OPTIMAL HEAT TRANSFER OF HEAT SINK DESIGN BASED ON ELECTRONIC PACKAGE THERMAL DISTRIBUTION USING COMSOL PACKAGE SOFTWARE

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ABSTRACT

Due to the advanced development in semiconductor technology, the size of electronic component and devices become smaller while the performance becomes significantly greater. The increased of power density in the system causes the system components to either operate at higher temperature which led to thermal problem. This thermal problem will reduce the performance and efficiency of the electronics package. The most popular device used for electronic cooling is heat sink. In order to improve the heat transfer process, various type of heat sink with different shapes, materials and dimensions have been designed. This study aims to provide the optimal heat transfer of heat sink to minimize electronic package thermal distribution. This study only focuses on circular and square types of pin fin heat sink with various arrangements. In this study, COMSOL Multiphysics software will be used to simulate various pin fins arrangement design of the heat sink model. The results have proposed a new arrangement of the pin fin that able to give better thermal performances which are 4.1% and 0.5% for circular type and 0.2% and 0.4% for square type compared to inline and staggered arrangement.

ABSTRAK

Oleh kerana pembangunan yang maju dalam teknologi semikonduktor, saiz komponen elektronik dan peranti menjadi lebih kecil manakala prestasinya semakin meningkat. Peningkatan ketumpatan kuasa dalam sistem menyebabkan komponen dalam sistem untuk beroperasi pada suhu yang lebih tinggi yang membawa kepada masalah termal. Masalah termal ini akan mengurangkan prestasi dan kecekapan pakej elektronik. Peranti yang paling popular digunakan untuk penyejukan elektronik adalah *heat sink*. Dalam usaha untuk meningkatkan proses pemindahan haba, pelbagai jenis *heat sink* dengan bentuk, bahan dan dimensi telah direka. Projek ini bertujuan untuk menyediakan pemindahan haba yang optimum dalam *heat sink* untuk mengurangkan pengagihan haba dalam pakej elektronik. Projek ini hanya memberi tumpuan kepada *heat sink* jenis bulat dan segi empat dengan pelbagai susunan pin. Dalam projek ini, perisian COMSOL Multiphysics akan digunakan untuk mensimulasikan pelbagai susunan pin di atas permukaan *heat sink*. Keputusan telah mencadangkan kaedah penyusunan baru pin yang dapat memberikan prestasi termal yang lebih baik iaitu sebanyak 4.1% dan 0.5% untuk jenis bulat dan 0.2% dan 0.4% untuk jenis empat segi berbanding dengan susunan pin sebaris dan berperingkat.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

HTS	-	High Temperature Superconductive
1D	-	One Dimensional
2D	-	Two Dimensional
3D	-	Three Dimensional
CPU	-	Computer Processing Unit
FEM	-	Finite Element Method
GA	-	Genetic Algorithm
CFD	-	Computational Fluid Dynamics
PSO	-	Particle Swarm Optimization
CCC	-	Carbon-Carbon Composite
CIA	-	Circular Inline Arrangement
CSA	-	Circular Staggered Arrangement
CRA	-	Circular Random Arrangement
SIA	-	Square Inline Arrangement
SSA	-	Square Staggered Arrangement
SRA	-	Square Random Arrangement

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)
$\dot{q}$	-	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	-	Emissivity value
σ	-	Stefan-Boltzmann constant
L_channel	-	Channel length (cm)
H_channel	-	Channel height (cm)
W_channel	-	Channel width (cm)
L_chip	-	Chip size (cm)
H_chip	-	Chip height (cm)
P_tot	-	Total power dissipated by electronic package (Watts)
L1	-	Pin height (cm)
L2	-	Pin length/diameter (cm)
H_size	-	Base height (cm)
L_size	-	Base length (square) (cm)
U0	-	Mean inlet velocity (cm/s)
T0	-	Inlet temperature (°C)

CHAPTER 1

INTRODUCTION

1.1 Background of study

Nowadays, the demand of using electronic devices such as computers, laptops and others are very high [1]. Recent advances in semiconductor technology have given rise to a size-reduced, high-tech device with an ever-greater system performance [2,3]. This tendency of development inevitably leads to the significant increase in power densities encountered in microelectronics equipment. It is also increased the heat generation rate per volume of the device. If the heat generation not appropriately removed, it would affect the normal operation of the device that will leads to device malfunctioning and the device lifetime can be substantially reduced or might be severely damaged.

Figure 1.1 shows the result of studies for major causes of electronic failure made by electronic company (AI Technology Inc). It shows that there are four major causes which are dust, humidity, vibration and temperature. The least factor that contribute the cause of electronic failure is dust (6%) followed by humidity (19%) and vibration (20%) meanwhile the major cause of electronic failure is temperature (55%). It can be conclude that poor thermal management leads to more than 50% of electronic failures. Thus it is essential to improve the transfer and dissipated heat generated from electronic devices.

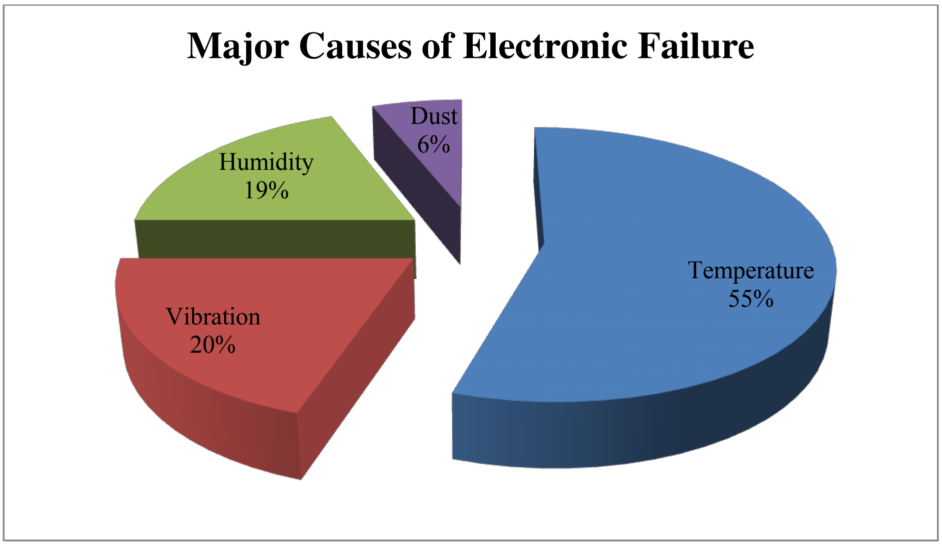

Figure 1.1 Major causes of electronic failure

There are many cooling technique that have been used in order to reduce thermal problem from electronic devices. Some of the cooling technique that has been used are heat pipes [4,5], water cooling, nitrogen liquid and heat sink. Yongling *et al*. [6] used heat pipe technology into the design of the hydraulic motor pump to solve the heat dissipation problem. Heat pipes technique is very efficient when transfer heat in large scale. However, it is not suitable to used for small electronic devices because of space constraint. Anbin *et al*. [7] used liquid nitrogen test system for cooling high temperature superconductive (HTS) synchronous motor. However, liquid nitrogen has never been used as cooling technique for electronic devices and the cost of liquid nitrogen is very expensive.

Heat sink is commonly used as cooling technique for electronic devices. Heat sink is the most simplest and effective way to dissipate the generated heat of a device compared to other techniques. Heat sink is a device that allows the transfer of heat away from the heat source. There are two common type of heat sink that widely used in the industry which is pin fin heat sink and plate fin heat sink. Besides that, there are lot of criteria that need to be considered in choosing the optimal heat sink such as selection of type of heat sink, material used, the heat sink dimension parameter and others.

1.2 Problem Statement

Due to the advanced development in semiconductor technology, the size of electronic component and devices become smaller while the performance becomes significantly greater [2]. The increased of power density in the system causes the system components to either operate at higher temperature which led to thermal problem. This thermal problem will reduce the performance and efficiency of the electronics package. Thus, it is a big challenge to the manufacturers to design electronic devices in terms of performance, size and functionality. Therefore, heat sink with high heat transfer rate is needed in order to remove the heat generated within the system.

According to the previous researchers, the common heat sinks that have been used are pin fin heat sink and plate fin heat sink. Between this two types of heat sink, the pin fin heat sink give more heat transfer than plate fin heat sink. The common arrangements of pin fin heat sinks that have being used are inline and staggered. Therefore, this project will introduce the new arrangement of pin fin heat sink with different geometry. This project is expected to develop a simple and effective arrangement of pin fin heat sink for optimal heat transfer of heat sink design to minimize electronic package thermal distribution.

1.3 Objective

The objective of this project can be dividing into three main objectives that are:

i. To simulate various pin fins arrangement design of the heat sink model using COMSOL Multiphysics software.
ii. To analyses the performance of the heat sink design based on the thermal image profile using heat transfer model.
iii. To propose a new arrangement by minimizing thermal distribution with high heat transfer rate.

1.4 Scope of Project

The scopes of this project are:

i. Literature review on heat sink design, method and analysis.
ii. Study pin fin heat sink thermal profile using resistance thermal model.
iii. Use COMSOL Multiphysics software to simulate the thermal profile.
iv. Study a new arrangement of pin fins by minimizing thermal distribution with high heat transfer rate.
v. Thermal image analysis for pin fin type heat sink

1.5 Thesis Outline

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

Chapter 2 focuses on literature reviews related to this project based on journals and other references. An introduction on heat transfer and the previous works related on the heat sink model from other researchers are explaining clearly.

Chapter 3 mainly discussed the methodology of the project. The modeling algorithm to create conventional heat sink arrangement and new arrangement are mention in this chapter. The parameter and boundaries are stated clearly in the steps of the modeling process. Details on the progress of the project are explained in this chapter.

Chapter 4 presents the results of the project. The discussion focused on the performance of various heat sink models. The optimal arrangement of pin fin is compared between the conventional arrangements.

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

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