THERMAL MODEL FOR MCM’S

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ABSTRACT

A model based on closed form expressions for steady state thermal resistance evaluation of chips and their thermal coupling, under adiabatic and isothermal boundary conditions, is presented.

The expressions for thermal resistance use the variable heat spreading angle approximation and the thermal coupling is calculated using the Green’s function approximation and the method of images.

The model shows good accuracy and behaviour over the conditions most often encountered in practice, so it can be used in many design situations.

1. INTRODUCTION

Thermal analysis of multiple device structures, as MCM, needs to consider both self-heating of devices and thermal coupling between them. This problem has been traditionally approached using analytical methods [1,2] or numerical techniques [3]. In both cases, the arrived solution embodies the mutual effects in problems including more than one heat source.

There are many situations, however, where the complexity of such methods precludes their use until some degree of concretion in the design is attained. In such cases, models based on the thermal resistance concept [4-6] can be useful. However, if thermal coupling stands for an important part of temperature rise on some or all of the devices, a way of considering the mutual effects has to be included.

In what follows, a closed form method for self-heating evaluation through the thermal resistance concept, jointly with the calculation of cross coupling effects between devices is presented.

2. THE MODEL

The proposed model is sketched in Figure 1, where the thermal-electrical duality is used.
The power dissipated in each element is modelled through a current generator of value $W_i$, the self-heating through the element's thermal resistance $R_{th}$, and the thermal coupling by means of current dependent voltage generators with mutual resistance $m_{ki}$. Then, the temperature of each individual element can be calculated as:

$$T_i = R_{th} \cdot W_i + \sum_{j \neq i} m_{ji} \cdot W_j$$ (1)

The model parameters are the thermal resistance $R_{th}$ of each element and the mutual thermal resistances $m_{ki}$ from every other element to it.

3. THE EVALUATION OF THERMAL RESISTANCE

It has been often assumed that heat spreads with a constant angle from the power dissipating element [1], $45^\circ$ being the most commonly used. The value for the thermal resistance of a square element of side $2l$ on a semi-infinite substrate of thickness $w$ and thermal conductivity $k$ is:

$$R_t = \frac{1}{4 \cdot k \cdot l} \cdot \frac{w}{l + w \cdot \tan \alpha}$$ (2)

For our development with a finite substrate, we define the dimensionless spreading resistance coefficient and system geometry parameters as:

$$H = 4 \cdot k \cdot l \cdot R_t; \quad l_n = l/L, 0 \leq l_n \leq 1; \quad w_n = w/L, 0 \leq w_n \leq \infty$$ (3)

where $l$ and $L$ are the (square) element and substrate half side.

The variable heat spreading angle method, described in detail elsewhere [5,6] will now be applied to find the thermal resistance for the following sets of boundary conditions, sketched in Figure 2, where the top surface is considered adiabatic in all cases:

- **Case I**: Side walls adiabatic and bottom surface isothermal.
- **Case II**: Side walls and bottom isothermal at the same temperature.
- **Case III**: Side walls isothermal and bottom surface adiabatic.