THERMAL MODEL FOR ELECTRONIC COMPONENTS PLACEMENT ON PRINTED CIRCUIT BOARD

ANWAR BIN MOHD ABD MAHI

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Especially for:

My parent who offered me unconditional love, understanding and support throughout my life

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ABSTRACT

This dissertation is regarding the fuzzy-thermal method for the placement of electronic components on a printed circuit board. In the conventional quadrisection placement method, the placement is according to components with higher power dissipation will be placed separately from other components with lower power dissipation. This is done in order to control the overall temperature of the printed circuit board. This principle is different from fuzzy thermal method, where the placement of component is placed randomly on printed circuit board. The fitness function is then calculated to get the best placement. The fitness function is taking into consideration the minimization of area and the temperature. In order to get the best value of fitness function, the area function and the temperature function must minimum. Comparative analysis has been done to verify the results, which show that Fuzzy thermal method has perform 4% better than quadrisection method.

ABSTRAK

Dissertasi ini berkaitan kaedah haba-fuzzy untuk penempatan komponen elektronik di atas papan litar bercetak. Dalam kaedah konvensional penempatan komponen elektronik quadrisection, penempatan adalah bergantung kepada komponen dengan penggunaan kuasa yang lebih tinggi diletakkan berasingan daripada komponen dengan penggunaan kuasa yang lebih rendah. Ini dilakukan dengan tujuan untuk mengawal suhu keseluruhan di atas papan litar bercetak. Ini adalah berbeza sekali dengan kaedah haba-fuzzy di mana penempatan komponen dilakukan secara rawak di atas papan litar bercetak. Fungsi muat kemudian dikira untuk mendapatkan penempatan komponen yang terbaik. Fungsi muat akan mengambil kira pengurangan luas dan haba bagi satu-satu papan litar bercetak. Untuk mendapatkan nilai fungsi muat yang terbaik, fungsi luas dan fungsi haba mestilah berada pada tahap minima Analisa perbandingan dilakukan bagi mengesahkan keputusan, di mana kaedah haba-fuzzy adalah 4% lebih baik daripada kaedah quadrisection.

TABLE OF CONTENTS

5 RESULT AND DISCUSSION

6 CONCLUSION

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

N_i - Shape function

ξ, η - Natural coordinates of any point in the rectangular element

ξ_i, η_i - Natural coordinates of nodes of the rectangular element

LIST OF ABBREVIATIONS

PCB	-	Printed Circuit Board
DC	-	Direct Current
FEM	-	Finite Element Method
MCM	-	Multi-Chip Module
QD	-	Quadrisection
GA	-	Genetic Algorithm
PDE	-	Partial Differential Equation
2-D	-	2 Dimension
3-D	-	3 Dimension

CHAPTER 1

INTRODUCTION

1.1 Project Background

The demand for high-performance, smaller-package, and multi-functional electronic systems poses a great challenge to the thermal management issues in a printed circuit board (PCB) design. When an electronic system is designed into a smaller package, more heat will be generated due to the electrical resistance of a large number of interconnections and smaller surface area available for heat removal. Extreme thermal coupling can damage electronic components because almost all of these components are dissipating heat in the electrical network and function as the heat source of a thermal network [1].

In general, each electronic component is producing heat, which contribute to the increased temperature of each of the components for a period of time. This temperature will spread within components and surrounding area causes one whole module / complete circuit's temperature to increase. There is a need for proper thermal management in electronic components placement. An optimization is needed to produce a balance temperature within a small area of electronic device. One of the conventional methods used for reducing thermal problem is the air-cooled heat sinks with fans or the liquid-cooled heat sink. In real applications, this thermal effect increases proportionally with the power dissipation and thermal resistance of each electronic component and interconnection, and so the cooling capacity needs to be enhanced using larger heat sinks. Heat sinks of various sizes and shapes have been designed in order to allow the heat to be dissipated more quickly. However, in some applications, it is very impractical to use large heat sinks, especially for small-package electronic systems.

Another practical approach for the thermal management of electronic systems is based on strategic placements of the components on the PCB. Bailey (2003) [2] and Bechtold et al. (2005) [2] found that the placement of components on PCBs has a great impact on the thermal distribution of the system because each electronic component has different operating temperatures, power dissipation as well as types of materials and sizes, which will affect the overall thermal distribution of the PCB. Improper components arrangements and layouts may produce hot spots, which can shorten the device lifetime, and can even cause damage to the system devices. Therefore, if the components are optimally placed on the PCB, the thermal effects can be well distributed and minimized [3].

Today, for certain applications, it is very difficult to produce electronic products that meet engineering, economic, logistical, and technical integration requirements of product manufacturing. From engineering point of view, several parameters are taken into consideration such as power, supply and input voltages, operating temperature, junction temperature, and storage temperature.

In terms of economic and logistic, the product manufacturers will consider area and cost as the key factor. Small size will contribute to lower cost of storing and production. Electronic devices with big a volume (10K to 100K) of production can make a lot of profit to manufacturer. A PCB size of 100cm X 100cm can make 100 pieces of small PCB size of 10cm X 10 cm. A small PCB size of 20cm X 20cm can only produce 50 pieces of small PCB.

Normally temperature range for electronic component is from 0 to 70°C. There is a requirement to produce electronic part that can be operated beyond this temperature. This is different from “industrial” which are from -40 to 85°C operating temperature range. These industrial operating temperature generally able to satisfy the demands of the semiconductor customers in the computer, telecommunications, and consumer electronic industries.

1.2 Problem Statement

Each electronic component is a heat sources, which contribute to the increased temperature of each of the components. This temperature will spread within the neighboring components by conduction or convection, which will increase the temperature of the system. If these temperature increasing over the limit, it will effect product performance and reliability.

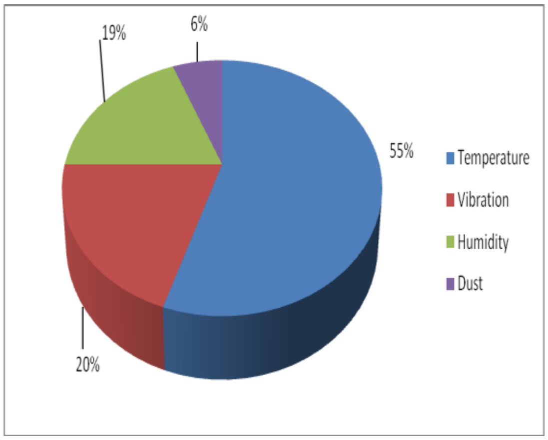

Figure 1.1: Major causes of electronic failure

Source: U.S. Air Force Avionics Integrity Program

Figure 1.1 above shows the major contributor of electronic failure. It can be seen that the major cause of electronic failure is due to temperature (55%), due to vibration

(20%), due to humidity (19%) and due to dust (6%). Figure 1.2 shows the lifespan of an electronic devices. The lifespan will decrease with an increase of temperature.

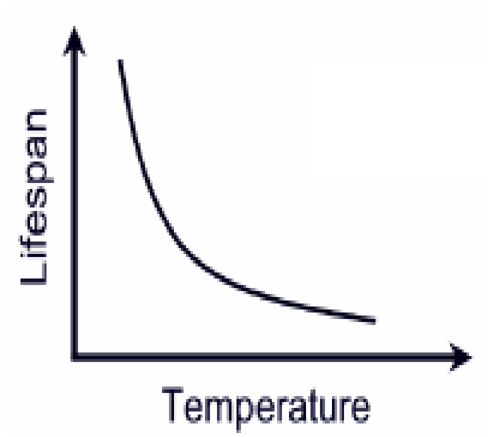

Figure 1.2: The lifespan of
electronic devices

There are some limitations to the approaches made in the previous studies, especially in ensuring the optimality of all the main variations of the electronic components on a PCB such as operating temperature, types of material, size and dimension, apart from power dissipation. Therefore, a new optimization technique that can organize all the objective functions globally and finally give a set of optimal solutions is needed.

In this study, the new placement method is proposed and applied in a PCB component placement optimization problem. Therefore, the optimization problem consists of 2 objective functions related to the junction temperature of each component and the PCB dimensional area. The approach ensures that an optimal placement of each electronic component on the PCB is achieved by minimizing the objective functions while satisfying some standard manufacturing specifications and constraints

1.3 Project Objectives

Following are the objectives that hopefully to be achieved at the end of this project implementation. The objectives are:-

1. To derive an algorithm based on fuzzy logic approach for electronic components placement on printed circuit board.
2. To minimize the objective functions of temperature distribution and area of printed circuit board.

1.4 Scope of Work

This project is done based on simulation and experimental work by using two optimization approach which are Quadrisection method and Fuzzy-Thermal method.

(a) Simulation

This research will focus on temperature and area as the key factor in product performance and reliability. A fuzzy logic approach is used to do an analysis and algorithm in the placement. According to principle, electronic components which dissipate high power must not be placed close to one another. This is to ensure thermal balance exists inside the product. High power dissipation also makes repulsive force between two components higher making uneven thermal distribution. So, the two components have to be placed farther.

(b) Experimental Setup

In accomplishing this research, the scope of the work has been divided into a few parts. The first part is designing and establishing the experimental setup where a hardware setup is required to measure the temperature as well as the area.

The second part is to measure the printed circuit board sample and collects the measured data in terms of temperature and area. The total number of printed circuit board samples is determined and the methods in doing the measurement are also determined during this stage.

The third part is data acquisition and data manipulation. At this stage the measured value will be transferred to computer for simulation and manipulation.

(c) Optimization Approach

There a two optimization method which is the quadrisection method and fuzzy-thermal method. The quadrisection method is a method where the components with higher power dissipation will be placed separately from other components with lower power dissipation. The fuzzy-thermal method is a method where the components are placed randomly on the PCB. In this project, 9 components will be used. 1 component is having a power dissipation of 2W with temperature of 30°C and 8 components with power dissipation of 1W and temperature of 18°C is used.

1.5 Thesis Outline

Chapter 1 discusses the important aspect of the research work such as project background, problem statement, project objectives, scope of work, as well as the thesis outline itself.

Chapter 2 presents the Literature Review which discusses some papers of the related area in optimizing the component placement on PCB. This chapter provides information on optimizing component placement based on several variables that are taken into consideration. This chapter also explains on the concept of optimizing using fuzzy-thermal method and quadrisection method.

Chapter 3 will explains on fuzzy-thermal method in details. The relationship between fuzzy-thermal method and PCB model relating the area and temperature are discussed in details. Fuzzy-thermal model are introduced in this chapter.

Chapter 4 will perform simulation based on mathematical model of area and temperature. The process of performing the simulation using MATLAB PDETool is discussed in details.

Chapter 5 presents the results and discussion. This chapter shows temperature reading with the optimized components placement using fuzzy-thermal method and quadrisection method. The results of fitness function iteration using both methods are also shown.

Chapter 6 concludes the dissertation and includes recommendation for future research and study.

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