

# **PERFORMANCE TEST OF DC ELECTRIC MOTORS**

By

Eric Santosa  
11501005

BACHELOR'S DEGREE  
in

MECHANICAL ENGINEERING – MECHATRONICS CONCENTRATION  
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY



SWISS GERMAN UNIVERSITY  
The Prominence Tower  
Jalan Jalur Sutera Barat No. 15, Alam Sutera  
Tangerang, Banten 15143 - Indonesia

July 2019

Revision after the Thesis Defense on July 16, 2019.

### STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Eric Santosa

Student

Approved by:



Date

Benny Widjaja, S.T, M.T.

Thesis Advisor

Date

Edward Boris Manurung, M. Eng.

Thesis Co-Advisor

Date

Dr. Maulahikmah S.Kom., M. Sc.

Dean

Date

Eric Santosa

## ABSTRACT

### PERFORMANCE TEST OF DC ELECTRIC MOTORS


By

Eric Santosa

Benny Widjaja, S.T, M.T, Advisor

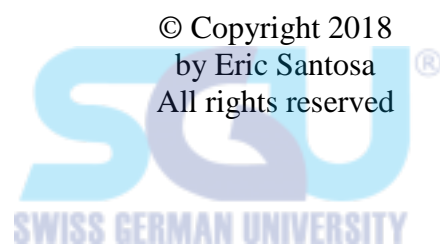
Edward Boris Manurung, M. Eng, Co-Advisor

SWISS GERMAN UNIVERSITY



The main purpose of this research is to develop a bench test to find the real-world specification of the Electric DC Motors. The main focus of this project is to find the efficiency of the DC electric motors. The project begins with make the program for run the motor and for run the sensors. After that applying the PID control to make a system that is able to maintaining the speed at certain Setpoint. Tuning the PID parameters is an important thing to develop a stable speed control system. After get the parameters that suitable for the PID, the data taking can be done. The sensors take the data, and the data process using Microsoft Excel. The features in Microsoft Excel is really helpful, such as the Trendline options to help the data processing. The Logarithmic Transform function also use to support the PID program for avoiding the Exponential function. Then, the data of Voltage, Current, Speed, and Torque of the motor will be determined. For the result, the efficiency of the motor will be determined.

*Keywords: Efficiency, PID Controls, Trendline Equation, Logarithmic Transform*



## **DEDICATION**

I dedicate this works for my family and my future career.



## ACKNOWLEDGEMENTS

I wish to express my gratitude to Mr. Benny Widjaja and Mr. Edward Boris Manurung that always guide me throughout my work; giving me support and ideas, also never get bored if I ask some questions related to my project. My colleagues, especially Arie Dwinarko who worked with me during this project, has also been a great support for me when I had a problem about my project.

Throughout my colleagues in university, Michael Charles, Thomas Tri Putra, Dean Febrius and Imelda Adhitama that always motivated and cheer me up during this project. Then, my partner at Physics' Laboratory, Felicia Kristy, Steven Jonathan, Tan Giovani, and Stefanus Michael that always support me when there was problem.

Finally, I would like to thanks to God because of His relief, I was able to did this project from the beginning until the end.

## TABLE OF CONTENTS

	Page
STATEMENT BY THE AUTHOR .....	2
ABSTRACT .....	3
DEDICATION .....	5
ACKNOWLEDGEMENTS .....	6
TABLE OF CONTENTS .....	7
LIST OF FIGURES .....	10
LIST OF TABLES .....	12
LIST OF EQUATIONS .....	13
CHAPTER 1 - INTRODUCTION .....	14
1.1 Background .....	14
1.2 Research Problem .....	15
1.3 Research Objectives .....	15
1.4 Significance of Study .....	15
1.5 Research Questions .....	15
1.6 Hypothesis .....	16
1.7 Thesis Purpose .....	16
1.8 Thesis Scope .....	16
1.9 Thesis Limitation .....	16
1.10 Thesis Outline .....	16
CHAPTER 2 - LITERATURE REVIEW .....	18
2.1 Electric Motor Bench Test .....	18
2.2 Basic Electrical Power Measurements .....	18
2.2.1 Current Measurement .....	18
2.2.2 Voltage Measurement .....	19
2.2.3 Power Measurement .....	20
2.3 Arduino .....	20
2.3.1 Introduction to Arduino .....	20
2.3.2 Digital Pin .....	21
2.3.3 Analog Pin .....	21
2.3.4 Pulse with Modulation (PWM) .....	21
2.3.5 Timer One .....	21

2.3.6	POW .....	22
2.3.7	Arduino PID .....	22
2.3.8	Arduino Serial Communication.....	22
2.4	Motor Driver.....	23
2.5	RPM Optical Sensor .....	23
2.6	Motor Efficiency.....	23
2.7	Type of DC Motors .....	24
2.7.1	Brushed DC Motor .....	24
2.7.2	Brushless DC Motor .....	27
2.7.3	Stepper Motor .....	28
2.8	Control System .....	29
2.8.1	Open Loop System .....	29
2.8.2	Closed Loop System.....	30
CHAPTER 3 - RESEARCH METHODS .....		31
3.1	Design Justification .....	31
3.1.1	System Level Diagram .....	32
3.2	Components of Design .....	33
3.2.1	Mechanical Components .....	33
3.2.2	Electrical Components .....	35
3.2.3	Software.....	43
3.2.4	Mathematical Equation.....	53
3.2.5	Solidworks Design .....	57
3.3	Preparation.....	59
3.3.1	Mechanical Preparation .....	59
3.3.2	Electrical Preparation .....	59
3.3.3	Program Preparation .....	60
3.3.4	Sensor Performance.....	60
CHAPTER 4 - RESULTS AND DISCUSSIONS .....		62
4.1	DC Motor Drive Performance .....	62
4.1.1	BLDC Excitation with Half Period of Pulse Function .....	62
4.1.2	BLDC Trendline Function.....	66
4.2	Stepper Motor Excitation with Half Period of Pulse Function.....	73
4.3	DC Motor Excitation using PWM Function.....	75
4.4	Speed Control using PID .....	78
4.4.1	BLDC Motor PID Performance .....	78
4.4.2	Stepper Motor PID Performance .....	80
4.4.3	DC Motor PID Performance.....	81
4.5	Efficiency Performance of DC Motor .....	83
4.5.1	BLDC Motor .....	83
4.5.2	Stepper Motor .....	86
4.5.3	DC Motor .....	89



CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS.....	92
5.1 Conclusions .....	92
5.2 Recommendations .....	93
APPENDIX.....	94
A.1 Mechanical Components.....	94
A.2 Electrical Components .....	95
A.3 Trendline Equation data with Logarithmic Transform .....	96
A.4 Best KP Value for BLDC Motor based on Standard Deviation .....	97
A.5 Best KP Value for Stepper Motor based on Standard Deviation.....	98
A.6 Best KP Value for DC Motor based on Standard Deviation .....	99
A.7 BLDC Motor Efficiency Based on Various Speed and Constant Torque ...	100
A.8 BLDC Motor Efficiency Based on Various Speed and Various Torque .....	100
A.9 Stepper Motor Efficiency Based on Various Speed and Constant Torque..	101
A.10 Stepper Motor Efficiency Based on Various Speed and Various Torque ...	101
A.11 DC Motor Efficiency Based on Various Speed and Constant Torque .....	102
A.12 DC Motor Efficiency Based on Various Speed and Various Torque .....	102

