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**A Servo Controller for Brushed DC Motor**

by

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ABSTRACT

TODO: Typical format of abstract usually begins with a short introduction to the project that you have done. It is normally covered in 2 to 3 sentences. It should not include what have not been done or what will be done. Furthermore, it is definitely not a general introduction that is not directly related to your project.

This is followed by a brief and concise description of the project implementation. This is basically a synopsis of ‘methodology’ or ‘design’ used in your project. It can include the operation of your project product (for hardware or software type) in brief. Specific model or rare items (hardware or software) can be mentioned. This part is limited to 150 words.

Next, the summary of significant results and findings of your project is presented. This usually comes from the chapter ‘data presentation’ and/or ‘discussion of findings’. The results or data and the discussion can be combined and presented in this part. Data/results can be mentioned in form of relative manner, e.g. x is proportional to y with proportional constant of w, or x = wy. Performance of hardware or software can be either quantitative or qualitative (descriptive) but the descriptive form should be result-oriented. Important comparisons between theoretical or ideal cases and practical cases can also be included.

Finally, the abstract ends with important or overall conclusion. Only the important or significant conclusions from chapter ‘conclusion’ are presented here. Alternatively, an overall conclusion which combines all the individual conclusions can be included here. Notes: You may write your abstract in one or two paragraphs. It is important to note that abstract is written in a case by case basis. However, a typical format can be useful as a guide or reference for you to write the abstract of your project report.

The following items CANNOT be included in the abstract: 1. Issues related to personal, e.g. learned a lot of things from this project. 2. First and second person pronouns (I, we, you, me, my, etc.). 3. Outline of chapters in your project report. 4. Any issues that are not produced from your project (except comparison cases with another person’s work). 5. Reference index or reference number.

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LIST OF ABBREVIATIONS

FYP Final Year Project

DC Direct Current

PID Proportional-Integral-Derivative

PWM Pulse Width Modulation

MOSFET Metal Oxide Semiconductor Field Effect Transistor

d

# INTRODUCTION

## 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 [1]. 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 [2].

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 [3]. 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. This project aims to forge a controller that focuses on performance, cost-efficiency, and minimal complexity, thereby extending the functional envelope of Brushed DC motors.

## Problem Statements

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.

The necessity for precise motor control becomes evident in applications like automated precision machining, unmanned aerial vehicles, and sophisticated navigational systems, where even minor deviations can lead to significant errors or failures. Conventional open-loop control systems are insufficient in these scenarios as they cannot provide real-time feedback and correction, resulting in inaccuracies and inefficiencies.

Moreover, as the complexity and demand for higher performance in technological systems increase, there is a pressing need for a robust control solution that can dynamically adjust to varying conditions and maintain optimal motor performance. This challenge is further compounded by the need for a cost-effective and minimally complex solution that can be easily implemented and maintained.

Thus, the primary problem addressed by this project is the development of a servo controller for Brushed DC motors that can provide precise and efficient control. This involves designing a system that integrates feedback mechanisms and advanced control algorithms to ensure accurate motor operation despite external disturbances and variations in operating conditions. By addressing these challenges, the project aims to enhance the functionality and applicability of Brushed DC motors in high-precision and demanding environments.

## Project Objectives

TODO:

## Project Scope

The 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 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 [4]. The driver circuit's role is pivotal as it acts as the primary mechanism for controlling the motor.

The project will incorporate a Proportional-Integral-Derivative (PID) closed-loop control system [5]. 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. An optical encoder will be used in the feedback loop to provide real-time data on the motor's position and velocity. 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. 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.

## Report Outline

TODO: This section serves to inform readers about the organisation of the report, e.g. what are presented and where and how they are presented.

# LITERATURE REVIEW

This chapter provides a comprehensive overview of the existing literature related to the development and implementation of servo controllers for Brushed DC motors. It outlines the various works that have been conducted in this area, emphasizing different methodologies used to enhance motor control precision and efficiency. More specifically, it highlights the approaches that integrate advanced control techniques, including Pulse Width Modulation (PWM) and Proportional-Integral-Derivative (PID) controllers, in motor control systems.

Particular attention is given to the design and application of H-bridge circuits and their role in controlling the speed and direction of Brushed DC motors. The review also delves into the integration of feedback mechanisms, such as optical encoders, which provide real-time data essential for closed-loop control systems. These feedback systems are crucial for maintaining strict adherence to predefined motion profiles, ensuring accurate and efficient motor performance.

This chapter critically evaluates the contributions of various methodologies, comparing their strengths and weaknesses in relation to the overall research context. The investigated research domains include real-time control techniques and the implementation of microcontrollers, specifically STM32, in embedded motor control applications. The adaptation of these advanced control systems to handle external influences, such as load variations, is also discussed.

The findings of this review will offer an in-depth analysis of the current state of research in the field of Brushed DC motor control. Additionally, it will highlight novel strategies and advancements in control algorithms and feedback mechanisms that contribute to the enhanced precision and efficiency of servo controllers for Brushed DC motors.

## Brushed DC Motor Driver Circuit Design

The design of driver circuits for Brushed DC motors is crucial in achieving precise control of motor speed and direction. Various methods and components are utilized to enhance the performance and efficiency of these driver circuits. This section reviews the key methodologies and components, focusing on the use of Pulse Width Modulation (PWM) and H-bridge circuits.

### H-Bridge Circuit Design

The H-bridge configuration is a fundamental circuit for driving DC motors, allowing them to operate in both forward and reverse directions. An H-bridge consists of four switching elements, typically transistors or MOSFETs, arranged in a configuration that can control the direction of the current flow through the motor, thus controlling its rotation direction [6].

Research has shown that designing an H-bridge DC motor driver using a microcontroller that generates high-frequency PWM signals can effectively control motor speed and direction. One study [7] implemented an H-bridge driver circuit utilizing NPN and PNP MOSFETs driven by TLP250 MOSFET drivers. The use of PWM signals allowed for efficient control of motor speed by adjusting the duty cycle, which directly influenced the motor terminal voltage.

A diagram of a circuit board

Description automatically generated

Figure 2.1 H-Bridge DC Motor Control Circuit [7]

The design included a current sensor to monitor the motor current, protecting the motor from high current conditions such as short circuits or overloading. This integration ensured the longevity and reliability of the motor and the driver circuit [7].

Another research [8] explores the use of Pulse Width Modulation (PWM) for controlling DC motor speed, employing an AT89S52 microcontroller and L293D IC. This method excels in providing precise control over small DC motors in a cost-effective manner. However, the reliance on L293D IC limits its applicability to small motors, posing a challenge for more complex operational contexts.

A diagram of a motor

Description automatically generated

Figure 2.2 Motor Driver L293D

Other research [9] the focus shifts to a PWM-based motor control circuit using an LM324 operational amplifier and four MOSFET to form the H-Bridge circuit. This design is lauded for its efficiency and suitability for small scale applications. Nonetheless, the LM324’s limitations in bandwidth and response accuracy may hinder performance in high-speed applications

### Pulse Width Modulation (PWM)

PWM is a key technique used in motor control to vary the average power delivered to the motor by switching the motor's supply on and off at a high frequency. The duty cycle of the PWM signal determines the motor speed: a higher duty cycle increases the motor speed, while a lower duty cycle reduces it.

One study illustrated the implementation of PWM for DC motor speed control using a microcontroller. In this design, the microcontroller generated the PWM signal, which was then used to control a motor driver IC consisting of two H-bridges, enabling the motor to operate in both directions. The use of a 555 timer IC with an optocoupler provided feedback on motor speed, ensuring precise control [12].

### Efficiency and Reliability

The efficiency of an H-bridge driver circuit is significantly enhanced by using PWM control. Traditional methods, such as using a variable resistor, result in considerable power loss due to heat dissipation. PWM, on the other hand, minimizes these losses by rapidly switching the supply voltage, reducing the time the transistors spend in the transition states where power loss is highest.

In their implementation, researchers emphasized the cost-effectiveness and reliability of their design, noting that it allowed for precise speed control without the need for expensive components. The use of microcontrollers for generating PWM signals further enhanced flexibility and control accuracy, making the design suitable for various industrial applications [12].

## PID Controller Design

# DETAILS OF THE DESIGN

In this chapter the detailed implementation of your project is described, be it analysis, simulation algorithm, software design or hardware design.

## Writing Style

Be systematic and concise. A popular style is to use simple past tense (because the project has been completed). First and second person pronouns (I, we, you, me, my, etc.) should be minimized or avoided.

## Figures and Tables

There are only two kinds of illustrations in a scientific report: tables and figures. A table is simply a grid of rows and columns filled by numbers or information. Any other kind of illustration - line graphs, bar charts, pie charts, photographs, clip art, etc. - is called a “figure.”

A good way to label each diagram is to use the caption “Figure C.x”, where C refers to the chapter and x refer to the sequence of the diagram in the chapter. Figure 3.1 illustrates this concept. Note the alignment and font style of the figure caption. The figure caption should be always aligned at the centre, as shown below.

Anti-aliasing filter

ADC

Anti-imagefilter

DAC

DSP

*x(t)*

*y(t)*

Figure ‎3.1: Example of figure and its caption.

Figures must be of acceptable quality. It should not be too small (difficult for readers to see) or too big (unnecessary waste of space). Avoid enlarging images beyond their print resolution. Example of good and bad quality figures are shown in Figure 3.2 and Figure 3.3 respectively.



Figure ‎3.2: Example of acceptable quality image.



Figure ‎3.3: Example of bad quality image (enlarged beyond their print resolution)

For table, the recommended table style is shown inTable 3.1. Most of the time, tables do not require colour. The quality of the table content is more important than the appearance.

Table 3.1: Table Styles

|  |  |  |  |
| --- | --- | --- | --- |
| Table heading | Table heading | | |
| Sub-heading | Sub-heading | Sub-heading |
| Data/Heading | Data | Data | Data |
| Data/Heading | Data | Data | Data |

Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Each figure and table need to be referred to and explained in the text.

## Equations

Equations and formulae should be typed clearly by using an appropriate equation editor and numbered according to its sequence of order within the chapter. The same principle for labeling a figure and table is applied to equations. For example, in Chapter 1, the first equation should be Equation 1.1; in Chapter 3, the first equation should be Equation 3.1. Below is an example of writing an equation:

 (3.1)

Equation numbers, within parentheses, are to position flush right. Avoid manual combinations spanning several lines which could get out of alignment. For example, (y/x) = ax + b is preferred compared to:

y

- = ax + b

x

# DATA PRESENTATION AND DISCUSSION OF FINDINGS

The results/data presentation and discussion sections can be both the most interesting as well as the most challenging sections to write. You may choose to write these sections separately, or combine them into a single chapter, depending on your preferences.

## Data Presentation

There are three main methods of presenting your data, be it the results of your experiments, information that you have collected and analysed, or statistics from secondary sources (such as books, journal articles or newspaper reports):

* it can be incorporated into the main body of text;
* it can be presented separately as a table; or
* it can be used to construct a graph or chart.

Determining which of these methods is the most appropriate depends upon the amount of data you are dealing with and their complexity. The choice about whether to use text, tables or graphs requires careful consideration in order to ensure that your readers understands your argument and they are not left struggling to interpret data that are poorly presented or in an inappropriate format.

If you are discussing three or more numbers, including them within the main body of text does not facilitate comprehension or comparison and it is often more useful to use a table incorporated within the text.

When presenting your data in a table, make sure to consider the items listed in Table 4.1.

Table 4.1: General Considerations when Using Table and Graphs

|  |  |
| --- | --- |
| **Tables** | **Graphs/Charts** |
| 1. All tables should have titles and table numbers. 2. Columns should have appropriate titles. 3. All units should be clearly identified. 4. All tables should be referred and elaborated in the text. 5. Columns can be numbered if the title is too complex. In this case, the elaboration should be given in the text. 6. Additional notes should be prepared if necessary. | 1. Every diagram should have relevant title and should be numbered. 2. Coordinate units (abscissa) should be written clearly in the graph. 3. All the data points and lines should be clear - generally it should not be more than 2 or 3 curves in every diagram. 4. Types of different data points must be shown in a legend. 5. Every diagram should be referred and elaborated in the text. 6. The gridlines should be in appropriate intervals. |

Next, the presented data or results should be analysed. Each table and graph needs a written explanation; do not assume the reader can understand it on their own. What may be obvious to the authors may not always be obvious to others.

## Discussion of Findings

This section has several purposes. Among others it should interpret and explain your results, answer your research questions or problem statement, justify your approach and critically evaluate your study. The discussion section therefore needs to review your findings in the context of the literature and the existing knowledge about the subject.

You also need to demonstrate that you understand the limitations of your research and the implications of your findings for policy and practice. This section should be written in the present tense. The discussion section needs to follow from your results and relate back to your literature review. Make sure that everything you discuss is covered in the results section. However leave the conclusions for the conclusion chapter.

# CONCLUSIONS

## Summary and Conclusions

This chapter describes briefly and concisely the overall achievement of the project in terms of what have been done, what are the features, what are the functions, etc..

Notes: You may write your conclusion in several paragraphs. Note that conclusions are written in a case by case basis. Hence, this typical format is used as a guide or reference for you to write conclusions. First and second person pronouns (I, we, you, me, my, etc.) should be minimized or avoided.

Conclusion CANNOT include the following items: 1. Issues related to personal, e.g. learned a lot of things from this project. 2. Any issues or works that are not produced from your project (except comparison cases with another person’s work). 3. Any issues that are not discussed in discussion chapter.

Individual conclusions: These individual conclusions are made based on the chapter ‘discussion of findings’. Each discussion in the discussion chapter is concluded here without further discussion. In some cases, a conclusion can be made based on several discussions. Conclusions are made in terms of advantages, disadvantages, limitations, dependencies, affecting factors, problems, etc. All the conclusions should be in justified or confirmed (either good or bad) manner and should not look like discussion.

Overall conclusion: In some cases, an overall conclusion can be made based on the individual conclusions which can be combined into one.

## Areas of Future Research

This section describes some of the issues, which remain to be tackled in the future.

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APPENDIX A

This section contains lengthy materials which are not suitable to be put inside the main text, for example; raw data, equipment and computer programs. Times New Roman typeface with font size 10 shall be used.