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Speed Control of BLDC Motor Using Arduino UNO

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Abstract: ***The project titled "Speed Control of BLDC Motor Using Arduino and Potentiometer" focuses on developing a simple, low-cost, and efficient method for controlling the speed of a Brushless DC (BLDC) motor. BLDC motors are preferred in modern applications due to their high efficiency, smooth operation, and long lifespan. However, they require an electronic controller for proper commutation and speed regulation.***
In this project, an Arduino microcontroller is used to generate a PWM (Pulse Width Modulated) signal, which acts as a control input for an Electronic Speed Controller (ESC). A potentiometer serves as the manual input device, allowing the user to vary the motor speed by adjusting its analog voltage. The Arduino reads this voltage, converts it to a corresponding PWM value, and sends it to the ESC, which drives the BLDC motor at the desired speed.
The system offers smooth speed variation, quick response, and stable performance. It is highly suitable for applications such as robotics, drones, automation systems, and laboratory experiments. This project demonstrates a practical, reliable, and user-friendly approach to BLDC motor control using basic electronic components.

I. INTRODUCTION

In today's rapidly advancing technological world, automation and efficient control systems play a crucial role in almost every field, including industrial automation, transportation, robotics, and consumer electronics. One of the most important components in such systems is the electric motor. Among the various types of motors available, Brushless DC (BLDC) motors have gained significant popularity due to their superior performance, high efficiency, compact size, low noise, and longer operational life.

Unlike conventional brushed DC motors, BLDC motors do not use mechanical brushes for commutation. Instead, they rely on electronic commutation, which eliminates friction losses and reduces maintenance requirements. This makes BLDC motors highly reliable and suitable for applications such as electric vehicles, drones, cooling fans, and automated machinery.

However, the operation of a BLDC motor is more complex compared to traditional motors, as it requires a proper electronic control system. This is achieved using an Electronic Speed Controller (ESC). The ESC plays a vital role in converting the DC input power into a three-phase output required to drive the BLDC motor. It also controls the speed and direction of the motor based on the input control signal.

In this project, the Arduino Uno is used as the main controller. Arduino is an open-source microcontroller platform that is widely used for embedded system applications due to its simplicity, flexibility, and ease of programming. It allows users to read inputs from various sensors and devices, process the data, and generate appropriate output signals.

The speed control of the BLDC motor in this project is achieved using a potentiometer, which acts as a variable input device. When the user rotates the potentiometer knob, it changes the voltage level, which is read by the Arduino as an analog input. Based on this input, Arduino generates a Pulse Width Modulation (PWM) signal. PWM is a technique used to control the average power delivered to a device by varying the width of the pulses. This PWM signal is sent to the ESC, which in turn adjusts the speed of the BLDC motor accordingly.

To enhance the usability and monitoring capability of the system, a 16x2 LCD display with I2C interface is incorporated. The LCD displays the motor speed or control signal value in real time, providing a clear visual indication to the user. The use of the I2C module reduces the number of connecting wires and simplifies the circuit design.

Furthermore, this project integrates an HC-05 Bluetooth module, which enables wireless communication between the system and a mobile device. The Arduino transmits the motor speed data via Bluetooth, allowing the user to monitor the system remotely using a smartphone. This adds an extra layer of convenience and demonstrates the concept of wireless data communication in embedded systems.

The integration of these components—Arduino, ESC, BLDC motor, potentiometer, LCD, and Bluetooth module—creates a complete system for efficient motor speed control and monitoring. This project not only demonstrates the practical implementation of embedded systems but also provides a platform for learning various concepts such as PWM generation, sensor interfacing,

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display interfacing, and wireless communication.

In conclusion, this project presents an effective and user-friendly solution for controlling the speed of a BLDC motor using Arduino. It highlights the importance of embedded systems in modern engineering applications and provides a strong foundation for developing more advanced motor control systems in the future.

II. LITERATURE REVIEW

The development of efficient motor control systems has been an important area of research in the field of electrical and electronics engineering. Various studies and projects have been carried out to improve the performance, efficiency, and control of electric motors, especially Brushless DC (BLDC) motors.

BLDC motors have gained significant attention due to their advantages over conventional brushed motors, such as higher efficiency, low maintenance, reduced noise, and longer lifespan. According to several research works, BLDC motors are widely used in applications like electric vehicles, robotics, drones, and industrial automation systems.

Many researchers have implemented BLDC motor control using microcontrollers. Among these, the Arduino Uno has become a popular choice due to its low cost, ease of programming, and flexibility. Arduino-based systems are commonly used for educational as well as industrial prototype development.

Previous studies have shown that motor speed can be effectively controlled using Pulse Width Modulation (PWM) techniques. PWM allows precise control over motor speed by varying the duty cycle of the input signal. In most implementations, an Electronic Speed Controller (ESC) is used to convert PWM signals into three-phase outputs required for BLDC motor operation.

In earlier projects, speed control was mainly achieved using simple input devices such as switches or potentiometers. However, with advancements in technology, additional features such as display units and wireless communication have been incorporated. For example, LCD displays are used to monitor system parameters in real time, providing better user interaction.

Furthermore, the integration of wireless communication technologies such as Bluetooth has enhanced the functionality of motor control systems. Modules like the HC-05 Bluetooth module enable data transmission between the system and mobile devices, allowing remote monitoring and control.

Recent developments also focus on combining motor control systems with Internet of Things (IoT) technologies, enabling smart and automated control. These systems can be monitored and controlled remotely through mobile applications or web interfaces.

Based on the review of existing systems, it is observed that combining Arduino, ESC, LCD, and Bluetooth provides a simple yet effective solution for BLDC motor speed control. This project builds upon these concepts and integrates multiple features into a single system, making it more efficient, user-friendly, and suitable for real-time applications.

III. COMPONENTS USED

A. Arduino Uno (Microcontroller Unit)

Arduino Uno is the central controller of the entire system. It reads the analog input from the potentiometer and converts it into a PWM (Pulse Width Modulated) signal, which is used to control the Electronic Speed Controller (ESC).

Key Features:

ATmega328P microcontroller Operating voltage: 5V

6 PWM output pins

10-bit ADC for reading analog signals Simple and user-friendly programming

Role in Project:

Reads analog voltage from potentiometer Generates corresponding PWM signal Sends PWM pulse (1000–2000 µs) to ESC

Ensures smooth speed control of BLDC motor



B. BLDC Motor (12V Brushless DC Motor)

The BLDC motor used in this project is a 12V, 3-phase brushless DC motor, commonly used in robotics, drones, and automation systems. It operates through electronic commutation and requires a three-phase AC signal from the ESC.

Key Features:

12V operating voltage

High efficiency and torque output

No brushes → reduced wear and maintenance Smooth and quiet operation

Role in Project

Converts electrical power into rotational motion Receives 3-phase signals from ESC

Speed varies according to PWM-controlled commutation



C. Electronic Speed Controller (ESC)

The ESC is a crucial component that drives the BLDC motor. It receives a PWM signal from the Arduino and converts the 12V DC input into 3-phase commutation signals required for BLDC motor operation.

Key Features:

Accepts servo-type PWM (1000–2000 µs) Provides 3-phase output for BLDC motor Contains internal MOSFET-based switching circuit Offers smooth acceleration and speed variation

Role in Project:

Interprets the PWM signal from Arduin Converts DC supply into three-phase AC signals Controls motor speed based on pulse width Ensures safe and efficient motor operation



D. Potentiometer (47kΩ Variable Resistor)

The potentiometer acts as the manual speed input device for the system. By rotating its knob, the user varies a voltage between 0V and 5V, which is read by the Arduino as an analog input.

Key Features: Resistance: 47kΩ Smooth rotational control

Accuracy in voltage variation

Role in Project:

Provides analog reference voltage for speed control Determines PWM output level from Arduino Enables user-friendly manual speed adjustment



E. 3S LIPO Battery

The 12V power supply is used to power the ESC and the BLDC motor. BLDC motors require a stable DC input to operate efficiently.

Key Features:

Constant 12V output

Provides sufficient current for motor operation

Role in Project:

Supplies power directly to the ESC Provides driving energy for BLDC motor



F. Connecting Wires

Connecting wires are used to establish proper electrical connections between the Arduino, ESC, potentiometer, and power supply.

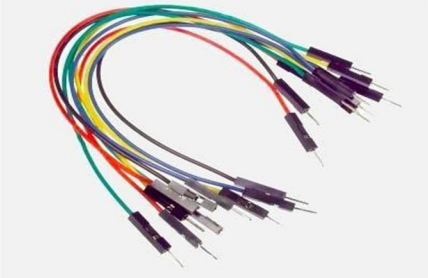
Key Features:

Good conductivity

Flexible and easy to connect

Role in Project:

Connects potentiometer to Arduino (A0) Connects Arduino PWM pin to ESC signal input Connects ESC to BLDC motor and power supply



G. BT Module (HC-05)

The HC-05 Bluetooth module is a wireless communication device used to transmit and receive data between Arduino and a mobile device.

Features

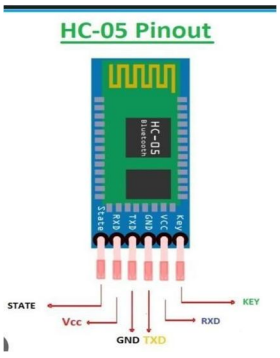
Operates on 2.4 GHz frequency Supports serial communication (UART) Range up to 10 meters

Can work as master or slave Easy to interface with Arduino

Role in Project:

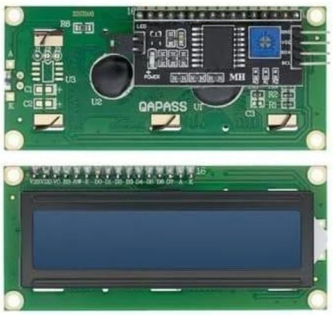
Bluetooth module (HC-05) is used for wireless control. It receives commands from a mobile application.

Arduino processes these commands to control motor speed. It makes the system flexible and user-friendly.



H. LCD Display With I2C Module

A 16×2 LCD with I2C module is used to display text data.
It can show 16 characters in 2 rows and uses only 2 communication pins, making wiring simple.
Features
Displays 16 characters × 2 lines
Uses I2C communication (SDA, SCL) Requires only 4 pins (VCC, GND, SDA, SCL) Low power consumption
Easy to interface with Arduino
Role in Project:
LCD (16x2 I2C) is used to display real-time information. It shows motor speed and control mode (POT / BT).
Helps in monitoring and user interaction.



IV. SPECIFICATION OF COMPONENTS

COMPONENTS	SPECIFICATION	FUNCTIONS
Arduino UNO	ATmega328P,5V	Generates PWM signal to control speed
BLDC Motor	A2212/10T, 1400KV	Convert electrical energy to mechanical rotation
3S LIPO Battery	2200mAh	Use to power the ESC
ESC(Electronic speed controller)	30A	Drives the BLDC motor using PWM signal
Potentiometer	47kohm	Acts as a variable speed input for user control
Connecting Wires	--	Establishes connections between components
HC-05 Bluetooth Module		Convert digital signal into electrical signal
LCD Display		Shows the speed of motor

V. WORKING PRINCIPLE

This project operates on the principle of embedded control using PWM (Pulse Width Modulation) to regulate the speed of a BLDC motor through an ESC, with additional modules for display and wireless communication.

A. Power Distribution and Initialization

A 3S LiPo battery (11.1V–12.6V) supplies power to the ESC ESC internally regulates and distributes power to:
BLDC motor (main load)
Arduino (through BEC, if available) At system startup:
ESC performs arming process
Arduino sends minimum pulse (~1000 µs) ESC confirms readiness using beep signals
Without proper arming, motor will jerk or not rotate properly

B. Analog Input Generation (Potentiometer)

The potentiometer works as a voltage divider circuit As knob rotates: Resistance changes
Output voltage varies from 0V to 5V
This voltage is fed to analog pin A0 of Arduino Uno

C. Analog to Digital Conversion (ADC)

Arduino has 10-bit ADC 0-1023
Input voltage (0–5V) is converted into digital value: This value represents user input precisely

D. Signal Mapping and Processing

Arduino processes ADC value using map() function Because many BLDC motors do not start below ~1100 µs

E. PWM Signal Generation

Arduino generates PWM signal at fixed frequency (~50 Hz for ESC) Only pulse width varies
More duty cycle → more power → higher speed

F. ESC Internal Operation

ESC performs 3 main functions:
Signal Interpretation
Reads PWM pulse width from Arduino Power Conversion
Converts DC → 3-phase AC using switching (MOSFETs) Electronic Commutation
Sequentially energizes motor windings This replaces mechanical brushes

G. BLDC Motor Rotation

BLDC motor contains:
Rotor (permanent magnets) Stator (coils)
ESC supplies current in sequence:
A → B → C phases
This creates rotating magnetic field → motor rotates

H. LCD Display Working

LCD uses I2C communication protocol
Only 2 wires used:
SDA (data) SCL (clock)
Arduino sends: Speed value Display message
Real-time monitoring achieved

I. Bluetooth Communication (HC-05)

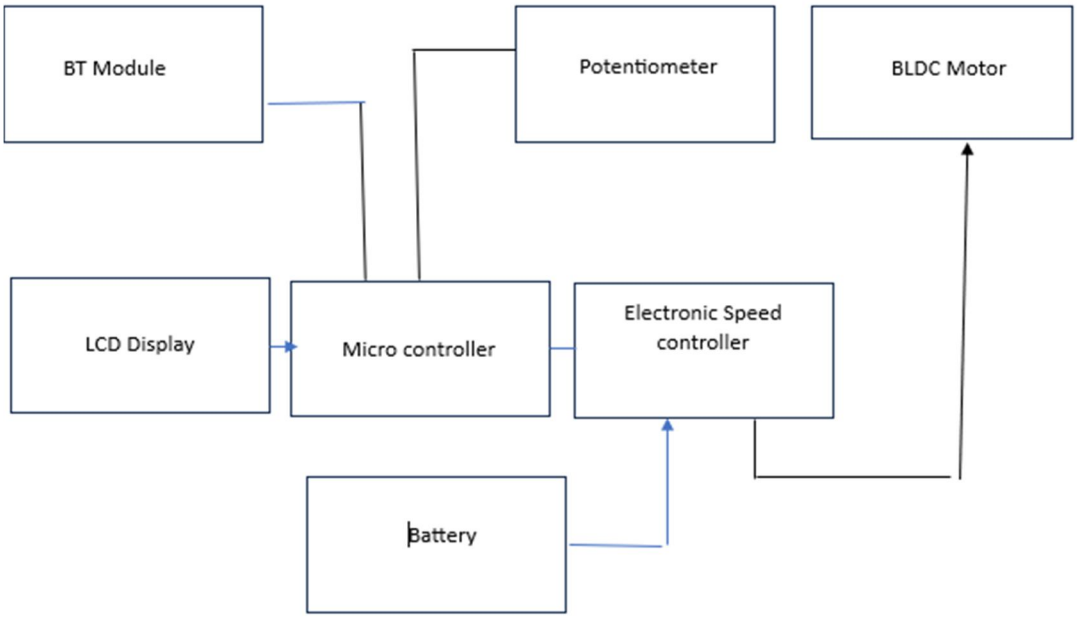
HC-05 uses serial communication (UART) Bluetooth sends speed data:
Speed: 1500
Arduin receive via Bluetooth app Enables wireless monitoring

J. Formula And Speed Calculation

RPM = KV* Voltage
RPM = 1400* 11.1 = 15540 RPM
RPM = (Analog Value/ 1023)* Maximum RPM FOR 3 POSITIONS
0% = 0 RPM
50% = 7770 RPM
100% = 15540 RPM

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VI. BLOCK DIAGRAM

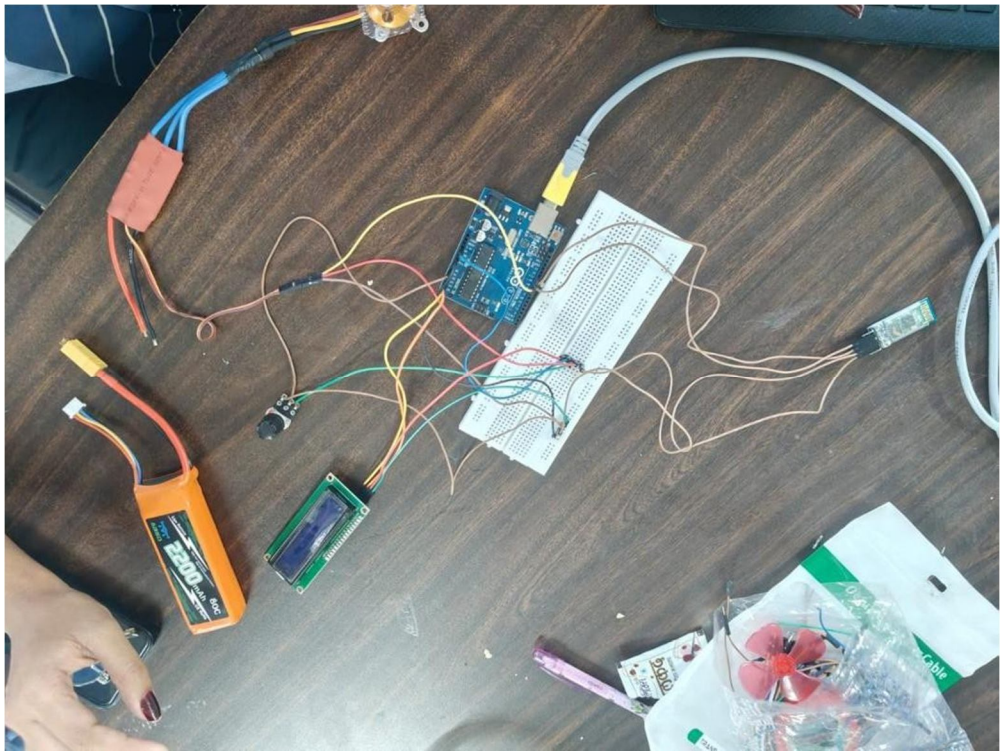


VII. ARDUINO CODE

```
#include <Servo.h>  #include <SoftwareSerial.h> #include <Wire.h>
#include <LiquidCrystal_I2C.h> Servo esc;
SoftwareSerial BT(10, 11);
LiquidCrystal_I2C lcd(0x27, 16, 2); int potValue;
int potSpeed;
int finalSpeed = 1000; int lastPot = 0;
String mode = "POT"; void setup() { esc.attach(9); BT.begin(9600); Serial.begin(9600); lcd.init(); lcd.backlight(); lcd.setCursor(0,0);
lcd.print("BLDC Control “) esc.writeMicroseconds(1000); delay(5000);
}
void loop() {
potValue = analogRead(A0);
potSpeed = map(potValue, 0, 1023, 1000, 1700); if (abs(potValue - lastPot) > 10) {
finalSpeed = potSpeed; lastPot = potValue; mode = "POT";
}
if (BT.available()) { char data = BT.read();
if (data == '1') finalSpeed = 1000; if (data == '2') finalSpeed = 1200; if (data == '3') finalSpeed = 1400; if (data == '4') finalSpeed =
1600; if (data == '5') finalSpeed = 1700; mode = "BT";
}
esc.writeMicroseconds(finalSpeed); lcd.setCursor(0,0);
if (finalSpeed <= 1020) { lcd.print("Motor: STOP  ");
} else { lcd.print("Speed: "); lcd.print(finalSpeed);
lcd.print("   ");
}
lcd.setCursor(0,1); lcd.print("Mode: "); lcd.print(mode); lcd.print("         "); delay(200);
}
```

VIII. PHASE 2 DEVELOPMENT WORK

Hardware connections completed successfully Arduino code developed and uploaded
PWM signal generated through pin D9 Potentiometer input tested on pin A0
BLDC motor speed tested at 0%,50% and 100% position Output readings and RPM values observed
Circuit performance verified with 3S Lipo Battery



IX. ESTIMATED COST OF PROJECT

SR.NO	COMPONENTS	QUANTITY	COST
1	Arduino Atmega328	1	450
2	BLDC Motor (A2212,1400KV)	1	450
3	ESC (30A)	1	450
4	Potentiometer (47kohm)	1	30
5	3S LIPO Battery(2200mAh)	1	1400
6	Connecting Wires	2 Set	60
7	Breadboard	1	80
8	BT Module (HC-05)	1	300
9	LCD Display	1	250
		Total	3470

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X. ADVANTAGES

1) Precise Speed Control: Using PWM signals from Arduino ensures accurate and smooth speed variation of the BLDC motor across the entire operating range.
2) High Efficiency: BLDC motors have low electrical and mechanical losses, resulting in high efficiency compared to brushed DC motors.
3) Low Maintenance: Since BLDC motors do not have brushes, there is:
4) No spark formation Less wear and tear Longer lifespan
5) Cost-Effective System: Using affordable components like Arduino, potentiometer, and a basic ESC makes the system economical for educational and small-scale projects.
6) Smooth Operation: The ESC provides smooth commutation, ensuring: Reduced noise, Less vibration, Stable motor operation

XI. LIMITATIONS

A. *Manual Speed Control Only*

The motor speed is controlled using a potentiometer, which requires manual adjustment. No automatic or closed-loop control is available.

B. *No Feedback Mechanism*

There is no sensor like:
Hall sensor output monitoring Speed encoder
Current sensor
So the system cannot confirm the actual speed or load conditions.

C. *Limited Power Handling*

The ESC and BLDC motor used are generally low-power (12V hobby-grade). This makes the system unsuitable for:
Heavy loads Industrial motors
High torque applications

D. *Basic Control Accuracy*

Speed control depends purely on PWM duty cycle, which may not be perfectly linear with motor speed under load variations.

E. *Single-Direction Rotation*

Most basic ESCs support only forward direction control unless programmed; reverse operation may not be available.

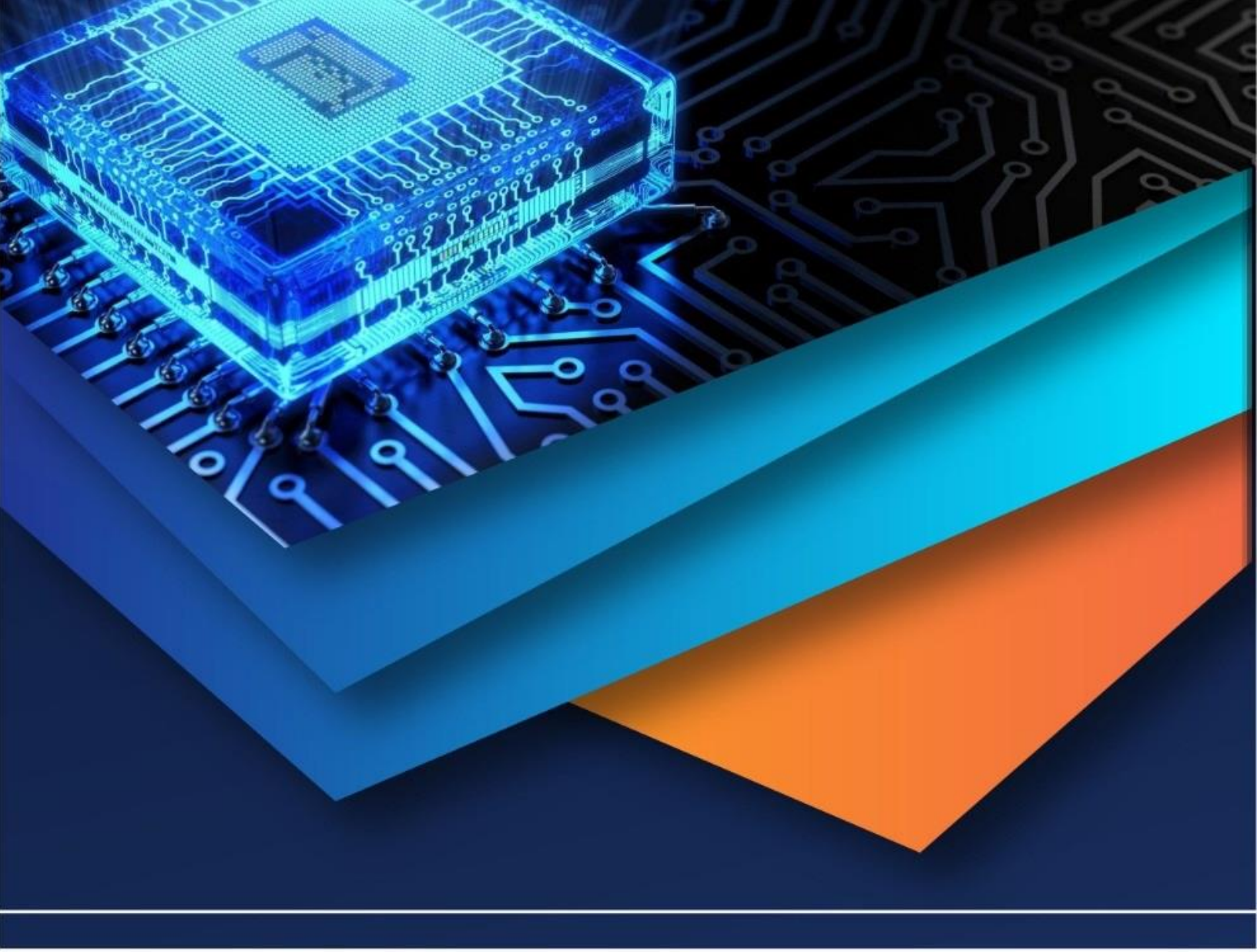
XII. CONCLUSION

The project successfully demonstrates the speed control of a BLDC motor using Arduino UNO.
Both potentiometer and Bluetooth-based control methods are implemented effectively.
The use of an ESC ensures smooth motor operation, while the LCD provides real-time feedback.
Overall, the system is cost-effective, efficient, and user-friendly, and suitable for practical applications.

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