THE ANALYSIS OF CURRENT CARRYING CAPACITY OF PCB

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Bachelor of Electrical Engineering
(Industrial Power)
May 2010

“ I hereby declare that I have read through this report entitle “The analysis of current carrying capacity of PCB” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

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This report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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I declare that this report entitle "*The analysis of current carrying capacity of PCB*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....Azwan..

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Date : 7th MAY 2010

To my beloved mother

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ABSTRACT

For PCB board carrying electrical current, it is generally desirable to be aware of any damage to the PCB track. Damage to PCB track may eventually result if the track exposed to the higher temperature than temperature limit of the PCB material. This situation is potentially resulting in a short circuit which may cause the PCB to fail. In preventing this problem, the period of erosion in PCB track due to the arc and temperature will be estimated from an analysis of temperature distribution in one dimensional PCB. The relation between current and temperature rise of a PCB with different width (size) and current that been inject to the track flow will be identified. An experiment will be set up to capture and analyze data using Minitab software and Microsoft Office Excel. From the tools we can analyze the temperature distribution. As a result, we will know between 2 parameters, which one is the most influencing thermal resistance.

ABSTRAK

Untuk membolehkan papan PCB mengalirkan arus elektrik, sebarang kerosakan pada litar di atas papan PCB hendaklah dielakkan. Kerosakan pada papan PCB biasanya berlaku apabila ia didedahkan kepada suhu yang tinggi berbanding had suhu yang telah ditetapkan kepada papan PCB. Hal ini boleh menyebabkan berlakunya litar pintas dan litar tidak boleh berfungsi. Sebagai pencegahan, masa terjadinya hakisan pada PCB bergantung pada kelengkungan dan suhu. Ini boleh dianggarkan daripada analisa PCB satu dimensi. Hubungan antara arus dan peningkatan suhu bergantung pada saiz dan nilai arus yang dimasukkan pada litar ini. Ujikaji ini dilakukan dan dianalisa menggunakan perisian Minitab dan Microsoft Office Excel. Berdasarkan data, pengaliran suhu akan dianalisa. Daripada keputusan yang diperolehi, dapat diketahui antara 2 parameter yang diuji terdapat salah satu factor yang mempunyai pengaruh yang besar terhadap rintangan suhu.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

A PCB is found in almost every electronic device. The bare board (without components) is also referred to as a 'Printed Wiring Board'.The boards are made from glass reinforced plastic and the conductive connections are generally copper and are made through an etching process. Damage to PCB track may eventually result if the track exposed to the higher temperature than temperature limit of the PCB material. Temperature rise can be affected by some parameters such as width and current flow. This project is to verify variable that may have a significant impact on the temperature distribution in PCB board.

1.2 Project Problem Statement

When the track of the PCB exposed to the higher temperature than temperature limit of the PCB material, it may damage to PCB track. This situation is potentially resulting in a short circuit which may cause the PCB to fail. As a result, the maintenance costs become expensive because the circuit must be replaced with new one. Temperature rise can be affected by some parameters such as width and current flow. The purpose of this project is to verify variable that may have a significant impact on the temperature distribution in PCB board. As a result, we will know between 2 parameters, which one the most influencing thermal resistance and maintenance cost can be reduced.

1.3 Project Objective

There are three objectives that need to be achieved to complete this project which are:

i. To define the variable which affect the temperature rise in PCB with different sizes and current flow.

ii. To analyze temperature distribution causes by all variables from data captured using regression analysis.

iii. To find the most influencing thermal resistance between 2 parameters.

1.4 Project Scope

This project focuses on one dimensional board. There are two types of parameters that will be identified to get the relation between current and temperature rise of a PCB. The parameters are size (width) and current flow. The different current between 1A to 5A will be injected to the PCB. The value of current will be injected is in the range that PCB board support. 1 sample shape of PCB board with constant thickness was designed. The width is 0.02 in, 0.03 in and 0.04 in. The data captured will be analyzed using multiple linear regressions. This project focuses on temperature versus current, temperature versus resistance and temperature width. The data was captured using temperature measurement device, FLIR i5 thermal imager.

1.5 Report Structure

This report consists of five chapters namely: Introduction, Literature Review, Methodology, Project Results and Analysis and finally Conclusion and Recommendation.

i. Introduction

This chapter will briefly describe the background of the project and its project problem along with the project objectives, project scopes and report structure.

ii. Literature Review

This chapter will illustrate and discuss previous work done on this topic and discuss the strength and weakness of the previous work done.

iii. Methodology

This chapter will describe the methods used in developing the project.

iv. Project Results and Outcome

This chapter will explain the results of this project.

v. Conclusion and Recommendation

These chapters will make the conclusion and give recommendation for future study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A PCB is found in almost every electronic device. If you have electronic components in a device, they are mounted on a PCB, either big or small. Besides keeping the components in place, its purpose of a PCB is to provide electrical connections between the components mounted on it. As electronic devices have become more complex, and require more components, the PCB has become more populated, and dense with wiring and components. The bare board (without components) is also referred to as a 'Printed Wiring Board'.The boards are made from glass reinforced plastic and the conductive connections are generally copper and are made through an etching process. Components are fixed in position by drilling holes through the board, locating the components and then soldering them in place. The copper tracks link the components together forming a circuit. However the current carrying capacity of PCB is limited by its temperature rise. There are 2 parameters that effect temperature rise on PCB. The parameters are PCB size (width) and current flow in PCB [5].

2.2 First Review

The first review is on the previous research from Yun Ling [1] with the title "On Current Carrying Capacities of PCB Traces". The current carrying capacity of a PCB, like any other electrical component, is limited by its temperature rise as the result of Joule heating. Thus determining PCB trace current carrying capacity is to define the relationship between current and temperature rise. The trace located at the edge of a PCB will have a lower current carrying capacity than the trace at the center. The relationship between current and temperature rise obviously does not just depends on the trace cross-sectional area [1].

There are a lot more variables that may have a significant impact on the PCB current carrying capacity. Some of the variables are:

a. PCB size and thickness
b. Number of traces that are involved in current carrying,
c. Trace separation or pitch,
d. Presence or absence of the ground and/or power copper plane
e. System cooling conditions.

Trace current carrying capacity is roughly proportional to the square root of temperature rise unless ΔT is very large. Increasing the allowable temperature rise from the typical 30°C to 40°C leads to a less than 15% increased in current carrying capacity. Basically, a trace on a bigger PCB will have a high current carrying capacity than the same trace on a smaller PCB. The trace located at the center will have about 20% higher current carrying capacity.

2.3 Second Review

The second review is a journal titled "Current Carrying of Copper Conductors in Printed Wiring Boards" by Tsung-Yu Pan, Russell H. Poulson and Howard D. Blair say that "conductor width and spacing are the primary parameters influencing thermal resistance. Conductor thickness is next and board thickness least sensitive parameter" [2].

In this journal, they discuss the effect of thermal management of the copper conductors on PWBs having different dimensions and arrangements. An infrared thermal imaging study will establish the experimental basis. Then finite element analysis will be applied to correlate temperature rise versus conductor dimensions and spacing, current amount and board dimensions. It is not the purpose of this paper to address the electrical effect of closely spaced conductor.

Thermal management of a typical automotive electronic package generally includes conduction, convection and radiation. For cost saving and robustness, automotive packaging usually utilizes free air convection with or without an attached heat sink. To consider the heat management of copper conductor, a heat sink is seldom considered because a copper conductor is not traditionally or IC chips. So R_t is a combination of (a) conduction through the board, (b) free air convection near the conductor and board surface and (c) radiation into adjacent neighborhoods.

2.3.1 Thermal resistance formulas

Thermal resistance, R_t, has been widely used to describe the thermal characteristics of electronic packaging. R_t is defined as:

$$R_t = \Delta T / Q \tag{2.1}$$

where

$\Delta T = temperature\ increase\ in\ °C$

$Q = heat\ flow\ rate\ in\ Watt$

$R_t = thermal\ resistance\ in\ °C/Watt,\ which\ is\ a\ parameter\ analogous\ to$
$electrical\ resistance$

The heat flow, Q, for the copper conductor is provided by an electrical current flow through the conductor is provided by an electrical current flow through the conductor. Q is proportional to current I and resistance R_e.

$$Q = I^2 R_e \tag{2.2}$$

where

$I = current\ in\ ampere$

$R_e = electric\ resistance\ in\ W$

$R_e = \rho(\ell / tw)$

where

$\rho = electric\ resistivity\ in\ \Omega mm$

$\ell = length\ of\ the\ conductor\ in\ mm$

$t = thickness\ of\ the\ conductor\ in\ mm$

$w = width\ of\ the\ conductor\ in\ mm$

Therefore, $\Delta T = R_t I^2 R_e$ (2.3)

If we assume R_t and R_e to be constant, ΔT should be proportional to the square of I only. However, the real case is not this simple.

Electric resistivity, ρ, is a function of temperature:

$$\rho = \rho_0[1+\alpha(T-T_0)] = \rho_0[1+\alpha\Delta T] \quad (2.4)$$

where

$\rho_0 = 1.75\times10^{-5}\ \Omega mm\ for\ copper$

$\alpha = 0.0039/°C\ for\ copper\ , \alpha = temperature\ coefficient\ of\ resistivity$

Combining these relations,

$$\Delta T = R_t I^2 R_e$$

$$\Delta T = R_t I^2 \rho_0[1+\alpha\Delta T](\ell / tw) \quad (2.5)$$

Since ℓ is much larger than either t or w, assume $\ell = 1$

$$\Delta T/(1+\alpha\Delta T) = R_t I^2 \rho_0 (1/tw)$$

$$R_t = \frac{\Delta T}{[I^2\rho_0(1/tw)][1+\alpha\Delta T]} \quad (2.6)$$

2.4 Third Review

The third review titled "PCB trace amperage chart" from internet source give a table that state trace width value and maximum amperage. The following ratings are based on 2 OZ per square foot of copper and an ambient temperature of 90 degree F (32 degree C) [3].

Table 2.1: PCB trace amperage

Acceptable temperature: 50 degree F (10 degree C)			
	MAX AMPERAGE		
Trace width	INTERNAL LAYER	EXTERNAL LAYER (open air)	Resistance per inch
0.005 (5 mils)	.360 amps (360ma)	1.013 amps(1013ma)	0.0535 ohms
0.010 (10 mils)	.602 amps (602ma)	1.616 amps(1616ma)	0.0268 ohms
0.015 (15 mils)	.811 amps (811ma)	2.124 amps	0.0178 ohms
0.020 (20 mils)	1.0025 amps	2.578 amps	0.01338 ohms
0.030 (30 mils)	1.350 amps	3.387 amps	0.00892 ohms
0.050 (50 mils)	1.966 amps	4.777 amps	0.00535 ohms
0.060 (60 mils)	2.248 amps	5.401 amps	0.00446 ohms
0.070 (70 mils)	2.517 amps	5.991 amps	0.00382 ohms
0.080 (80 mils)	2.777 amps	6.555 amps	0.003346 ohms
0.100 (100 mils)	3.272 amps	7.617 amps	0.002676 ohms
0.125 (125 mils) 1/8''	3.855 amps	8.852 amps	0.002141 ohms
0.250 (250 mils) 1/4"	6.415 amps	14.1154 amps	0.00107 ohms
0.500 (500 mils) 1/2"	10.676 amps	22.509 amps	0.000535 ohms

2.5 Fourth Review

The fourth review titled "Using IHLP's in Automotive Applications" by Vishay Dale states that each power inductor manufacturer provides "Rated Current" numbers for their products. These ratings are usually based on temperature rise or saturation. In the most cases, manufactures have adopted temperature rise as the deciding factor for rated current. Many times, the rated current is the amount of DC current that results in a temperature rise of 40 °C due to the DCR or self heating due to the resistance of the copper coil in the inductor. This current rating is performed under DC conditions only and does not take into account the self heating due to core losses. However, the rated current numbers do assume that the termination pads and copper traces on the designer's printed circuit board are adequate to carry the rated current and to carry away the heat produced by the copper winding. While there are many factors that will affect a printed circuit board's ability to transmit heat, guidelines have been established to ensure proper trace width to handle high currents [4].

Table 2.2: Recommended external trace carrying based on temperature rise.

Temperature Rise	30 °C			40 °C			50 °C			60 °C			70 °C		
Trace Thickness (mm)	0.0175	0.035	0.07	0.0175	0.035	0.07	0.0175	0.035	0.07	0.0175	0.035	0.07	0.0175	0.035	0.07
Trace Width (mm)	Maximum Current (A)														
0.250	0.6	0.8	1.2	0.7	0.9	1.4	0.7	1.0	1.5	0.8	1.1	1.6	0.8	1.2	1.8
0.500	1.0	1.4	2.1	1.1	1.6	2.4	1.3	1.8	2.6	1.4	2.0	2.8	1.5	2.1	3.0
0.750	1.4	2.0	2.9	1.6	2.3	3.3	1.7	2.5	3.6	1.9	2.7	3.9	2.0	2.9	4.2
1.000	1.7	2.5	3.6	2.0	2.8	4.1	2.2	3.1	4.5	2.4	3.4	4.9	2.5	3.6	5.3
1.250	2.1	3.0	4.3	2.3	3.4	4.9	2.6	3.7	5.4	2.8	4.1	5.9	3.0	4.4	6.3
1.500	2.4	3.4	5.0	2.7	3.9	5.6	3.0	4.3	6.2	3.2	4.7	6.8	3.5	5.0	7.3
1.750	2.7	3.9	5.6	3.1	4.4	6.4	3.4	4.9	7.0	3.7	5.3	7.6	3.9	5.7	8.2
2.000	3.0	4.3	6.2	3.4	4.9	7.1	3.8	5.4	7.8	4.1	5.9	8.5	4.4	6.3	9.1
2.250	3.3	4.7	6.8	3.7	5.4	7.8	4.1	6.0	8.6	4.5	6.5	9.3	4.8	6.9	10.0
2.500	3.6	5.1	7.4	4.1	5.9	8.4	4.5	6.5	9.3	4.9	7.0	10.1	5.2	7.5	10.9
2.750	3.8	5.5	8.0	4.4	6.3	9.1	4.8	7.0	10.1	5.2	7.6	10.9	5.6	8.1	11.7
3.000	4.1	5.9	8.6	4.7	6.8	9.8	5.2	7.5	10.8	5.6	8.1	11.7	6.0	8.7	12.5
3.250	4.4	6.3	9.1	5.0	7.2	10.4	5.5	8.0	11.5	6.0	8.6	12.5	6.4	9.3	13.4
3.500	4.6	6.7	9.7	5.3	7.6	11.0	5.8	8.4	12.2	6.3	9.2	13.2	6.8	9.8	14.2
3.750	4.9	7.1	10.2	5.6	8.1	11.6	6.2	8.9	12.9	6.7	9.7	14.0	7.2	10.4	15.0
4.000	5.2	7.5	10.8	5.9	8.5	12.2	6.5	9.4	13.5	7.0	10.2	14.7	7.6	10.9	15.8
4.250	5.4	7.8	11.3	6.2	8.9	12.8	6.8	9.8	14.2	7.4	10.7	15.4	7.9	11.4	16.5
4.500	5.7	8.2	11.8	6.4	9.3	13.4	7.1	10.3	14.9	7.7	11.2	16.1	8.3	12.0	17.3
4.750	5.9	8.5	12.3	6.7	9.7	14.0	7.4	10.7	15.5	8.1	11.7	16.8	8.7	12.5	18.0
5.000	6.2	8.9	12.8	7.0	10.1	14.6	7.7	11.2	16.1	8.4	12.1	17.5	9.0	13.0	18.8

Table 2.2 summarizes the recommended maximum current for a PCB trace based on trace width and thickness. These recommendations were developed using the following model:

$$I = 3.188 \times \Delta T^{0.45} \times W^{0.79} \times Th^{0.53} \tag{2.7}$$