

## الآية

قال تعالى:

إِنَّ اللَّهَ وَمَلَائِكَتَهُ يُصَلُّونَ عَلَى النَّبِيِّ يَا أَيُّهَا الَّذِينَ آمَنُوا  
صَلُّوا عَلَيْهِ وَسَلِّمُوا تَسْلِيمًا ﴿٥٦﴾

صدق الله العظيم

[سورة الاحزاب: الآية 56]

# **DEDICATION**

I dedicate this work to the most precious human beings without whom this project wouldn't be possible, my mother and my father. And I will love to thank them for their continuous believe and support. I also would like to dedicate this piece of work to the rest of my family members for always being there and there unconditional love and faith. My friends who have always support me and have a real faith on me. Thank you to everyone who helped me through this journey and believes in this project till it reaches to this point. Thank you from the heart I dedicate this work to you.

# **ACKNOWLEDGEMENT**

We wish to express our profound gratitude to our Supervisor Associate professor **Awadalla Taifour Ali** for his valuable guidance, continues encouragement, worthwhile suggestions and constructive ideas throughout this project. His support, pragmatic analysis and understanding made this study a success and knowledgeable experience for us.

## **ABSTRACT**

Since the beginning of the 19th century progress has increased in scientific and practical life. There are many requirements, including control systems. The Brushless DC motor is one of the most commonly used engines in the working life due to high efficiency and high resolution. Due to the remaining magnetism and the speed error of the motor, the control methods such as the differential integral proportional control are used to adjust the speed and estimate the error, making the motor very suitable for applications requiring precise speeds such as small aircraft and motor winding. This study use PID controller tuned manually to adjust these PID controller parameters.

## المستخلص

منذ بداية العصر التاسع عشر ازداد التقدم في الحياة العلمية والعملية فأصبح هنالك كثير من المتطلبات من بينها أنظمة التحكم . ومحركات التيار المستمر خالية الفرش تعتبر من المحركات الأكثر استخداما وشيوعا في الحياة العملية نظرا للكفاءة والعزم العالي الذي يعتبر أكثر ما يميزها. نظرا للمغناطيسية المتبقية ومقدار الخطأ في سرعة المحركات تستخدم طرق التحكم مثل المتحكم التناسبي التكاملي التفاضلي في ضبط السرعة وتقدير الخطأ مما يجعل المحرك مناسب جدا للتطبيقات التي تحتاج الى سرعات دقيقة مثل الطائرات الصغيرة و لف المحركات. هذه الدراسة تستخدم المتحكم التناسبي التكاملي التفاضلي بطريقة الضبط اليدوي لتحديد قيم المتحكم.

# TABLE OF CONTENTS

	Page
الاية	i
DEDICATION	ii
ACKNOWLEDEGMENT	iii
ABSTRACT	iv
المستخلص	v
TABLE OF CONTENTS	vi
LIST OF FIGURES	viii
LIST OF TABLES	ix
LIST OF ABBREVIATIONS	x
LIST OF SYMBOLS	xi
<b>CHAPTER ONE INTRODUCTION</b>	
1.1 General Concept	1
1.2 Problem statement	1
1.3 Objective	2
1.4 Methodology	2
1.5 Layout	2
<b>CHAPTER TWO THEORETICAL, BACKGROUND AND LITERATURE REVIEW</b>	
2.1 Introduction	3
2.2 Brushless DC Motor	3
2.2.1 Construction of BLDC motor	5
2.2.2 Theory of operation	8
2.2.3 Torque and efficiency	10
2.2.4 Compared BLDC motor to other motors type	10
2.2.5 Applications of brushless dc motor	11
2.3 Arduino Microcontroller	11
2.4 Proportional, Integral, Derivate Controller	14
2.4.1 PID effect	15
2.4.2 Proportional controller	16
2.4.3 Integral controller	17
2.4.4 Proportional derivative	17
2.4.5 Guideline for selection of controller mode	18
2.4.6 The characteristics of P, I, and D controllers	19
2.5 literature review	20

<b>CHAPTER THREE</b>	
<b>SYSTEM MODELING AND DESIGN</b>	
3.1 System Description	23
3.2 The Brushless DC Motor Model	24
3.2.1 The transfer function of BLDC motor	25
3.3 System Flow Chart	26
3.4 System with PID Controller Design	26
<b>CHAPTER FOUR</b>	
<b>SYSTEM IMPLEMENTATION AND</b>	
<b>EXPERIMENTAL RESULTS</b>	
4.1 System Components	30
4.1.1 BLDC motor	30
4.1.2 IR sensor	30
4.1.3 Power supply	31
4.1.4 Arduino Uno	31
4.1.5 Bluetooth module	32
4.1.6 ESC driver	32
4.2 Software Type	33
4.3 System Implementations	33
4.4 System Experimental results	34
<b>CHAPTER FIVE</b>	
<b>CONCLUSION AND RECOMMENDATIONS</b>	
5.1 Conclusion	41
5.2 Recommendations	41
<b>REFERENCES</b>	42
<b>APPENDIX A</b>	43
<b>APPENDIX B</b>	53

## LIST OF FIGURES

Figure	Title	Page
2.1	Theory of operation of BLDC motor	9
2.2	Content of Arduino UNO board	14
2.3	Proportional Integral Derivative	15
3.1	Block diagram of complete system	23
3.2	Per phase equivalent circuit of brushless DC motor	24
3.3	System flow chart	27
3.4	Simulink of control system	28
3.5	Block diagram of PID controller	28
4.1	BLDC motor	30
4.2	IR sensor	31
4.3	Arduino UNO	32
4.4	Bluetooth module	32
4.5	ESC driver	33
4.6	The electrical circuit connections	34
4.7	System time response with $K_p=9.6473$ , $K_i=13.0625$ , $K_d=0$	36
4.8	System time response with $K_p=260$ , $K_i=360$ , $K_d=60$	37
4.9	System time response with $K_p=260$ , $K_i=500$ , $K_d=15$	38
4.10	System time response with $K_p=230$ , $K_i=200$ , $K_d=0$	39
4.11	System time response with $K_p=80$ , $K_i=50$ , $K_d=0$	40



## LIST OF TABLES

Table	Title	page
2.1	Explain the characteristic of PID parameter.	20
3.1	The BLDC parameter used in Simulink	26
3.2	Experimental of PID parameters.	29

## LIST OF SYMBOLS

$K_p$	Proportional gain
$K_i$	Integral gain
$K_d$	Derivative gain
$T_i$	Integral time
$T_d$	Derivative time
E	Set point-process value
T	Instantaneous time
$V_r, V_b, V_y$	Terminal phase voltage
R	Armature resistance
$i_r, i_b, i_y$	Motor input current
L	Armature-self inductance
$e_r$	Motor back EMF
$K_w$	Back EMF constant
$\theta_e$	Electrical rotor angle
$\omega$	Rotor speed
P	Pole pairs
$\theta_m$	Mechanical rotor angle
$T_e$	Total torque output
F	Frequency

## LIST OF ABBREVIATIONS

DC	Direct Current
BLDC	Brushless Direct Current
AC	Alternating Current
PID	Proportional-Integral-Derivative
EMF	Electro Motive Force
N	North
S	South
EMI	Electro Magnetic Interference
FOC	Field Oriented Control
CPU	Central Process Unit
RAM	Random Access Memory
ROM	Read Only Memory
<i>I/O</i>	Input and Output
<i>A/D</i>	Analog to Digital
<i>D/A</i>	Digital to Analog
VCR	Video Cassette Recording
USB	Universal Serial Bus
KB	Kilo Byte
EEPROM	Electrical Erasable Programmable Read Only Memory
SISO	Single Input and Single Output
MIMO	Multiple Input and Multiple Output
PI	Proportional Integral
PD	Proportional Derivative
PCB	Printed Circuit Board
IDE	Institute of Devolving and Economies
IR	Infrared
AMP	Ampere
LED	Light Emitting Diodes
PWM	Pulse Width Modulation
PAN	Personal Area Network
ID	Identity Document
ESC	Electronic Speed Controller
MATLAB	Matrix Laboratory