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**FACULTY OF ENGINEERING**

**REPORT PROPOSAL**

**EPE 4036 FYP1 PROJECT**

**Project Title: A Servo Controller for Brushed DC Motor**

**Supervisor: Dr. Lo Yew Chiong**

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**Table of Contents**

[**Table of Figures:** iii](#_Toc154264812)

[**Chapter 1.** **Introduction** 1](#_Toc154264813)

[**1.1** **Background Overview** 1](#_Toc154264814)

[**1.2** **Problem Statement** 3](#_Toc154264815)

[**1.3** **Project Scope** 4](#_Toc154264816)

[**Chapter 2.** **Objectives** 5](#_Toc154264817)

[**Chapter 3.** **Preliminary Literature Review** 6](#_Toc154264818)

[**3.1** **“DC Motor Speed Control Using PWM” Literature Review** 6](#_Toc154264819)

[**3.2** **“Design and Implementation of Fuzzy PID DC Motor Control System Based on STM32” Literature Review.** 8](#_Toc154264820)

[**3.3** **“Design of Real-time PID tracking controller using Arduino Mega 2560 for a permanent magnet DC motor under real disturbances” Literature Review** 10](#_Toc154264821)

[**3.4** **“Pulse Width Modulation for DC Motor Control Based on LM32” Literature Review** 12](#_Toc154264822)

[**3.5** **“five” Literature Review** 13](#_Toc154264823)

[**Chapter 4.** **Methodology** 15](#_Toc154264824)

[**4.1** **Project Milestone** 16](#_Toc154264825)

[**4.2** **Project Budget** 17](#_Toc154264826)

[**References** 1](#_Toc154264827)

# **Table of Figures:**

[Figure ‎3.1 L293D IC 6](#_Toc154264804)

[Figure ‎3.2 Block diagram of fuzzy PID DC motor control system 8](#_Toc154264805)

[Figure ‎3.3 Main circuit of DC motor control system 8](#_Toc154264806)

[Figure ‎3.4 The PMDC motor control interface designed with MATLAB GUI 10](#_Toc154264807)

[Figure ‎3.5 Bi-directional rotation using a full-bridge 12](#_Toc154264808)

[Figure ‎3.6 Use of high current gain transistor QN2222 for proper 13](#_Toc154264809)

[Figure ‎3.7 Circuit construction of H – Bridge and testing photos 13](#_Toc154264810)

[Figure ‎4.1 Project Gantt Chart 16](#_Toc154264811)

# **Introduction**

## **Background Overview**

The advent of electric motors has been pivotal in the evolution of various mechanical systems, and among the spectrum of motors utilized, the Brushed DC motor is known for its straightforward architecture and control. This type of motor is ubiquitous across multiple sectors due to its operational simplicity and cost-effectiveness, making it a preferred choice for mass-produced goods. Brushed DC motors are characterized by their direct compatibility with DC power sources, a feature that has solidified their position in applications where easy power access is a prerequisite. However, with the advent of more sophisticated technological demands, there is a pressing need for precision in motor operations. Precision, a non-negotiable quality in contemporary applications such as automated precision machining, unmanned aerial vehicles, and sophisticated navigational systems, requires an advanced degree of control that surpasses the capabilities of conventional open-loop controllers.

Considering these requirements, the domain of servo controllers has gained popularity, offering the potential for refined control and enhanced operational efficiency of Brushed DC motors. These controllers employ feedback mechanisms, principally through encoders, to furnish a continuous stream of data regarding motor position and velocity, facilitating an immediate corrective response via closed-loop control systems. The implementation of such feedback loops is fundamental to the servo control methodology, enabling the system to counteract any deviations from predefined motor performance criteria. Nonetheless, the task of engineering a servo controller that is both precise and efficient is fraught with challenges. It necessitates meticulous signal processing, effective power management, and a resilient design that can withstand the exigencies of operation. As the application spectrum of Brushed DC motors broadens to more demanding tasks, the controller technology must concurrently advance, incorporating sophisticated control algorithms such as PID control. This project endeavours to forge a controller that focuses on the performance, cost-efficiency, and minimal complexity, thereby extending the functional envelope of Brushed DC motors.

## **Problem Statement**

The inherent mechanical properties of Brushed DC motors limit their capacity for precision control when relying solely on conventional driver circuits. These standard circuits lack the sophistication to finely tune the motor’s speed and positioning, which is a critical deficiency for applications that necessitate exact movements and strict adherence to motion profiles. The driver circuit alone is not equipped to account for the dynamic variables that impact motor performance, such as external loads and power supply irregularities. To achieve the high level of precision required in advanced technological applications, it is essential to go beyond the basic control that driver circuits offer.

## **Project Scope**

The overarching objective of this project is to engineer a servo controller tailored for Brushed DC motors, with a focus on significantly enhancing their precision in terms of speed and positioning control. A critical part of the project involves designing and building a driver circuit. This circuit will be controlled by a Pulse Width Modulation (PWM) signal originating from a microcontroller. The driver circuit's role is pivotal as it acts as the primary mechanism for efficient power management to the motor. Traditional driver circuits, while forming the basic infrastructure for motor operations, fall short in providing the necessary finesse in motor performance, especially in scenarios where high precision and rapid responsiveness are crucial.

To overcome these limitations, the project will incorporate a Proportional-Integral-Derivative (PID) closed-loop control system. This system will be integrated seamlessly with the driver circuit and microcontroller, establishing the PID controller as the core unit responsible for continuously monitoring and fine-tuning the motor's output. Through this dynamic regulation, the system will be able to maintain strict adherence to the predefined motion profiles, effectively handling external influences such as variations in load and inconsistencies in power supply. This comprehensive approach aims to elevate the performance of Brushed DC motors to meet the demanding precision standards of modern applications, ensuring they operate efficiently and accurately under a wide array of conditions.

# **Objectives**

The objectives of this project are devised to construct a comprehensive solution for the control of Brushed DC motors. By addressing the technical challenges through a systematic approach, the project aims to achieve the following:

1. To design a driver circuit that ensures efficient power regulation for the motor, minimizing energy waste and enhancing performance.
2. To develop a serial communication protocol that enables user interaction with the motor control system, allowing for immediate and precise control modifications.
3. To engineer a closed-loop control system that can accurately manage the speed and position of a Brushed DC motor using feedback from an optical encoder.
4. To implement a PID control system that is capable of real-time adjustments, providing stability and precision in motor responses.
5. To establish a methodology for tuning and calibrating the control system to maintain optimal performance across a range of conditions and applications.

The successful completion of these objectives will lead to the development of a servo controller that not only improves the functionality of Brushed DC motors but also extends their applicability in sophisticated and precision-demanding environments.

# **Preliminary Literature Review**

## **“DC Motor Speed Control Using PWM” Literature Review**

The paper [1] presents a detailed method for regulating the speed of a DC motor utilizing Pulse Width Modulation (PWM). This process is achieved using an AT89S52 microcontroller, which interfaces with an L293D IC for driving the motor and a 555 IC combined with an optocoupler for speed sensing. This setup is geared towards providing precise control over small DC motors in a cost-effective manner, ensuring consistent performance even with varying load conditions.

A diagram of a motor

Description automatically generated

Figure ‎3.1 L293D IC

However, the study is limited by its reliance on L293D IC to drive the DC motor. L293D IC is dual H-bridge motor driver designed to drive a small DC motor, which could restrict its wider application across different motor types or more complex operational contexts. Despite this limitation, the research is valuable for its practical implications in industrial settings. It offers an efficient, reliable, and economically viable solution for controlling the speed of DC motors, highlighting the potential for PWM in motor control applications.

## **“Design and Implementation of Fuzzy PID DC Motor Control System Based on STM32” Literature Review.**

The paper [2] presents an innovative approach to DC motor control, combining fuzzy logic with PID control. Fuzzy logic allows for more adaptable and nuanced control, enhancing the system's robustness. This method is particularly useful for dealing with imprecise or uncertain information, which is common in control systems.

A diagram of a software system

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Figure ‎3.2 Block diagram of fuzzy PID DC motor control system

The system's driving circuit is composed of three IR2110S and a three-phase full-bridge inverter circuit. The IR2110S features undervoltage protection and external overcurrent protection ports. A 120-degree motor is utilized for position detection, with the Hall signal transmitted to the STM32 microcontroller via optical coupling. As the motor rotates, the STM32 generates PWM signals in response to the Hall signal, controlling the MOSFET's operation, thus enabling motor reversing and speed calculation.

A diagram of a circuit

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Figure ‎3.3 Main circuit of DC motor control system

However, notable weakness of this paper is complexity involved in integrating fuzzy logic with PID control, which can be computationally intensive and affect system efficiency. Additionally, there's a lack of detail on software implementation and algorithm optimization for the STM32 microcontroller, which is crucial for understanding performance and scalability.

## **“Design of Real-time PID tracking controller using Arduino Mega 2560 for a permanent magnet DC motor under real disturbances” Literature Review**

The paper [3] primarily focuses on the application and evaluation of a Proportional-Integral-Derivative (PID) control system for a Permanent Magnet Direct Current (PMDC) motor. The study utilizes the Arduino Mega 2560 microcontroller and MATLAB software for implementing and testing the PID controller. Key aspects include the controller's design, tuning, and real-time response to disturbances, showcasing its adaptability and performance in varying conditions.

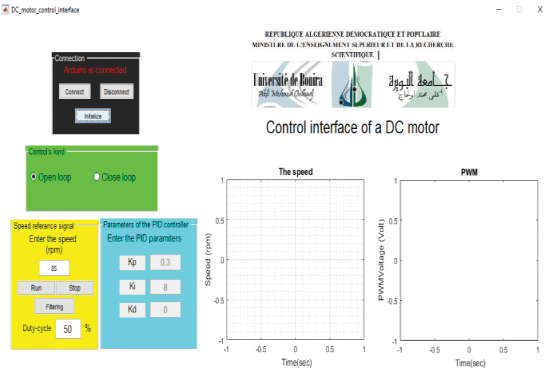


Figure ‎3.4 The PMDC motor control interface designed with MATLAB GUI

The literature review section of the paper provides an in-depth comparison of different control strategies for PMDC motors. It examines traditional methods like PID controllers and delves into more advanced techniques, including fuzzy logic and neural network-based controllers. The comparison is rooted in various performance metrics such as response time, stability, and adaptability to disturbances. This comprehensive analysis underscores the relevance and effectiveness of PID controllers in real-world applications, particularly in scenarios where cost and simplicity are significant factors.

In the study, the use of Arduino Mega 2560 for the PID controller's implementation might present performance limitations. Arduino's hardware constraints, such as processing speed and memory capacity, can impact the controller's ability to handle complex computations or high-speed data processing required for more sophisticated control scenarios. This may limit the controller's responsiveness and precision, particularly in industrial applications where faster and more precise control is crucial. Additionally, Arduino's scalability and integration with other industrial systems might be limited, potentially affecting its applicability in larger or more complex setups.

## **“Pulse Width Modulation for DC Motor Control Based on LM32” Literature Review**

The paper [4] discusses the development of a PWM-based motor control circuit, integrating an H-bridge for bi-directional control of a DC motor. Using the LM324 operational amplifier, the design aims for cost-effectiveness and efficiency, suitable for small-scale applications. It emphasizes the advantages of PWM in controlling motor speed and direction, ensuring effective control with reduced heat dissipation.

A diagram of a circuit

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Figure ‎3.5 Bi-directional rotation using a full-bridge

One potential weakness of this approach is the reliance on the LM324 operational amplifier, which may limit the system's performance in terms of speed and response accuracy, especially in more demanding or high-speed applications. The LM324's characteristics, such as its bandwidth and slew rate, might not be optimal for all DC motor control scenarios, potentially affecting the precision and responsiveness of the PWM control, especially at higher speeds or under varying load conditions.

## **“five” Literature Review**

The paper "Working and Analysis of the H-Bridge Motor Driver Circuit Designed for Wheeled Mobile Robots" discusses the design and implementation of an H-bridge motor driver circuit for controlling wheeled mobile robots (WMRs). The study emphasizes the application of the H-bridge circuit in driving DC geared motors, providing detailed insights into the circuit's construction and functionality. It includes an analysis of different circuit designs for varying load conditions, focusing on enhancing the efficiency and versatility of the motor driver circuit for mobile robotic applications.

A diagram of a motor

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Figure ‎3.6 Use of high current gain transistor QN2222 for proper

A circuit board with wires and cables

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Figure ‎3.7 Circuit construction of H – Bridge and testing photos

A significant weakness of this design is the use of Bipolar Junction Transistors (BJTs) instead of Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs). BJTs, while cost-effective and straightforward in their operation, may not offer the same level of efficiency as MOSFETs, especially regarding power consumption and heat dissipation. This choice can impact the overall performance and durability of the motor driver circuit, particularly in applications requiring high efficiency and thermal management. The limitations imposed by BJTs could be a critical factor in determining the circuit's suitability for more advanced or demanding robotic applications.

# **Methodology**

## **Project Milestone**

**A screenshot of a computer screen

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Figure ‎4.1 Project Gantt Chart

## **Project Budget**

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