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Developing an equivalent thermal model for discrete DIODE packages

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A B S T R A C T

The paper covers a useful and practical method for users of power semiconductor devices to derive dynamic thermal models of discrete diode packages. Temperature estimation of power electronic devices has generally been performed using transient thermal equivalent circuits. The study leads to correcting the junction temperature values estimated from the transient thermal impedance. The corrections depend on multidimensional thermal phenomena in the structure.

An advanced 1D thermal model based on the finite element method is proposed. It takes into account the effect of the heat spreading angle in the device.

It takes into account the main thermal temperature-related non-linearities of package layers. The derived thermal models offer an excellent trade-off between accuracy, efficiency and CPU-cost.

1. Introduction

Deriving dynamic models from thermal impedance data of packaged semiconductor devices is useful to evaluate the junction temperature of these devices during operation. Such models should take into account the package thermal impedance including the silicon chip, the die attach layers and the heat spreader.

Junction-to-case thermal impedance can be measured experimentally and they are available on semiconductor manufacturer data sheets. These data are used from several tens of years to estimate (by hand) the junction temperature knowing the average power losses. In Power Electronic applications, power losses may be represented by cyclic step functions. The transient thermal impedance curves give the increase in junction temperature as a function of the peak value, the duration and the duty cycle of power loss input waveforms.

However such transient thermal impedance curves do not fit with time-domain simulation, like those involved in circuit simulators. So time-domain thermal models are required to achieve electrothermal simulations of power systems. They are compatible with circuit simulators in which most of the semiconductor device models are implemented. This paper present an equivalent thermal model of a discrete device using the step transient thermal impedance curves.

In the first part of the paper we have studied the thermal behavior of the power diode. After a brief description of the internal structure, a 3D numerical simulator is used to implements the structure.

The thermal impedance $Z_{th}(t)$ between junction and case of the power diode is compared to the thermal impedance deduced from manufacturer data sheet. The variations of the device thermal resistance, according to the dissipated power and the boundary conditions at the case, are studied.

In the second part of the paper, an advanced 1D thermal model is proposed. It is based on finite element method (FEM) represented by an equivalent electrical circuit which sweet well with circuit simulators where electrical behavior are studied. The multidimensional phenomena are taken into account by considering the heat spreading angle in the device.

In the third part of the paper, 3D numerical simulations and experimental investigations are performed in order to validate the proposed advanced model. The effect of non-linearities of the silicon thermal conductivity on temperature responses is studied. The final section concerns the device behavior in the case of large power surges of short time duration. Discussion about the thermal model accuracy is presented.

2. Thermal investigations in the power diode

The essential input value characterizing the thermal behavior in the component is the transient thermal impedance $Z_{th}(t)$ between

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