IMPROVEMENT OF ELECTRONIC COMPONENTS ARRANGEMENT ON PRINTED CIRCUIT BOARD BASED ON THERMAL DISTRIBUTION PROFILE USING COMSOL MULTIPHYSICS

NURUL KAUSAR BINTI AB MAJID

UNIVERSITI TEKNOLOGI MALAYSIA

IMPROVEMENT OF ELECTRONIC COMPONENTS ARRANGEMENT ON PRINTED CIRCUIT BOARD BASED ON THERMAL DISTRIBUTION PROFILE USING COMSOL MULTIPHYSICS.

NURUL KAUSAR BINTI AB MAJID

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechatronics and Automatic Control)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2018

Thanks to ALLAH S.W.T and his Prophet Muhammad S.A.W.

Dedicated to my beloved mother, father,husband, kids, siblings, friends and not to forget my supervisor and lecturers who have a prayer, supported, encouraged, guided and inspired me throughout my journey of education.

ACKNOWLEDGEMENT

First of all, i grateful to Allah (S.W.T) for establishing me and grant me with a good health to carry out this project.

I would like to express the deepest appreciation to my project supervisor, Dr. Fatimah Sham Ismail for her guidance, support and advises through this period of completing this project.

I would also like to acknowledge my friends and my lecturers for their support. I am gratefully indebted to their very valuable comments on this thesis.

Finally, I must express my very profound gratitude to my parents, my spouse, and my kids for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

ABSTRACT

The increasing demand for high speed, high performance, robust and smaller packaging and high-power density leads to the need for an optimal electronic system design. These features will increase the thermal distribution of electronics components, which directly affect the lifespan of the electronic product, performance, and the reliability. This project presents the 3D simulation of the optimal thermal profile of component placement on Printed Circuit Board (PCB) using COMSOL Multiphysics software package. The simulation was carried out for various model of component arrangement on (PCB). The objectives are to find an optimum component arrangement with minimal heat dissipation and smaller area of PCB. Nelder-Mead Optimization tools have been used to solve the multi-objective problems. The result shows that with the proper arrangement, the area of PCB able reduces up to 26% while the temperature of components able to reduce up to 40%. Therefore, this research will significantly benefit for the case of thermal performance improvement onto the electronic product and package size.

ABSTRAK

Dengan pertambahan permintaan terhadap barangan elektronik yang berkuasa tinggi, berkelajuan tinggi, tahan lasak,saiz yang kecil serta tinggi ketumpatan kuasa menyebabkan rekabentuk barangan elektronik haruslah dioptimumkan untuk meminimumkan tahap pelepasan haba. Ciri- ciri ini akan meningkatkan pelepasan haba daripada komponen elektronik yang secara langsung akan mempengaruhi prestasi, ketahanan dan jangka hayat sistem elektronik tersebut. Projek ini akan menunjukkan hasil simulasi terhadap profil haba pada sistem elektronik di atas PCB dalam bentuk 3 dimensi menggunakan aplikasi COMSOL Multiphysics.Objektif projek ini adalah untuk meminumumkan pelepasan haba oleh setiap komponen dan mengurangkan saiz PCB. *Nelder -Mead Optimization Solver* telah dipilih sebagai kaedah untuk mengoptimumkan susunan komponen di atas PCB disamping meminimumkan keluasan PCB. Keputusan kajian ini telah menunjukkan bahawa dengan susunan komponen yang baik, saiz PCB dapat dikurangkan sehingga 26% dan suhu komponen dapat dikurangkan sehingga 40%. Oleh itu, projek ini memberikan sumbangan yang bernilai dalam menghasilkan profil haba yang lebih baik di samping saiz yang lebih kecil untuk sistem elektronik sedia ada.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PCB	-	Printed Circuit Board
1D	-	One Dimensional
2D	-	Two Dimensional
3D	-	Three Dimensional
FEM	-	Finite Element Method
GA	-	Genetic Algorithm
CFD	-	Computational Fluid Dynamics
PSO	-	Particle Swarm Optimization
MCM	-	Multi Component Module
SOIC	-	Small Outline Integrated Chip
LED	-	Light Emitting Diode

LIST OF SYMBOLS

Q	-	Heat transfer rate (Watts)
k	-	Thermal conductivity of the material (W/mK)
A	-	Area of the surface (m^2)
ρ	-	Density (kg/m^3)
C_p	-	Heat capacity (J/Kg°C)
q	-	Energy generated per unit volume (W/m^3)
H	-	Convection heat transfer coefficient (W/m^2K)
T_a	-	Ambient temperature (°C @ K)
Ts	-	Surface temperature (°C @ K)
ε	-	Eemissivity value (W/m^2)
σ	-	Stefan-Boltzmann constant ($W.m.K^{-4}$)

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The increasing demand for high speed, robust and smaller size of packaging in modern electronics leads to the need for optimization of electronic system design. The performance of the electronic system increased while the package becomes smaller leads to high-temperature dissipation inside the device. Temperature and thermal distribution directly affect the lifespan of the electronic product, which can reduce the system reliability and performance.

The recent trends in an electronic package show that more components are integrated into a smaller package [1], [2].According to Moore's Law "The numbers of transistor incorporated in a chip will be approximately double every 24 months." This will increase the power density and eventually will increase the heat generation per volume [3].

Figure 1.1 shows the study done by US air force of avionic Integrity Program that the major causes of electronics failure are due to the temperature which is 55%

while another factor such as vibration, humidity, and dust only contribute 20% to 6% of the causes for electronics failure. This study shows that thermal management is essential criteria in designing the Printed Circuit Board (PCB).

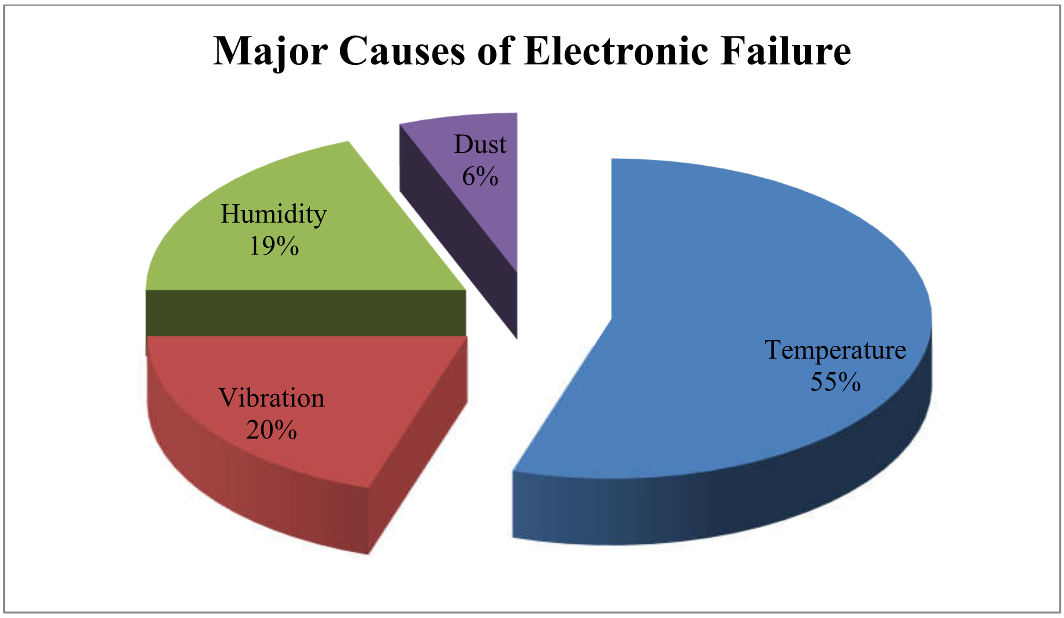

Figure1.1: Major Causes for Electronic Failure

1.2 Problem Statement

Nowadays, the trend of the electronic system is showing that the system packaging is smaller in size while the application becomes high functionality with greater performance such a smartphone, computer, and television. With the decreasing in size of the system, the arrangement of components on PCB will be placed close to each other in order to minimize the area of the PCB, this will lead to increasing the heat dissipation within the components that will slow down the system and eventually will decrease the reliability and the performance of the system.

Thus, the component arrangement on PCB is crucial to minimize the temperature of the system where it can affect the performance of the overall system. Therefore, thermal management is one of the important factors at the early stage of the PCB design. With the modern technology, by using the finite element analysis, the thermal behaviour of the system can be observed by simulation before the product is fabricated.

There are a lot of researches have been done using Finite Element Method (FEM) with a various package software such as [4], [5] and [6] that using ANSYS to model the system. There is also another software package such as FloEFD that been used by [1] and BETASoft [7]. With the various facilities of the software package, enable the optimal output to be obtained at the design stage and finally reduces the development cost.

1.3 Objective

The Objectives of this project are as follows:

i. To improve the optimal components arrangement on Printed Circuit Board based on thermal profile.
ii. To minimize the area of Printed Circuit Board for an acceptable thermal profile.
iii. To do the comparative analysis of the current Printed Circuit Board design with the proposed optimal design.

1.4 Scope of Project

The scopes of this project are:

i. Literature review on electronic component arrangement method and analysis.
ii. Optimize the Thermal distribution and Area of PCB
iii. Simulate using COMSOL Multiphysics Software and Nelder-mead Optimization Module.
iv. Use Copper as material for PCB and Silicon as material of the Component
v. Heat transfer model based on heat conduction and heat convection

1.5 Thesis Outline

This report consists of five chapters. Chapter 1 introduces the background of the study, problem statement, the objective of this project, scope of the project and the overall thesis outline.

Chapter 2 focuses on literature reviews related to this project based on journals and other references. An introduction to heat transfer and the previous works related to the optimization and components arrangement on PCB and Multi-Component Module (MCM) was discussed in this chapter.

Chapter 3 mainly discussed the methodology of the project. The modelling of the PCB and component on PCB explain in this chapter. This chapter also will explain regarding the Optimization for solving the objective functions.

Chapter 4 presents the results of the project. The discussion focused on the temperature of the components and area of PCB. The optimal result of PCB model is compared with the current design.

Chapter 5 concludes overall the project. The recommendation for future works also suggested in this chapter.

REFERENCE

[1] N. Ye, I. Member, Z. Yuan, and J. Di, "An Optimization Algorithm Based on TFPA for Multiple Components Modules," no. 1, pp. 12–15, 2016.

[2] F. S. Ismail, R. Yusof, and a muhd Ma. Waqiyuddin, "Multi-Objective Optimization Problems : Method and Application," 2011.

[3] W. M. Holt, "Moore ' s Law : A Path Going Forward," pp. 8–13, 2016.

[4] R. Rosli, "Optimal heat transfer of heat sink design based on Electronic package thermal distribution usinf comsol package software," 2015.

[5] K. Azha, M. Annuar, F. S. Ismail, M. H. Harun, M. Firdaus, and M. Ab, "Inline pin fin heat sink model and thermal performance analysis for central processing unit," no. March, pp. 35–36, 2015.

[6] A. M. E. Arefin, "Thermal analysis of modified pin fin heat sink for natural convection," *2016 5th Int. Conf. Informatics, Electron. Vis.*, pp. 1–5, 2016.

[7] M. Z. M. Hanafi, F. S. Ismail, and R. Rosli, "Radial plate fins heat sink model design and optimization," *2015 10th Asian Control Conf.*, no. February, pp. 1–5, 2015.

[8] A. Journal, O. F. Basicapplied, F. Sham, and I. Universiti, "Australian Journal of Basic and Applied Sciences Thermal Analysis of Staggered Pin Fin Heat Sink for Central Processing Unit," no. JANUARY, 2015.

[9] E. L. Wilson and R. E. Nickell, "Application of the finite element method to heat conduction analysis," *Nucl. Eng. Des.*, vol. 4, no. 3, pp. 276–286, 1966.

[10] H. C. Cheng, I. C. Chung, and W. H. Chen, "Thermal chip placement in MCMs using a novel hybrid optimization algorithm," *IEEE Trans. Components, Packag. Manuf. Technol.*, vol. 2, no. 5, pp. 764–774, 2012.

[11] X. Li and S. Xu, "Analysis on thermal reliability of key electronic components on PCB," *Inf.*, vol. 15, no. 12 B, pp. 5719–5724, 2012.

[12] M. B. Dogruoz, "Transient Thermal Behavior of SOIC Packages — An Optimization Study," 2016.

[13] K. C. Yung, H. M. Liem, and H. S. Choy, "Thermal performance and placement design of LED array package on PCB," *14th Int. Conf. Electron. Mater. Packag. EMAP 2012*, pp. 1–5, 2012.

[14] K. C. Yung, H. Liem, H. S. Choy, and W. K. Lun, "Thermal performance of high brightness LED array package on PCB," *Int. Commun. Heat Mass Transf.*,

vol. 37, no. 9, pp. 1266–1272, 2010.

[15] N. V Srinivasulu, “Thermal analysis of printed circuit board (PCB) of avionics equipment,” *Int. J. Adv. reaserch Comput. Eng. Technol.*, vol. 1, no. 6, pp. 216–224, 2012.

[16] Y.-J. Huang and S.-L. Fu, “Thermal placement design for MCM applications,” *Trans. Soc. Mech. Eng. J. Electron. Packag.*, vol. 122, no. 2, pp. 115–120, 2000.

[17] H. C. Cheng, Y. H. Tsai, K. N. Chen, and J. Fang, “Thermal placement optimization of multichip modules using a sequential metamodeling-based optimization approach,” *Appl. Therm. Eng.*, vol. 30, no. 17–18, pp. 2632–2642, 2010.

[18] F. S. Ismail and R. Yusof, “Thermal optimization formulation strategies for multi-constraints electronic devices placement on PCB,” *IEEE Reg. 10 Annu. Int. Conf. Proceedings/TENCON*, pp. 1–6, 2009.

[19] F. S. Ismail, R. Yusof, and M. Khalid, “Optimization of electronics component placement design on PCB using self organizing genetic algorithm (SOGA),” *J. Intell. Manuf.*, vol. 23, no. 3, pp. 883–895, 2012.

[20] A. K. Abubakar, F. S. Ismail, and N. W. B. Hisham, “Optimal Thermal Distribution by using Inverse Genetic Algorithm Optimization Technique,” vol. 8, no. 11, pp. 15–21, 1843.

[21] T. Suwa and H. Hadim, “Optimal placement of heat generating components at various levels of electronics packaging,” *Microelectronics J.*, vol. 41, no. 2–3, pp. 129–134, 2010.

[22] J. A. Nelder and R. Mead, “A simplex method for function minimization,” *Comput. J.*, vol. 7, no. 4, pp. 308–313, 1965.

[23] A. Ouyang, Y. Zhou, and Q. Luo, “Hybrid Particle Swarm Optimization Algorithm for Solving Systems of Nonlinear Equations,” 1995.

[24] S. Xu, X. Zou, W. Liu, X. Wang, H. Zhu, and T. Zhao, “Research of Particle Swarm Optimization Algorithm Based on Nelder-Mead Simplex and its application on partial discharge parameter recognition,” no. 1965, pp. 727–730, 2010.

[25] L. Miguel and R. Nikolaos, “Derivative-free optimization : a review of algorithms and comparison of software implementations,” pp. 1247–1293, 2013.