at the speed of 2500 RPM.

CONCLUSION :

ESP32-based motor speed control system successfully demonstrates a cost-effective and efficient solution for dynamic DC motor control. By leveraging the potentiometer as an intuitive input device and utilizing the PWM capabilities of the ESP32, the system achieves smooth and precise motor speed regulation. The integration with the L298N motor driver ensures compatibility with a wide range of motors and simplifies direction control. The experimental results highlight the system's reliability, responsiveness, and adaptability, making it a viable choice for diverse applications, including robotics, electric vehicles, and renewable energy systems. Its scalability and ease of implementation further position it as a practical solution for real-world projects requiring motor control with user interaction.

REFERENCES :

[1] A. M. Ilupeju, B. O. Adegoke, and A. Yakubu, “Temperature-dependent Speed Control Device for an AC Standing Fan,” *J. Eng. Eng. Technol.*, vol. 18, no. 1, pp. 58–64, 2024.

[2] Q. Zhou, J. Shu, Z. Cai, Q. Liu and G. Du, "Improved PWM-OFF-PWM to Reduce Commutation Torque Ripple of Brushless DC Motor Under Braking Conditions," in IEEE Access, vol. 8, pp. 204020-204030, 2020, 10.1109/ACCESS.2020.3036724.

[3] S. Kumar Krishnamoorthy, N. Das, P. Gudimetla and K. Emami, "Enhanced Speed Control for BLDC Motors Using WOA-Integrated PID Controller Optimization," in IEEE Access, vol. 12, pp. 162465-162475, 2024, 10.1109/ACCESS.2024.3480349.

[4] G. R. Morales, S. Escalera Canto and V. Guerrero Hernandez, "Speed Control of DC Servo Motor Under Comparison with PID Tuner Control and Neural Network Control Using Simulink and ESP32," 2023 IEEE International Conference on Engineering Veracruz (ICEV), Boca del Río, Veracruz, Mexico, 2023, pp.1-8, 10.1109/ICEV59168.2023.10329699.

[5] B. Kanchanapalli, S. Banka, G. V. Bacchu, D. Nimmala, A. Ganji and R. Begari, "ESP32-Based Fan Speed Regulation System," 2024 International Conference on Computational Intelligence for Green and Sustainable Technologies (ICCIGST), Vijayawada, India, 2024, pp. 1-6, 10.1109/ICCIGST60741.2024.10717499.