

CONTENT

PRONOUNCEMENT	ii
PREFACE	iii
NOMENCLATURE	vii
ABSTRACT	viii
INTISARI.....	ix
CONTENT	x
LIST OF TABLE.....	xii
LIST OF FIGURE.....	xiii
CHAPTER I INTRODUCTION	1
1.1. Research Motivation.....	1
1.2. Problem Statement	2
1.3. Organization	2
1.4. Benefit	3
CHAPTER II BRUSHLESS DC (BLDC) MOTOR FUNDAMENTALS.....	4
2.1. Construction and Operating Principle	4
2.2. Stator	4
2.3. Rotor.....	6
2.4. Hall Sensor	7
2.5. Theory of Operation	9
2.6. General Torque and Speed Characteristics.....	9
2.7. Comparing BLDC Motor to Other Motor Type	10
2.8. Commutation Sequence.....	12
CHAPTER III PROPOSED HARDWARE CONCEPT	16
3.1. IGBT Gate Driver.....	17
3.2. Isolated Power Supply	22
3.3. Digital Signal Controller	23
3.4. Current Sensor.....	24
CHAPTER IV STRATEGY AND SIMULATION	28
4.1. Block Commutation	28
4.2. Improved Round Robin	32
4.3. Current Control Simulation	36
CHAPTER V RESULT AND ANALYSIS	41
5.1. Hall Effect Filter.....	41
5.2. Temperature Characteristic on Gate Driver.....	46
5.3. Switching Frequency	52

5.4. Current Control and Protection	57
CHAPTER VI CONCLUSION AND FUTURE WORK	67
6.1. Conclusion.....	67
6.2. Future Work.....	67
REFERENCES.....	68
APPENDIX	1
A. Tools	1
B. Bill of Material	2
Capacitor Bank	2
Gate driver and IGBT	2
Digital Signal Controller.....	6
C. Printed Circuit Board.....	9
Capacitor Bank	9
Gate Driver	10
Digital Signal Controller.....	12
Adapter Board.....	13
D. Source Code.....	14
E. Raw Data.....	46
F. Gallery	59

LIST OF TABLE

Table 1 : Comparing BLDC to DC Motor.....	11
Table 2 : Comparing BLDC to an Induction Motor.	12
Table 3 : CCW Truth table of inverter activation switch	29
Table 4 : CW Truth table of inverter activation switch	29
Table 5 : R-C Value for low pass filter.	42
Table 6 : Heat Propagation Data	51
Table 7 : Switching frequency data	56
Table 8 : Data output power with different input voltage	65
Table 9 : 100V input voltage data	66

LIST OF FIGURE

Figure 1 : BLDC Motor 80 kW.	4
Figure 2 : Stator of BLDC.....	5
Figure 3 : a. trapezoidal back EMF (left); b. sinusoidal back EMF (right)	5
Figure 4 : Rotor Magnet Cross Section.....	7
Figure 5 : Torque/Speed Characteristics.	10
Figure 6 : Hall Sensor Signal, Back EMF, Output Torque and Phase Current.	13
Figure 7 : Winding Energizing Sequence With Respect To the Hall Sensor.....	14
Figure 8 : General block diagram for driving BLDC motor.	16
Figure 9 : Main block inside 3 phase inverter.....	17
Figure 10 : PG-DSO-16-15 (top view).	18
Figure 11 : Typical Application EiceDRIVER.....	19
Figure 12 : Desaturation switch-off behavior.....	19
Figure 13 : Application Example Bipolar Supply.	20
Figure 14 : a. Short Circuit without Active Clamp (left);	21
Figure 15 : Isolated power supply.	22
Figure 16 : Characteristic Output Voltage.....	23
Figure 17 : Pin diagram of dsPIC30F4012	23
Figure 18 : Schematic of current sensor ACS758ECB-200B-PSS-T	24
Figure 19 : ACS758ECB-200B-PSS-T	25
Figure 20 : Schematic of comparator LM 339.....	26
Figure 21 : Period of a hall signal	28
Figure 22 : Differential time between 2 signals	28
Figure 23 : Simplified BLDC motor diagram.....	30
Figure 24 : Sensor versus drive timing	30
Figure 25 : Three phase bridge.....	31
Figure 26 : The output signal without round robin mechanism	33
Figure 27 : The output signal after Round robin mechanism was implemented ..	34
Figure 28 : Improved Round Robin flowchart.....	35
Figure 29 : Signal Back EMF with improved round robin.	36
Figure 30 : The system without feedback.	37
Figure 31 : The system with feedback.	38
Figure 32 : Uncontrolled current signal	38
Figure 33 : Controlled current signal	39
Figure 34 : Controlled current signal with PI constant	40
Figure 35 : Unfiltered Hall-Effect signal.	41
Figure 36 : Filtered Hall-effect signal.....	43
Figure 37 filter with higher C value.....	44
Figure 38 : Proper Hall-effect signal.....	44
Figure 39 : Output voltage and output current signals without filter.	45
Figure 40 : Output voltage and output current signals with filter.	45
Figure 41 : Image of gate driver.....	46
Figure 42 : Gate driver IGBT temperature image.....	47

Figure 43: Cropping image of gate driver.....	47
Figure 44 : a. Greyscale image (left side), b. Filtered image (right side).	48
Figure 45 : Histogram of greyscale image	48
Figure 46 : a. cropped image (left-side), b. Enhanced image (right-side)	49
Figure 47 : Image with different threshold value	50
Figure 48 : 16 different temperature images.	51
Figure 49 : Trend of gate driver heat propagation.....	52
Figure 50 : DB meter against duty cycle.....	54
Figure 51 : Speed against duty cycle	55
Figure 52 : Efficiency against duty cycle.....	55
Figure 53 : Output current against output reference.	57
Figure 54 : Open loop input and output current	58
Figure 55 : Open loop Current Sensor Data.....	59
Figure 56 : close loop input output current.	59
Figure 57: Close loop current sensor data.....	60
Figure 58 : Input and output current with PID current control.	61
Figure 59 : Current sensor data with PID	62
Figure 60 : Current, reference, and error data.....	62
Figure 61 : Signals response after protection is turn on.....	63
Figure 62 : Protection, PWM, output voltage and current signal.	63
Figure 63 : Output signal with 25V input 100% duty cycle	64
Figure 64 : Output power to BLDC motor.....	65
Figure 65 : Output signal with 100 V input duty cycle 25%.....	66
Figure 66 : 3 Phase Inverter	59
Figure 67 : Tools	59
Figure 68 : BLDC motor 80 kW	59
Figure 69 : Trapezoidal signal with 50V input voltage.....	60