

IMPROVEMENT OF SMART REFRIGERATED LOCKER

By

Patrick Fernando

11801004

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

Revision after the Thesis Defense on 12 July 2023

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.



Patrick Fernando

Student

Monday, 24 July
2023

Date

Approved by:



Leonard P. Rusli, M.Sc., Ph.D.

Thesis Advisor

Tuesday, 25 July
2023

Date

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

Dean

Wednesday, 26
July 2023

Date

ABSTRACT

IMPROVEMENT OF SMART REFRIGERATED LOCKER

By

Patrick Fernando
Leonard P. Rusli, M.Sc., Ph.D., Advisor

SWISS GERMAN UNIVERSITY

In the recent era, every item and ingredients can be delivered online. But storing the items efficiently is a problem, because there is no deposit box that is able to keep the items at a desired temperature. The smart refrigerated locker is made to solve this problem. To keep the maintenance simpler and easier, Peltier module is used to replace the use of compressor, condenser, and evaporator. The locker chamber's temperature is cooled down using Peltier effect, meaning that the Peltier module absorbs heat inside the chamber, and transferring it into the system surrounding. The single Peltier module TEC1 – 12706 with 15V and cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 12V achieved the best cooling effect.

Keywords: Thermoelectric Cooling, Peltier module, Peltier Effect, Refrigeration



DEDICATION

I dedicate this work for the advancement of new refrigeration method



ACKNOWLEDGEMENTS

First of all, I would like to express my endless gratitude to God for giving me the strength and perseverance for being able to work on this paper.

I would also like to give my gratitude to every individual that encouraged me and motivated me on the journey of finishing this paper:

Firstly, I would like to express my gratitude and love to my family that supported me regardless of any difficulties or hard circumstances for the past half year. Their diligence and hard-working spirit change me into the better individual that I am now. No matter how many more hardships will come in our family, I will still look up to you. Please know that you all will have a special place in my heart.

Second, I would also like to express my gratitude to my advisor, Mr. Leonard P. Rusli for always being patient with me. Your discipline and diligent attitude also motivated me to strive more for the best to my abilities for this past half year. This paper could not have been accomplished without your guidance and support and motivation.

Thirdly, I want to thank Zefanya Feberaldine Kusumaputri for never giving up on me no matter how hard I stumble. Your perseverance and fighting spirit made me realize that I can change for the better too. Even though there are many hardships come to us, you will always find a way to overcome it all. You will always have a special place in my heart, living rent-free. I would have never been able to come to this point if not from all the love and support that you always give to me. Thankyou for believing in me. iLy.

Furthermore, I would also like to express my gratitude for all the friends that helped me during all of this journey, which is Dana, Bisma, Michael Darmawan, Jason Budiman, Ezra Levino, Richardo Litanius, and many more names that may be not included.

TABLE OF CONTENTS

	Page
STATEMENT BY THE AUTHOR.....	2
ABSTRACT.....	3
DEDICATION	5
ACKNOWLEDGEMENTS	6
TABLE OF CONTENTS.....	7
LIST OF FIGURES	9
LIST OF TABLES	11
CHAPTER 1 - INTRODUCTION.....	14
1.1. Background	14
1.2. Research Problems.....	15
1.3. Significance of Study	15
1.4. Research Questions	16
1.5. Research Objectives.....	16
1.6. Hypothesis.....	16
CHAPTER 2 - LITERATURE REVIEW	17
2.1. Study on Refrigeration System	17
2.2. Refrigeration by Using Peltier Thermoelectric Cooling.....	18
CHAPTER 3 – RESEARCH METHODS	22
3.1. Design Justification.....	22
3.1.1. Mechanical Design Improvement.....	22
3.1.2. Electrical Design.....	27
3.2. Materials and Equipment	28
3.2.1. Electrical Components.....	28
3.2.1.1. Power Supply	28
3.2.1.2. Arduino UNO	29
3.2.1.3. DS18B20 Temperature Sensor	30

3.2.1.4. TEC1 – 12706 Peltier Module	31
3.2.1.5. TEC1 – 12710 Peltier Module	32
3.2.1.6. SZBK07 DC 6-40V to DC 1.2-36V Step-Down Module	34
3.2.1.7. Terminal Block TB – 2508L.....	35
3.2.2. Mechanical Components	36
3.2.2.1. Steel Locker	36
3.2.2.2. Heatsink	37
3.2.2.3. Aluminum thermal insulation	38
3.2.2.4. Thermal Paste	39
3.2.2.5. Styrofoam.....	40
3.3. Flowcharts.....	41
3.3.1. Refrigeration System	41
3.3.2. Locker Selection System	42
3.3.3. Program Flowchart	43
3.4. Equation	44
3.4.1. Power Supply Justification	44
3.4.2. Peltier Module Justification.....	45
CHAPTER 4 – RESULTS AND DISCUSSIONS.....	49
4.1. Electrical Component Assembly.....	49
4.1.1. Terminal Block.....	49
4.1.2. Step-Down Module.....	49
4.2. Temperature change analysis	50
4.2.1. Single Peltier module TEC1 – 12706 with 12V	50
4.2.2. Single Peltier module TEC1 – 12710 with 12V	57
4.2.3. Cascade stacked Peltier module TEC1 – 12706 and TEC1 -12710 with 12V	63
4.2.4. Single Peltier module TEC1 – 12706 with 15V	71
4.2.5. Single Peltier module TEC1 – 12710 with 15V	81
4.2.6. Cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 15V	91
CHAPTER 5 – CONCLUSIONS AND RECOMENDATIONS.....	103
5.1. Conclusions.....	103
5.2. Recommendations.....	103
GLOSSARY	104
REFERENCES	105
APPENDIX.....	106
CURRICULUM VITAE.....	107

LIST OF FIGURES

Figures	Page
Figure 1. Demand and availability of land-based cold storage in Indonesia	18
Figure 2. Structure of Peltier Module	19
Figure 3. Configuration of Thermoelectric Cooler	20
Figure 4. Temperature of the box versus time	21
Figure 5. Previous Design	22
Figure 6. Previous Chamber Insulation Design	23
Figure 7. New Smart Refrigerated Locker Design	24
Figure 8. New Smart Refrigerated Locker Insulation Design	25
Figure 9. New model hot side heatsink	26
Figure 10. New model cold side heatsink	26
Figure 11. Fritzing Smart Refrigerated Locker	27
Figure 12. Power Supply	28
Figure 13. Arduino UNO pin layout	29
Figure 14. DS18B20 Temperature Sensor pin layout	30
Figure 15. TEC1 – 12706 Peltier Module	31
Figure 16. TEC1 – 12710 Peltier Module	32
Figure 17. SZBK07 DC 6-40V to DC 1.2-36V step-down module	34
Figure 18. Terminal Block TB – 2508L	35
Figure 19. Krisbow 6 Stage Steel Locker	36
Figure 20. Cold Side Heatsink with fan	37
Figure 21. Hot Side Heatsink with Fan	37
Figure 22. Aluminium thermal insulation	38
Figure 23. Thermal Paste	39
Figure 24. Styrofoam box	40
Figure 25. Refrigeration System Flowchart	42
Figure 26. Locker Selection Flowchart	42
Figure 27. Program Flowchart	43

Figure 28. Peltier Module Diagram	45
Figure 29. Peltier module TEC1 – 12706 specifications	47
Figure 30. Peltier module TEC1 – 12710 Specifications.....	47
Figure 31. Graph of single 6A Peltier module TEC1 – 12706 with 12V	57
Figure 32. Graph of single Peltier module TEC1 – 12706 with 12V	57
Figure 33. Graph of single Peltier module TEC1 – 12710 with 12V	63
Figure 34. Graph of cascade stacked Peltier module TEC1 – 12706 and TEC1 -12710 with 12V graph	70
Figure 35. Graph of single Peltier module TEC1 – 12706 with 15V	80
Figure 36. Graph of single Peltier TEC1 – 12710 with 15V	90
Figure 37. Graph of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 15V.....	101

LIST OF TABLES

Table	Page
Table 1. Results of single Peltier module TEC1 – 12706 with 12V (testing one).....	50
Table 2. Power consumption of each component from testing one.....	51
Table 3. Results of single Peltier module TEC1 – 12706 with 12V (testing two).....	52
Table 4. Power consumption of each component from testing two.....	53
Table 5. Results of single Peltier module TEC1 – 12706 with 12V (testing three).....	54
Table 6. Power consumption of each component from testing three.....	55
Table 7. Performance results of single Peltier module TEC1 – 12706 with 12V.....	56
Table 8. Results of single Peltier module TEC1 – 12710 with 12V (testing four).....	57
Table 9. Power consumption of each component from testing four.....	58
Table 10. Results of single Peltier module TEC1 – 12710 with 12V (testing five).....	59
Table 11. Power consumption from each component from testing five.....	60
Table 12. Results of single Peltier module TEC1 – 12710 with 12V (testing six).....	61
Table 13. Power consumption of each component from testing six.....	62
Table 14. Performance results of single Peltier TEC1 -12710 with 12V.....	62
Table 15. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 12V (testing seven).....	64
Table 16. Power consumption of each component from testing seven.....	65
Table 17. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 12V (testing eight).....	66
Table 18. Power consumption of each component from testing eight.....	67
Table 19. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 12V (testing nine).....	68
Table 20. Power consumption of each component from testing nine.....	69
Table 21. Performance results of cascade stacker Peltier module TEC1- 12706 and TEC1 – 12710 with 12V.....	70
Table 22. Results of single Peltier module TEC1- 12706 with 15V (testing ten).....	71
Table 23. Power consumption of each component from testing ten.....	72

Table 24. Results of single Peltier module TEC1 – 12706 with 15V (testing eleven)	72
Table 25. Power consumption of each component from testing eleven	73
Table 26. Results of single Peltier module TEC1 – 12706 with 15V (testing twelve)	74
Table 27. Power consumption of each component from testing twelve	75
Table 28. Results of single Peltier module TEC1 – 12706 with 15V (testing thirteen)	76
Table 29. Power consumption of each component from testing thirteen.....	77
Table 30. Results of single Peltier module TEC1 – 12706 with 15V (testing fourteen)	78
Table 31. Power consumption of each component from testing fourteen	79
Table 32. Performance results of single Peltier module TEC1 – 12706.....	80
Table 33. Results of single Peltier module TEC1 – 12710 with 15V (testing fifteen)	81
Table 34. Power consumption of each component from testing fifteen	82
Table 35. Results of single Peltier module TEC1 – 12710 with 15V (testing sixteen)	82
Table 36. Power consumption of each component from testing sixteen	83
Table 37. Results of single Peltier module TEC1 – 12710 with 15V (testing seventeen)	84
Table 38. Power consumption of each component from testing seventeen	85
Table 39. Results of single Peltier module TEC1 – 12710 with 15V (testing eighteen)	86
Table 40. Power consumption of each component from testing eighteen	87
Table 41. Results of single Peltier module TEC1 – 12710 with 15V (testing nineteen)	88
Table 42. Power consumption of each component from testing nineteen	89
Table 43. Performance results of single Peltier module TEC1 – 12710 with 15V	90
Table 44. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 15V (testing twenty)	91
Table 45. Power consumption of each component from testing twenty	92
Table 46. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 15V (testing twenty-one)	93
Table 47. Power consumption of each component from testing twenty-one.....	94

Table 48. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 15V (testing twenty-two)	95
Table 49. Power consumption of each component from testing twenty-two.....	96
Table 50. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 15V (testing twenty-three)	97
Table 51. Power consumption of each component from testing twenty-three.....	98
Table 52. Results of cascade stacked Peltier module TEC1 – 12706 and TEC1 – 12710 with 15V (testing twenty-four)	99
Table 53. Power consumption of each component from testing twenty-four	100
Table 54. Performance results of cascade stacked Peltier TEC1 – 12706 and TEC1 – 12710 with 15V.....	101

