The Study on Thermal Analysis Method of PCB

Fan Yang1,*, Chen He2, a, Qian Xu2, b and Hua Xiao1, c
1 Lianyungang JARI Electronics CO., LTD, Lianyungang 222000, China
2 Jiangsu Automation Research Institute, Lianyungang 222000, China

*Corresponding author e-mail: yfjari@163.com, a247429217@qq.com, bxuqian02041524@qq.com, cxhbc21@163.com

Abstract. This essay makes the reliable analysis and modelling on printed circuit boards (PCB) by software of Flotherm and get conclusions of three points through simulation analysis: 1) there is an important impact on heat transfer of the distribution of copper foil on PCB, and the actual condition should be selected for different precision simulation modules; 2) the heating device with simple structure and small thermal resistance can be dealt with as the simple square; 3) in the case of knowing the internal thermal resistance, integrated chip adopts double thermal resistance model as much as possible. In accordance with above inference, Flotherm modelling and simulation is carried out for certain printing circuit board, and computing results are compared with actual testing data to verify the correction of analysis methods.

1. Introduction

With the development of electronic technology, electronic components, assembly density and power density of equipment is enhanced quickly while the wiring density of PCB widely used in the equipment is higher and higher. The study shows chip-level heat flux reaches 300W/cm² while junction temperature of semiconductor integrated circuit chip is generally lowered than 100℃, therefore, it will seriously influence the reliability of electronic components and equipment if the thermal design technology is not adopted properly [1].

Flotherm has powerful thermal analysis functions in the aspects of semiconductors, integrated circuits and components, which adopts board level thermal simulation analysis. The main difficulties which apply FLOIHERM to the thermal reliability analysis of PCB is how to model the PCB and components properly. Aiming at thermal reliability analysis of certain printing board, this essay’s purpose is to compute the temperature of each components on PCB, make sure whether it is beyond the working temperature of the maximum allowable under the specific working condition. Due to the difficulty of accurate modelling on printing circuit board and components, the each components on the board must be simplified so as to establish proper Flotherm modelling.

2. Modelling method of the PCB

On the thermal simulation analysis of the PCB, it is mainly to consider the modelling problems about power components and PCB substrate. How to properly model the components and PCB will influence thermal simulation accuracy of the whole electric circuit.
2.1. Modelling and analysis of the PCB

PCB is both electronic connections provided by components but also the support of components [2]. The structure of PCB board is generally composed of Epoxy resin plate and copper foil. The copper thermal conductivity is 385W/(m·℃) while thermal conductivity of Epoxy resin is only 0.3W/(m·℃). Usually, copper foil distribution on PCB is spread very complicated with difficulties of accurate modelling, but the area, thickness and number of layers of copper foil have great impact on the heating conduction of PCB. Here, the PCB with 4 layers is carried out models as below (Plate thickness is 1.2mm, each layer of copper thickness is 10Z): 1) primary precision modeling: PCB is simplified as solid block of fixed thermal conductivity; 2) Intermediate precision modeling: PCB is divided into 4 layers, which the copper content of each layer is set evenly and non-isotropic thermal conductivity is adopted to set; 3) advanced precision modeling: PCB is divided into 4 layers, which is considered in details the copper content per layer and method for subdividing thermal conductivity of a wiring layer. Under the condition of same component consumption and layout, room temperature 20℃, no other heating sink, natural convection and free radiation, the PCB temperature cloud picture is obtained as shown in picture 1.

![Picture 1. PCB temperature cloud map.](image)

It can be known through simulation, due to the uneven distribution of PCB copper, there exist some certain errors to make primary precision, intermediate precision and advanced precision. If there are detailed understanding of PCB situations or relatively higher for thermal design demand for PCB, the advanced precision simulation is suggested; if there are not detailed understanding of PCB situations, and uniformed thermal power distribution in the PCB, it can be considered primary precision modelling, but the error is large; on the general situation, it is recommended for PCB to carry out intermediate precision modelling.

2.2. Modelling and analysis of MOS Tube

MOS Tube is mainly composed of Epoxy housing, silicon wafer and bottom copper alloy heat sink [3]. Silicon wafer is at the inner part of MOS tube, which is main heating part. Here, MOS tube is carried out for modelling as below: 1) primary precision simulation: set MOS tube as simple solid body, and set as physical parameter in accordance with actual condition; 2) Flotherm modelling is established in details in accordance with inner structure of MOS tube. Shown as picture 2, the left side is detailed modelling and right side is simplified modelling. Under the free radiation condition of room...
temperature of 20℃ and 60℃, same power consumption, natural convection and free radiation, MOS tube is separately calculated thermal distribution condition, shown as picture 3.

![MOS tube modelling](image)

**Picture 2.** MOS tube modelling.

![MOS tube thermal distribution state](image)

(a) MOS tube thermal distribution state(20℃)        (b) MOS tube thermal distribution state(60℃)

**Picture 3.** MOS tube thermal distribution state.

It is known from picture 3, whatever it is working temperature in the normal temperature 20℃ or high temperature 60℃, the effects on these two modelling is basically same. Despite MOS tube has relatively complicated inner structure, there are only few degrees of difference temperature between inner and outer surface. In accordance with analysis of heating conductivity, due to better heating conductivity of MOS tube main materials, there are low heating resistance and small temperature differences from inner components to the surface. Therefore, the MOS tube is set as simple solid body in the actual modelling, as long as there is same parameters of thermal properties.

2.3. The modelling and analysis of integrated circuit

The integrated circuit has relatively complicated inner structure, when there are relatively more chips on the PCB, detailed modelling is relatively difficult, where the integrated circuit board for SOIC package and PLCC package is separately adopted the modelling methods as below: 1) integrated circuit is simplified as solid body with material property and evenly distribution of inner thermal; 2) double thermal resistance model is adopted, which is set separately as thermal resistances of θJC and θJB of chip junction as well as upper and lower surface. Under the condition of working temperature in the normal temperature 20℃ or 60℃, same consumption, natural air convection and free radiation, the thermal distribution of integrated circuit board is separately calculated. Picture 4 is thermal distribution condition of PLCC chips, and picture 5 is the thermal distribution condition of SOIC chips, among which left side is double thermal resistance model and right side is simplified modelling. It is known from this picture, the two kinds of modelling have relatively distinctive differences at the final simulation results and there is about 10℃ of device temperature difference. Therefore, double thermal resistance model of device is established in accordance with the related information on the manual of device and make sure the precision of simulation.
3. Experimental verification

The previous analysis has already proved that MOS tube adopts simplified modelling and integrated circuit board adopts double thermal resistance model while the modelling of PCB substrate can be decided in accordance with actual situation (here, the advanced precision simulation is adopted to model for monolithic printed circuit board and simulate under the condition of natural convection and free radiation at the normal temperature of 20℃). Meanwhile, the temperature measurement of board is carried out and table 1 is the comparison of calculated value and actual measurement value.

**Table 1.** Comparison of calculated value and actual measurement value.

| Parameter name                              | Calculated value/℃ | Measured value/℃ | Error/% |
|---------------------------------------------|---------------------|------------------|---------|
| Highest temperature of MOS tube             | 89.8                | 88               | 2.05%   |
| Highest temperature of component (PLCC)     | 108                 | 105.8            | 2.08%   |
| Highest temperature of component (SOIC)     | 124                 | 120.7            | 3.07%   |
| Highest temperature of PCB                  | 106                 | 105              | 0.95%   |
| Edge board temperature                      | 45                  | 44.3             | 1.58%   |

4. Conclusion

It can be known in accordance with previous analysis, when the thermal reliability analysis is performed on the PCB, it made some simplifications on the aspects of modelling: 1) the thermal components of simple structure and small heating resistance can be handled as simple block; 2) the integrated chips can be adopted as double thermal resistance model as much as possible. In addition, due to thickness,distribution and the number of layers of copper foil has important impact on PCB thermal transfer, it can be detailed as much as possible when modelling. The thermal analysis of board adopting the simplified modelling method as above, can reduce largely the demand of computer’s memory and the computing time will be obviously shortened. The experiment shows that this method has relatively higher accuracy as well as simple modelling and convenient and practical operation which can better complete the work of thermal simulation analysis on complicated printing circuit board.
References
[1] Zhao dun shu. Thermal design of electronic equipment. Beijing: electronic industry press, 2009.
[2] Li fangmin, Electronic equipment automation technology and application. Beijing: Tsinghua University Press, 2006.
[3] Ma zhigeng, Ren lingbai. Handbook of modern engineering materials. Beijing: National Defense Industry Press, 2005.