The Influence of a 3D Model of a Radio Electronic Component on Thermal Simulation

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Abstract. Very often, when designing and developing radio electronic devices, engineers are regularly faced with the need to solve various kinds of problems to ensure the operation of a product under the required mechanical loads or thermal conditions during operation. One of the main issues that arise when conducting thermal modeling of radio electronics is the correct assessment of the results. There are a number of electronic components that need to be cooled, mainly through a printed circuit board: power supply transistors, power diodes, microcircuits, etc. For such elements, 90% (or more) of the heat flux from the component is diverted through the printed circuit board, and then to the radiator. Therefore, when carrying out the simulation, it is necessary to have previously obtained reliable temperature results on the power elements. The use of a detailed 3D model for modeling is most often unjustified and can introduce certain errors in the calculations. This article compares different 3D transistor models and the effect of detailing on the modeling process in CAD SolidWorks.

1. Introduction
When designing an electronic device, many companies conduct simulations to obtain results in advance, that is, at the stage of product development, which allows to take into account some problems or problems that may arise in the future during the operation of the product. In addition, at the modeling stage, an understanding of some of the processes that can occur and affect the final result, in real conditions, appears. The definition of modeling itself is quite extensive, and a lot of it is stated, but briefly we can say that modeling conducts the study of any parameters, phenomena, or a whole system of united objects by constructing and analyzing their idealized models, to obtain or refine their values. Modeling can be a method of scientific research, as a result of which you can gain new knowledge about objects or phenomena that may occur. When carrying out modeling, there is a mandatory replacement of any modeled (investigated object (phenomenon) with another material - material, or idealized object, which in this case is an ideal model. An idealized object is usually built on mathematical hypotheses and models, and must have the same properties as a real one). (studied) object of research But sometimes there is no need to use an overly idealized object for modeling.

2. Meshing elements for modeling
In the development and manufacture of electronic devices and electronic computing facilities, it is constantly necessary to perform a large number of different kinds of calculations and measurements.
And in the end, the information obtained from the measurement result can be used to develop logical conclusions and judgments in various procedures. But how to measure the required parameters if the product is at the design stage and exists only in the form of drawings and diagrams. In this case, the way out is software simulation, for example, simulation of heat transfer. Currently, there are many analysis tools for thermal modeling of electronic devices: ANSYS, SolidWorks, CreoParametric, etc. Most of the software in the world uses the finite element method (FEM) or the finite volume method (FVM) in their calculations, which is a numerical method for the analysis of technical structures. In essence, this method divides the model under study into a large number of small components connected to each other, which have a simpler form (Fig. 1.), called elements, which ultimately allows you to split the problem into several small subtasks that are solved simultaneously [1].

![Figure 1. An example of building a mesh of a product.](image)

I Creation (construction) of a mesh in CAD is precisely the process of dividing the created 3D model into smaller constituent parts (elements), which then take part in the calculation itself. The elements themselves in the finite element method can have different shapes during construction, this is influenced by several factors. Ultimately, when building a mesh of the model, it is necessary to obtain elements connected to each other, which in turn form common connection points, called nodes (Fig. 2.), shown by red dots in Fig. 2. As a result, a mesh is obtained on the model, which can be visually seen and analyze, and, if anything, make adjustments. If we analyze the final model, then each resulting node should be described by predetermined parameters that depend on the type of analysis and the element used. As an example, consider the node temperature, which is described by its reaction in thermal analysis. [one]. In computer simulation of physical processes in electronic products, a number of certain problems often arise that are inherent in the simulation process. One of the main problems is the construction of the geometric model required for the calculation. The model greatly influences the result, as well as the setting of the necessary boundary conditions, without which it is impossible to carry out the simulation.

![Figure 2. Tetrahedral element.](image)

During the simulation, the software builds a mesh on the model under study, and then does the construction of the corresponding calculation equation that controls the behavior of each nodal element, while necessarily taking into account the connection of all elements, but you can also set the mesh accuracy for various constituent parts of the model. For example, if a straight wall practically does not affect the simulation result, since it is far from the element under study, then you can simplify the mesh in this place. As a result, it will be possible to save time for the calculation. Then these equations are associated with the material properties previously set by the user, the boundary conditions and the
corresponding loads. Then this equation is formed into a large system of joint algebraic equations. As an example, consider the calculation of thermal analysis, where the user enters a source of thermal radiation, material properties, environmental parameters, etc. Then the solver finds the temperature at each node of the element, and then calculates the total temperature of the model under study and displays the result in the form of graphs or temperature fields for greater visualization. There are several methods for thermal modeling of microcircuits, characterized by different accuracy, complexity, applicability in one or another design CAD, etc. The modeling methods and thermal models used are divided into two large classes - detailed thermal models (DTM - Detailed Thermal Model) and compact thermal models (CTM - Compact Thermal Model). The DTM model reproduces the real physical structure of the microcircuit with varying degrees of detail. This model is the most accurate, and the more detailed the real structure of the chip is reproduced, the more accurate the simulation result is. In general, CTM models do not require binding to the real structure of the microcircuits, however, for their integration and use in thermal models of the entire product, such a binding is necessary. CTM is an idealization of the structure of a microcircuit in the form of a chain or network of thermal resistances [2].

3. The main parameters of the model under study
To carry out this thermal simulation, the computer-aided design (CAD) system SolidWorks Flow Simulation is used. Since this software package is one of the most widespread and demanded CAD-packages in the world. In addition, the engineer can carry out modeling and see the results literally in one window, which allows you to visually see the result and, if anything, stop the simulation in case of an error. Also SolidWorks can carry out both the analysis of mechanical processes and the analysis of thermal processes in various environments. The key role is played by the accuracy of constructing the mesh of the product, the more accurate the mesh, the more real the result will be, but you have to pay for this in time of calculations and computer resources. In addition, sometimes situations arise when there is no need to refine the mesh to the smallest elements, since the obtained data will be within the program error and therefore, when carrying out the simulation, first select a mesh with an average construction value, followed by an increase in this value (decrease in mesh cells). The investigated model consists of a radiator of the SK 514 series from fischerelektronik (material aluminum) 100 mm long. The printed circuit board consists of seven layers: four layers of copper conductors with a thickness of 105 microns for each layer and three dielectric layers with prepreg FR4. The board itself is described by a parallelepiped with dimensions of 40x40 mm and an anisotropic material with properties calculated from averaging a stack of layers of a real board, with transverse thermal conductivity 0.35 W/m·K and a longitudinal thermal conductivity of 16.5 W/m·K. Metallization by layers is set at 90%. Of course, this PCB material has a low thermal conductivity, but PCBs with FR4 prepreg are the most popular due to their low price and availability [3]. Between the printed circuit board and the heatsink, a 0.75 mm thick heat-conducting gasket with a thermal conductivity of 1.4 W / m · K is installed. Ambient temperature is 24 ° C. A transistor with a heat dissipation power of 6.6 W is used as a heat source. For comparison, the 3D model of the transistor is presented in two views. The first model is a detailed PowerFlat 5x6 case, and the second is in the form of two parallelepipeds with dimensions similar to those of the case. In both cases, the transistor is represented by a 2R-model with the parameters crystal-package thermal resistance 1.7 K / W, and the package-printed circuit board 1.7 K / W. JC) should be interpreted as the source-to-board resistance and should be set this way in the model. Source-to-environment resistance is virtually equivalent to source-to-case resistance for components cooled through a heatsink. In the design CAD, as a rule, for 2R models the resistances "source-body" and "source-board" are set, and ignorance of the above feature can lead to confusion and incorrect simulation results [4]. It is worth mentioning separately one feature related to the indication of resistances for components cooled through the boards. In fact, such components are cooled through the case to the board, so the source-to-case resistance (R_{0JC} or R_{0JB}) and "source-housing" or "source-environment "(R_h this method is convenient in that the documentation for electronic components usually indicates data on thermal properties just for such a model, namely: thermal resistances "source-
to-board" (R As a result, the model for research is shown in Figure 3, which shows a transistor in a detailed package.

![Figure 3. Explored detailed 3D model.](image)

In presented array (Fig. 3), for beam pattern balancing in H-plane, its log-periodic structures are arranged mirror symmetrically with respect to the axial line.

Construction of one of the two log-periodic structures is shown in Fig. 4 (top view). Black circles show the vibrators under the carriers. The numbers denote: 1 - place of soldering of the cable central core to the upper carrier; 2, 3 - braid of the cable is soldered to the lower carrier; 4-coaxial cable connects to one of the outputs of broadband 3-dB power divider (another log-periodic antenna is connected to its other output, located mirror-symmetrically with respect to the dot-dashed line shown in Fig. 4).

4. CAD Simulation Results
The results are displayed in the form of pictures with a multi-colored palette, from blue (low temperature) to red (high temperature). To understand the temperature inside solid objects, a section of all models is made. Figure 4 shows 2 models with a grid factor of 1, the upper one is a detailed model, the lower one, on the contrary, is simplified. With such a mesh, the tetrahedral element is built of a large size and the number of such elements is small. This is the minimum level for setting automatic generation of the global mesh.

![Figure 4. Simulation result with grid level 1.](image)

With such a mesh construction for a detailed 3D model, the result is erroneous, many small elements at the heat source (transistor) do not allow the mesh to be built correctly. More precisely, the mesh
simply ignores the elements at the junction of the transistor and the printed circuit board, the heat flux is not transferred to the printed circuit board, but is completely accumulated in the transistor, which can be seen from Figure 4, in contrast to the model that is not detailed. Hence it turns out that the result is very different. Next, Figure 5 shows a model with a mesh level of 4. This is the average for mesh definition in SolidWorks CAD.

![Simulation result with a grid factor of 4.](image)

Figure 5. Simulation result with a grid factor of 4.

At grid level 4, the result for the detailed 3D model is again erroneous, although the temperature has dropped, but the grid is still too large for correct calculation. On a non-detailed model, the result is already close to the real possible, the heat distribution is already better transmitted downward. The error of the detailed model relative to the simplified one is about 2851%. Figure 6 shows a model with a mesh level of 7. With such a mesh, the mesh element is built of a small size and the number of such elements is much larger than in the first variant. This is the maximum value for automatic meshing, and the simulation time is increased accordingly. Since you have to make a lot more iterations.

![Simulation result with a grid factor of 7.](image)

Figure 6. Simulation result with a grid factor of 7.

With this mesh construction for a detailed 3D model, the result is again erroneous, although the temperature dropped by more than 10 times, but still the mesh is too large for correct calculation, for further modeling, in order to get an acceptable result, it is necessary to construct the mesh manually, that is, break the mesh into smaller cells and the so-called local grid or local grid is obtained. On a non-detailed model, the result is already very close to real. The error of the detailed model relative to the simplified one is about 208%. The general comparison of temperatures is presented in Table 1 for a visual comparison of the results obtained.
Table 1. General comparison of temperatures based on simulation results.

| Detailed model | Simplified model | Detailed model | Simplified model |
|----------------|-----------------|----------------|-----------------|
| Graduated grid 1 | 3092.02 | 87.92 | 39.5 | 41.2 |
| Graduated grid 4 | 2623.49 | 92 | 41.3 | 44.7 |
| Graduated grid 7 | 199.31 | 95.52 | 43.7 | 52.3 |

This calculation is not ideal, since some parameters are not taken into account, for example, the printed circuit board is represented by a simplified and too idealized model; for a more accurate result, it is necessary to carry out thermal modeling of a multilayer printed circuit board with the appropriate topology, vias and clamping means. This source just gives the result of this experiment in practical conditions [5].

5. Conclusion

Based on the simulation results, it turns out that the use of a detailed model is not always justified, since a mesh with a high density of cells and a small size is required for its calculation. The use of a grid with a construction level of 7, in this case, is the closest to the real one for a non-detailed model, and further subdivision of the cells no longer makes sense, since the temperature is acceptable and can be considered correct, in contrast to the detailed model. At the same time, the result of modeling a detailed model is very unstable and erroneous; when performing a new calculation, the result may differ greatly from the one obtained earlier.

6. References

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