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RESEARCH ARTICLE OPEN ACCESS

# SIMULATION AND IMPLEMENTATION OF BLDC MOTOR CONTROL WITH ARDUINO MEGA IN PROTEUS

**Naima Rahoua[1], Hani Benguesmia[2], Meriem Elhamami[3], Rofaida Becha[4], and Abir Betka[5]**

[1,3,4]Department of Electrical Engineering, University of Biskra, BP 145, Biskra 07000 Algeria;
[2]Laboratory, Electrical Engineering (LGE),Department, Faculty of technology, University of M'sila, University Pole, Road Bourdj Bou Arreiridj, M'sila 28000, Algeria
[5]Department of Electrical Engineering, Echahid Hamma Lakhdar University,El oued, Algeria

[1]http://orcid.org/0009-0001-1181-4670, [2]http://orcid.org/0000-0003-0437-1194, [3]http://orcid.org/0000-0002-2142-1088
[4]http://orcid.org/0009-0001-5581-4875, [5]https://orcid.org/0009-0001-7196-5278

Email: *naima.rahoua@univ-biskra.dz, hani.benguesmia@univ-msila.dz, meriemelhamami7@gmail.com, rofaidabecha@gmail.com, betkaabir@gmail.com,

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## ABSTRACT

Accurate speed control of Brushless DC (BLDC) motors generally requires rotor position sensors to be integrated into the system. This is more expensive and complicated, especially in educational or prototyping contexts. In this paper, a novel and inexpensive method to achieve closed loop control of a BLDC motor without a physical speed sensor is presented. A system was designed where control signals were generated by an Arduino Mega 2560 microcontroller driving an Electronic Speed Controller (ESC) to power an A2212/13T motor for closed-loop control without using a speed sensor. The limitation of not having a sensor was overcome by using a second microcontroller (Arduino Uno R3) to create a synthetic tachometer signal that was proportional to the actual speed of the motor to provide adequate feedback for the blended-traditional Proportional-Integral-Derivative (PID) control algorithm. This control architecture was first developed and rigorously tested in the Proteus Design Suite simulation software, then physical implementation. The experimental results have concluded a substantial improvement in performance: closed-loop control reduced steady state oscillation of speed by approximately 70% as the loads were modified and created consistent current draw that was stabilized compared to open-loop control which was unstable. This work is evidence that a unique sensor-less control method can provide similar function (robustness and reliability) as existing control methods.

## I. INTRODUCTION

Brushless DC (BLDC) motors are prevalent in today's automation and robotics because of their improved performance, reliability, lifespan, and fine control capabilities. They are electronically operated like any other motor, and thus, do not have physical brushes or commutators, unlike brushed DC motors. [1], [2] Controlling Brushless DC (BLDC) motors have been a hot research topic, with many researchers investigating numerous control schemes using both simulation and experimental validation. For example, Prashanthi et al. [3] explored a commutation based BLDC motor model in MATLAB/Simulink, validating an open-loop control scheme (i.e. PWM voltage to control speed) through a comparison of simulation results with physical hardware. As another example, Usha et al. [4] conducted a real-time comparison of many different speed control schemes including a modified proportional integral (PI) and a proportional integral derivative (PID) controller as well as a new current controller. A common research focus is the improvement of PID controllers. Kim et al. [5] developed a new PID structure with an internal PD feedback loop, and showed it as a convex combination of PID and PI-PD controllers. Using a new optimal tuning method, they adopted this controller to BLDC motor speed control, showing better time-domain performance than prior tuning methods. Similarly, Aravanan et al. [6] developed a PID controller for a DC motor with metaheuristic algorithms (KOA and RPOA). Their results showed that KOA minimized rise time, while RPOA was best for minimizing settling time and ITAE equals overall error, and that both methods demonstrated strong robustness.

Another important concept is the implementation of intelligent and advanced controllers for performance improvement. Nayathullaah, et al. [7], carried out a comparison of four different controllers for a five-phase PMBLDC motor for electric vehicles, in which they found that an ANFIS controller produced greater starting torque as well as a better dynamic response (i.e. quick settling time and minimal overshoot) under various load changes than the Hybrid Fuzzy-PI, PI and FLC controllers. Abdullah et al. [8] suggested a fuzzy logic-based expert controller to improve disturbance rejection. The simulations carried out presented a considerable improvement in performance compared to a traditional controller with fuzzy logic controller produced marked less overshoot/undershoot, considerably quicker settling time, better stability and improved disturbance rejection, but order of magnitude possible data issue. Along with other simulation models presented in [9-17], these studies establish a solid foundation to continue the development of advanced controllers for BLDC motors.

Precise speed control of a BLDC motor typically requires a closed-loop system that uses feedback from sensors, such as Hall effect sensors or encoders, to monitor the motor's actual speed. However, in resource-constrained or educational environments, access to such sensors can be limited, posing a significant challenge for implementing effective control strategies. This paper proposes a practical and accessible solution by utilizing the Arduino microcontroller platform. To overcome the lack of physical sensors, an Arduino Uno is programmed to act as a virtual sensor, generating a simulated speed feedback signal. This allows for the implementation of a Proportional-Integral-Derivative (PID) control algorithm on an Arduino Mega, creating a stable closed-loop system without dedicated hardware.

The primary objectives of this work are to:

- Design a control circuit for an A2212/13T BLDC motor using an Arduino Mega, an ESC, and a potentiometer.
- Simulate the entire system using Proteus software to validate the design before physical implementation.
- Implement a closed-loop control system using a software-based feedback mechanism.
- Demonstrate the performance difference between open-loop and closed-loop control.

This paper is structured as follows: Section 2 describes the materials and methods used. Section 3 presents the results and discusses the findings. Finally, Section 4 provides the conclusion and suggests future work.

## II. MATERIALS AND METHODS

### II.1 SYSTEM ARCHITECTURE

The system architecture, as shown in Figure 1, is based on a closed-loop control system. The user sets a desired speed via a potentiometer. The Arduino Mega reads this value, calculates the required PWM output using a PID algorithm, and sends it to the ESC. The ESC drives the BLDC motor. The Arduino Uno generates a simulated feedback signal (current Speed) based on the system's operation, which is read by the Arduino Mega to close the loop.

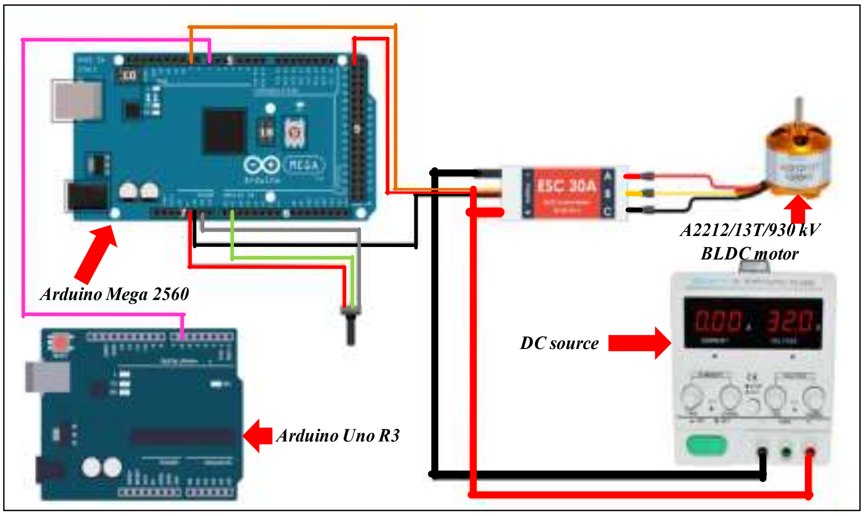


Figure 1: System block diagram.
Source: Authors, (2025).

### II.2 HARDWARE COMPONENTS

#### II.2.1.BLDC motor (A2212/13T/930 KV)

Selected for its reliability and suitable speed-torque characteristics. Its key specifications are summarized in Table 1.[18]

Table 1: A2212/13T BLDC Motor Specifications

| Parameter | Specification |
|---|---|
| Model | A2212/13T/930KV |
| KV Rating | 930 RPM/V |
| Max Current | 13 A |
| Max Voltage | 11.1 V (3S LiPo) |
| Max Power | 220 W |

Source: [18].

### II.2.2. Microcontrollers

An Arduino Mega 2560 was used as the main controller for its numerous I/O pins and processing power. An **Arduino Uno R3** was used to simulate the speed sensor.

### II.2.3. Electronic Speed Controller (ESC 30A)

This circuit interprets the PWM signal from the Arduino and provides the appropriate three-phase power to the BLDC motor.

### II.2.4. Peripheral Hardware

A potentiometer was used for user input, a laboratory DC power supply provided stable voltage, and a breadboard with connecting cables was used for circuit assembly.

## II.3 SOFTWARE TOOLS

### II.3.1. Arduino IDE (v2.3.4)

Used to write, compile, and upload the control code to both Arduino boards.

### II.3.2. Proteus Professional (v8.17)

Used to design the circuit schematic, simulate the interaction between the microcontroller code and the electronic components, and validate system logic before physical construction.

## II.4 CONTROL STRATEGY

The control strategy evolved through two phases:

### II.4.1. Open-Loop Control

Initial tests involved directly mapping the potentiometer value to the PWM output signal without any feedback. This led to unstable performance.

### II.4.2. Closed-Loop PID Control

A PID algorithm was implemented on the Arduino Mega. The "current Speed" feedback was provided by the Arduino Uno, which was programmed to toggle a digital pin (PIN 6) in a fixed loop (HIGH for 1s, LOW for 1s) every 20ms to emulate a square wave signal a real sensor might produce.

## II.5 IMPLEMENTATION PROCESS

The process began with coding the logic in the Arduino IDE. The schematic was then designed and tested in Proteus (Figure 2). Finally, all hardware components were assembled on a breadboard according to the validated schematic.

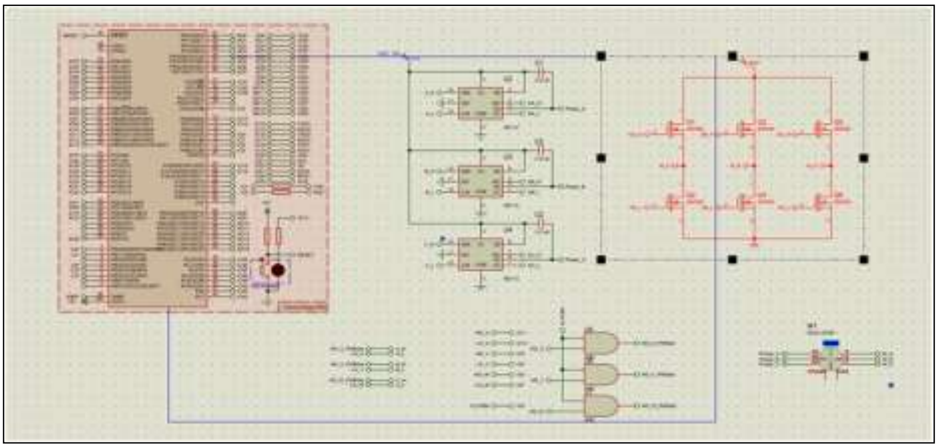


Figure 2: Proteus Simulation Schematic.
Source: Authors, (2025).

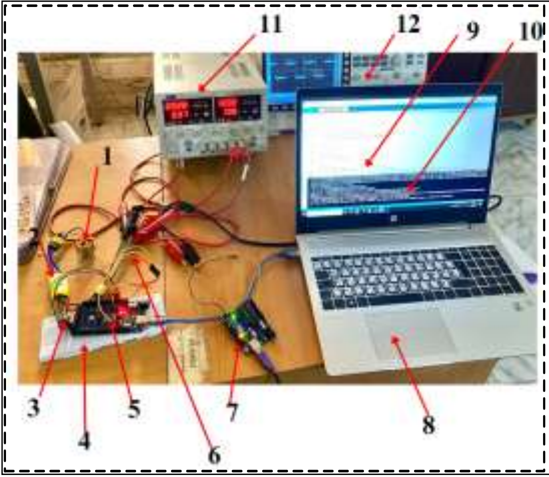
# III. RESULTS AND DISCUSSION

## III.1 SIMULATION RESULTS

The Proteus simulation allowed for the testing of the control logic and circuit behavior in a risk-free virtual environment. The simulation confirmed the correct operation of the PWM generation, signal processing, and motor drive circuitry before any physical components were connected.

## III.2 EXPERIMENTAL RESULTS

The physical setup, shown in Figure 3, consisted of the assembled circuit on a breadboard, connected to the DC power supply and a PC for programming. An oscilloscope was used to monitor signals.



1-BLDC Motor
2-ESC
3-Potentimeter
4-Breadboard
5-Arduino Mega 2560
6-Cables
7-Arduino Uno R3
8-PC
9-Code of Arduino
10-Run of code
11- DC Power Supply
12-Oscilloscope

Figure 3: Photo of Assembled Project.
Source: Authors, (2025).

## III.3 SIGNAL ANALYSIS

The oscilloscope capture in Figure 4 shows the square wave signal generated by the Arduino Uno on pin 6. This signal, with its regular on-off pattern, successfully served as the simulated "currentSpeed" input for the PID controller on the Arduino Mega.

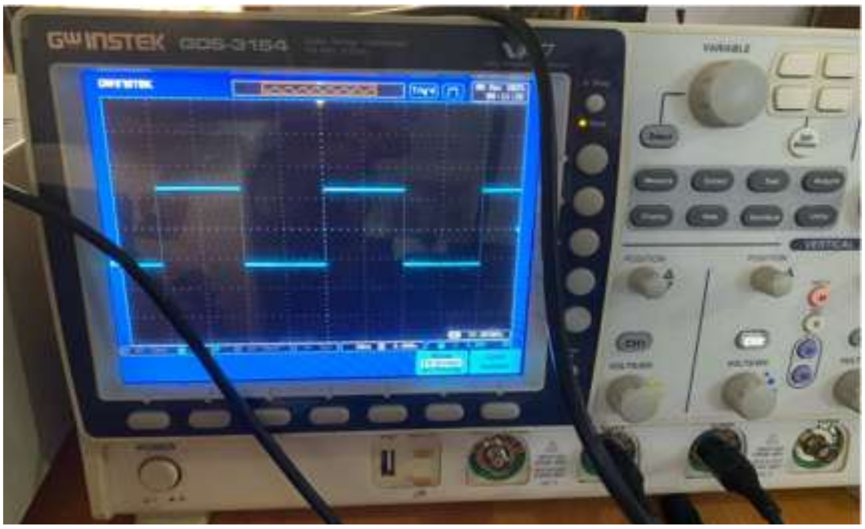


Figure 4: Oscilloscope Capture of Simulated Speed Signal.
Source: Authors, (2025).

## III.4 PERFORMANCE EVALUATION

### III.4.1. Open-Loop Performance

In open-loop mode, the motor speed was erratic and highly sensitive to load and voltage variations. noticeable fluctuations in current and voltage were observed, leading to inconsistent and unpredictable performance.

### III.4.2. Closed-Loop Performance

After activating the closed-loop PID control with the simulated feedback, the motor speed stabilized significantly. The system demonstrated robust performance, maintaining a consistent speed despite variations, and the current and voltage values became stable.

### III.4.3. Speed Estimation

Lacking a direct sensor, speed was estimated using the motor's KV rating (930 RPM/V). With an applied voltage of 12.32V from the power supply, the estimated no-load speed was calculated to be approximately **11,457.6 RPM** (930 RPM/V * 12.32V).

### III.5 DISCUSSION

The results clearly demonstrate the superiority of closed-loop control over open-loop for achieving stable motor operation. The innovative use of a second microcontroller to generate simulated feedback proved to be a highly effective and low-cost solution for enabling closed-loop control in the absence of physical sensors. While the feedback was not based on actual rotor position, the deterministic nature of the signal provided a stable reference point for the PID algorithm to regulate against, effectively emulating the behavior of a real closed-loop system. The Proteus simulation was an invaluable step, saving time and resources by identifying potential issues early in the design phase.

## IV. CONCLUSION

This paper successfully designed, simulated, and implemented a functional closed-loop control system for a BLDC motor using the Arduino platform. The core challenge of missing sensors was overcome by developing a software-based virtual sensor using an Arduino Uno. The results confirm that the implemented PID control with simulated feedback effectively stabilizes the motor's operation, transforming an unstable open-loop system into a reliable one. The main challenges included the initial lack of physical speed sensors and the time constraints associated with integrating and troubleshooting the hardware and software components.

To build upon this work, future iterations could:

1. Integrate a real Hall effect sensor or rotary encoder to provide true speed feedback for more accurate control.
2. Implement a more advanced sensorless control algorithm that uses Back-EMF detection for commutation and speed estimation.
3. Design a custom printed circuit board (PCB) to replace the breadboard for improved reliability and compactness.
4. Develop a user interface, such as an LCD display or a Bluetooth module, for enhanced user interaction and real-time data monitoring.

## V. AUTHOR'S CONTRIBUTION

**Conceptualization:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha
**Methodology:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.
**Investigation:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.
**Discussion of results:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.
**Writing – Original Draft:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.
**Writing – Review and Editing:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.
**Resources:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.
**Supervision:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.
**Approval of the final text:** Naima Rahoua, Hani Benguesmia, Abir Betka, Meriem Elhamami and Rofaida Becha.

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