LODZ UNIVERSITY OF TECHNOLOGY

FACULTY OF ELECTRICAL, ELECTRONIC, COMPUTER AND CONTROL ENGINEERING

DEPARTMENT OF MICROELECTRONICS AND COMPUTER SCIENCE

PhD THESIS (ABSTRACT)

Estimation algorithms for selected parameters of electronic system thermal models

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1. Motivation

Technological advances of recent years have led to the appearance of new challenges and thermal problems, which have to be solved by the designers of electronic systems. Both the proper system design and the estimation of device temperature contribute to the correct operation and the extended lifetime of electronic devices. Thermal problems are one of the main causes of electronic system failures and malfunctions. Therefore, the analysis of thermal phenomena is one of the most crucial factors, which should be taken into account during the design of electronic systems.

Thermal processes occurring in solids are modeled using a partial differential heat equation. Standard thermal simulators used in the analysis of electronic systems assume the independence of thermal model parameters from temperature, but this assumption is incorrect due to the fact that certain physical quantities, e.g. the heat transfer coefficient or the material thermal conductivity depend on temperature. The neglecting of such dependencies can cause significant simulation errors.

2. Thesis Focus and Scope

Therefore, the main aim of this research was to analyze the dependencies of thermal model parameters on temperature. The research presented in this dissertation was carried out as a part of the project of the National Science Center UMO-2013/11/B/ST7/01678 entitled 'Modeling of nonlinear thermal phenomena in electronic systems'. The principal goal of this project was to verify the hypothesis on the significance of various nonlinear effects on the results of thermal simulations. In particular, the experimental validation of thermal model parameters temperature dependencies on temperature and the development of thermal analysis tools taking into account the most important nonlinear phenomena were to be investigated.

3. Main Contributions

The theoretical part of the dissertation consists of two chapters related to the modeling of thermal phenomena and the methods of solving inverse heat transfer problems. The first chapter presents the classic model of heat transfer in the form of the partial Fourier-Kirchhoff differential equation as well as different methods for solving this equation, both analytical and numerical ones. Compact thermal model of electronic systems, consisting of various networks of thermal resistances and capacities also are described there.

The second theoretical chapter of the thesis contains a brief description of inverse heat transfer problems and classic algorithms used to the determination of solutions, as well as the characteristics of other optimization algorithms used by the Author in the practical part of the thesis.

The practical part of this dissertation includes three chapters. The first one presents the problem of determining the eigenvalues of three-dimensional detailed thermal models, which are necessary to obtain a solution to the heat equation employing the Green function method. The determination of these values, which are the roots of a so-called transcendental equation, in the case of multilayered structures may occur extremely difficult due to the fact that they are located between two neighboring asymptotes whose values might only slightly differ from the eigenvalues, e.g. only at the sixth significant digit.

The problem becomes even more complex when between two neighboring asymptotes several eigenvalues are located. The algorithm proposed by the Author effectively determines the eigenvalues for all cases considered in the dissertation. Additionally, the Author presented a method for the generation of compact thermal models by dividing the frequency spectrum of the eigenvalues.

The next two chapters present the problem of estimating the thermal parameter values of three-dimensional and compact thermal models. The author, based on a real example of the hybrid system and power diodes, analyzed the application of various types of algorithms. Initially, the estimation of thermal model parameter values, such as resistance, capacity and heat transfer coefficient, has been carried out. These analyses have shown that the simple algorithm proposed by the author may in some cases be more effective than other algorithms commonly used to solve inverse and optimization problems.

Then, for the thermal model parameters whose values depend on the operating and cooling conditions, some parametric dependencies have been proposed. The determination of coefficient values occurring in these dependencies have been carried out applying the bee swarm intelligence algorithm. The obtained results of thermal simulations were very accurate and observed errors result mainly from the simplification of the proposed thermal models.

The research described in this dissertation can have significant influence on the design of modern electronic systems. Accurate estimation of the hot spot temperature is crucial for the proper and effective operation of the entire system. The application of obtained results may allow optimization and significant improvement of the reliability of electronic systems.

4. Doctoral Theses

Based on the obtained results, the following doctoral theses have been formulated:

1. it is possible to develop an algorithm allowing automated determination of eigenvalues necessary to obtain the solutions of the heat equation for multilayer structures employing the analytic method of the Green’s functions,
2. the use of inverse heat transfer and optimization algorithms in thermal simulators allows the estimation of thermal model parameter values and obtaining of solutions for the non-linear thermal conduction equation,
3. the swarm algorithms can be used for parametric identification of functions describing the thermal model element values.