

Application of the model of the printed circuit board with regard to the topology of external conductive layers for calculation of the thermal conditions of the printed circuit board

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Abstract. The paper proves the necessity of taking into account external conductive layers of the printed circuit board with the thermal physical designing radio-electronic means. For example, a single printed circuit board shows the level of influence of the external conductive layer on the thermal conditions of the printed circuit board. It proved the influence of Joule heat in the thermal conditions of a single conductor. Developed geometrical and thermal printed circuit board models take into account the topological layer and can improve the accuracy of determining the thermal conditions of the printed circuit board.

1. Introduction

The problem of ensuring proper thermal conditions of the printed circuit board with a high density of conductors' topology

A modern electronic product can not be imagined without the use of a variety of semiconductor devices and integrated circuits. The characteristics of these electric articles (EA) are often dependent on the deviation of the temperature that adversely affects the reliability and quality of radio-electronic means (REM) and thus has a negative impact on their performance.

The increasing distribution of printed circuit boards (PCB) in the REM both with a dense arrangement of EA and with dense topology of conductors deteriorates the situation (Figure 1).



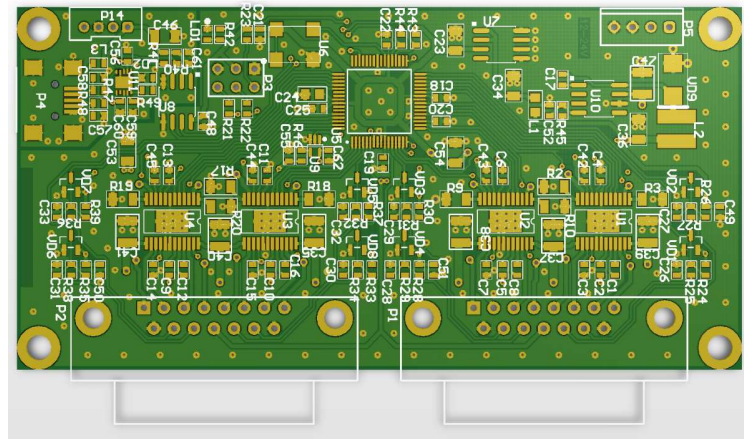


Figure 1. The PCB with high-density topology

All the heat produced by radio-electronic components is released in the form of losses, and if in active elements such as resistors element overheating can be regarded as a directly proportional to the dissipation power, the passive elements, such as condensers, have low power of dissipation, which amounts to 10 - 15%. Most passive elements has a greater sensitivity to changes in temperature, so putting them beside the intense heat radiating elements or unit placement in low temperatures, can lead to failure of the element. Because of this, the arrangement of the EA PCB surface and placing the latter in the housing of REM are also an important factor affecting the thermal treatment of a device (Figure 2).

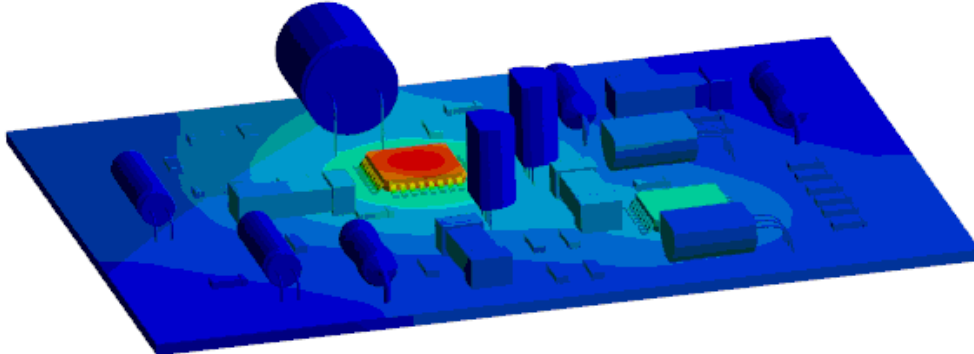


Figure 2. Thermal conditions of the PCB

For the selection of the optimal thermal conditions of operation of the electronic equipment, it is necessary to carry out thermal calculations at the early stages of design to predict the possible outcome of the thermal-physical design.

Existing methods of thermal calculation and analysis of the PCB and the REM have different accuracy and are time consuming. The most important factor in obtaining reliable results is to carry out calculations with a sufficient amount of raw data. Initial data for calculations are the thermal characteristics of radioelectronic components. Thermal characteristics represent the dependence of EA temperature on the power, scattered by EA and by surrounding bodies, at constant temperature of the environment, taking into account the structure and physical properties of the body. For the thermal calculation of PCB and REM, it is necessary to know the thermal characteristics of the EA used in the device, the operating temperature range, etc. Most of the thermal characteristics, used in calculating of the thermal conditions, are taken from the documentation for the EA. External factors, including the ambient temperature, are usually stipulated in the terms of reference for the design of the product.

Modern REM is constructed of a plurality of EA, which have a complex shape and can emit large quantities of heat per unit area. This structure, in thermal-physical respect, is an extremely complex system, and it is often impossible for actual REM to make a complete system of equations and solve it analytically. Therefore, the processes occurring in the REM are in most cases schematized, taking a number of simplifications that helps to get a thermal model of PCB REM, which is convenient to carry out thermal calculations and analysis.

The authors of a number of studies suggest an approach and model of the printed board assembly, taking into account the topology of the outer conductive layers. Here is the experience of the application of this model in the evaluation of the thermal conditions of PU.

2. The use of a model that takes into account the topology of the conducting layers to calculate the thermal conditions of the printed circuit board

In each system, which have an electric current conductivity, and wherein the specific conductivity of the material is finite, the heat losses are expected. Heat losses, also called ohm heating, are in many cases an undesirable side effect of current conductivity of electric current.

The model simulates the system consisting of a small portion of the printed circuit board assembly comprising a chip and copper path (trace), associated with the transistor. This model has a specific performance that later will assess the adequacy of the data (Figure 3). The derived equation to determine the thermal characteristics, allows estimating the operating temperature of the chip and the printed conductors, which is higher than the ambient temperature due to undesirable thermal radiation.

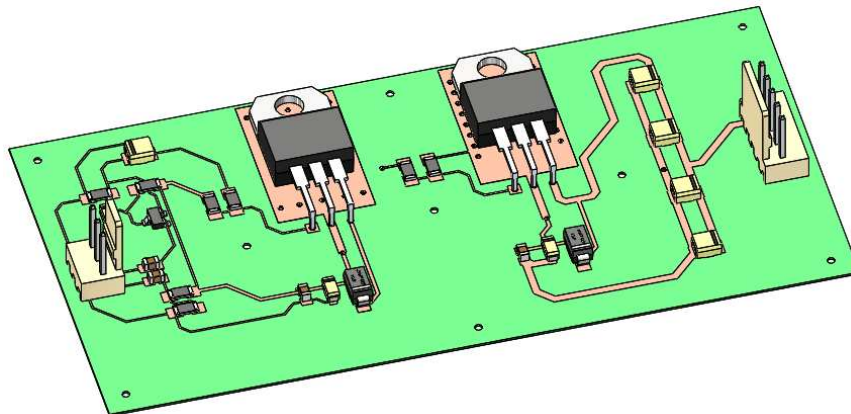


Figure 3. The full geometric model of the PCB

A chip, in this case - a standard product, can be mounted on the radiator, but during determination of thermal conditions it does not have additional cooling elements in the structure. However, for this simulation, the influence of Joule heat and the heat flow, radiated from the chip, on the thermal PCB conditions will be detected and evaluated. A major positive effect, in most cases is to determine the need to install additional cooling elements in the PCB structure. Therefore, it will be defined whether the installation of the radiator is required, or if the operating temperature can be sufficiently low not to cause damage to the system in the absence of the radiator.

Figure 4 shows the geometry of the model to be used in the simulation. The chip is mounted on the circuit board using a through-hole technology. The solder in the holes provides mechanical support and electronic contact between the copper conductors and the legs of the chip.

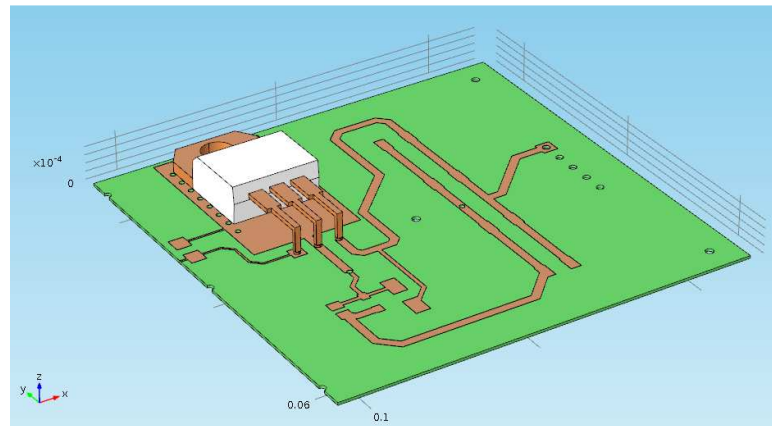


Figure 4.The model of the geometry used in simulation

The core of the chip itself is located in the interior of the housing, shown in Figure 4. It will radiate the heat flow; the core is connected with legs, which transfer the heating from the core owing to heat transmission in a solid body, which further extends both to the printed conductors and to the area of the PCB itself. These compounds, as expected, have significant effects on the thermal conditions of the PCB.

The chip front part is made of ceramics, while the rear portion, which can be clamped to the heat sink, is made of copper. At the feet of the transistor and the front of the pack, there is a correspondence to thermalphysical properties. Brass legs are soldered to the circuit board with the solder material consisting of 60Sn-40Pb (60% tin and 40% lead). The mounting plate is made of fiberglass.

Current conductivity and ohm heating occur in copper routes of solders and in legs. In these parts, the physics of heat transfer and heat release due to ohm heating is fully connected to the electric current conductivity. All other parts of the microcircuit can exchange only heat transfer and heat release with the environment.

The core of the transistor is represented by the inner edge with internal generation of high temperature, corresponding to 1.0 W. The cooling via convection takes place in all external borders having a heat transfer coefficient of $2.5 \text{ W} / (\text{m}^2 \cdot \text{K})$. This value of the heat transfer coefficient corresponds to the normal case scenario, when the printed circuit board is located in the housing. The ambient temperature is 293.15 K.

The flow enters the circuit board through the vertical borders of copper traces connected with the base, the emitter and the collector, shown in Figure 5. The value of the flow in the path boundary connected with the transmitter, is 0.099 A. The value of the flow in the path boundary connected with the collector is 0.10 A. The difference in the absolute flow between the emitter and the flows of the collector corresponds to the flow in the path boundary, connected with the base, which amounts to 1.0 mA.

The maximum temperature is approximately 340 K. This is appropriate within the acceptable operating temperature range for the chip, which implies that in this case its attachment to the radiator is not required.

Another interesting observation is that the effect of ohm heating (Joule heat) is substantial in the copper tracks in the interval between the chip and the input. Figure 6 represents a graph of temperature along the copper conductors connected to the PCB base.

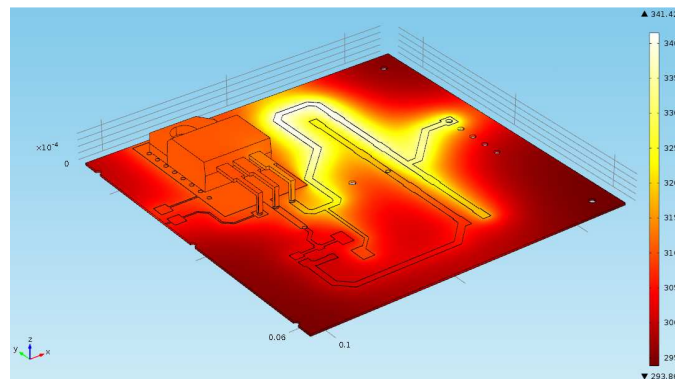


Figure 5. Temperature distribution in the printed conductor

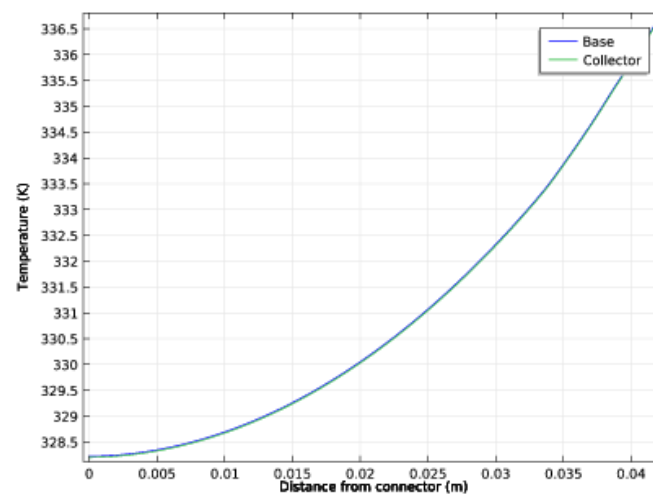


Figure 6. The temperature along the topology of the copper conductors

The fact that the effect of ohm heating increases the temperature in the copper conductors, which leads to the conclusion that a higher temperature in these routes is due to high thermal conductivity of copper. The copper conductors have a high temperature, which is the same as that produced in the chip, but the wiring board has insufficient heat conductivity and therefore is not heated to the same extent as copper conductors.

Further calculations were carried out using a complete geometric model of the PCB.

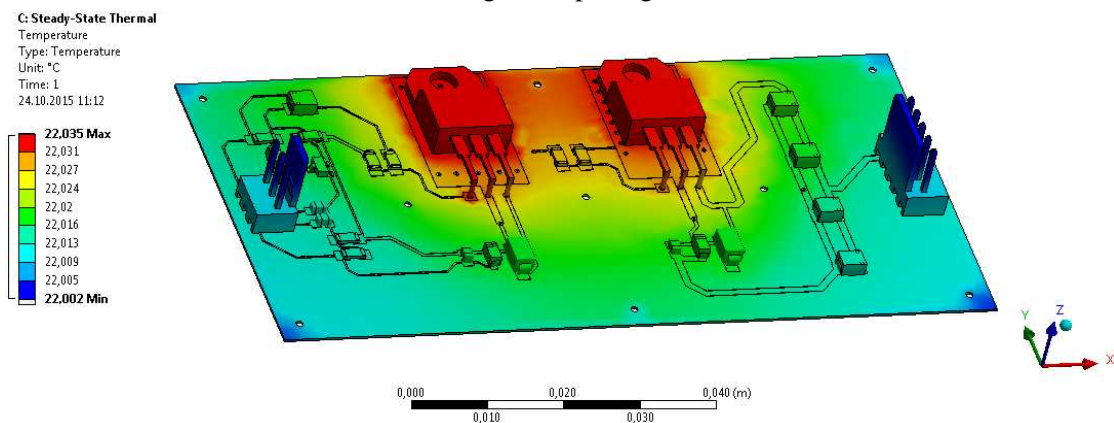


Figure 7. Visualization analysis of the complete geometric model

These studies have helped to create and organize the whole sequence of actions related to the ordering method of thermal calculation. Taking into consideration the heating factors, such as Joule heat emitted from the printed conductors, has a significant effect.

3. Conclusion

The authors conducting the study clearly confirmed the importance of taking into account the topology of the conductive layer in the thermal analysis of the printed board assembly. Thermal conditions of a single conductor are determined not only by a common temperature background of the printed circuit board, but also by the effect of Joule heat. This fact should be considered especially when designing PCB for power devices, since the current density of the conductive layer in such devices is much higher than in the printed board assembly of small-signal devices.

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