EMC Computer Modelling Techniques for CPU Heat Sink Simulation

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Abstract — The paper presents the EMC computer modeling of the electromagnetic radiation emissions from heat sinks on high power microelectronics using FEM based simulator. The heat sink model of IEEE EMC challenging problems has been used to investigate several different grounding configurations. A new model of P4 CPU heat sink and its grounding configuration have been also investigated in this work.

1. Introduction

Modern microelectronic technology in wafer fabrication easily allows component densities to exceed 1 million transistors per die. Some components consume more of DC power. Certain components require separate cooling provided by a fan built into their heat sink or by location of the device adjacent to a fan or cooling devices. Since these high-power and high-speed processors are being implemented in more designs, special design techniques are now required for EMI suppression and heat removal at the component level. As a result, traditional techniques are no longer valid for representing electrical behaviour and full wave numerical analysis tools are required. In this paper we mainly consider RF domain problems based on a proper thermal implementation and use of heatsinks, and provided thermal conductor. This conductor contains excellent thermal properties for transferring heat from the component to the heatsink. The metal heatsink in RF domain considering grounded heatsink for traditional heatsink and not grounded heatsink for a new model of P4 CPU heat sink. The investigation is based on the simulation of FEM in frequency domain based simulation tool, such as Ansoft HFSS.

2. EMC Modelling for CPU Heat Sink

The power generated from processor currents can reach levels of 50 W and also have clocking speeds of over 1 GHz. Thus heat sinks radiators on high power microelectronics are able to produce significant EMI. As a result, EMC engineers need to understand the cause of radiated emissions from heat sinks, and find ways to reduce them whenever possible. IEEE EMC Society, Technical Committee 9 (TC-9) have partnered in an effort to develop specific standard problems. CPU heat sink problem is one of EMC challenging problems. The purpose of these problems is to provide EMI/EMC engineers and vendors a way of testing their EM modeling software to determine its validity and accuracy. In this paper we call this heat sink model as a traditional heat sink model in contrast with new heat sink model of Intel P4 CPU heat sink, as Intel P4 CPU heat sink model has different configuration with traditional one.

To model the heat sink structure it is useful to brake down the structure into three regions, the ground plane, the source region and the heat sink. A realistic representation of a VLSI however must take into account the electromagnetic source characteristics and an actual physical model e.g. a conducting patch [1]. Real heat sinks have fins to increase the thermal conductivity. However Brench [2] found that the heat sink could be modelled as a solid block. One approach from Das and Roy [3] models the source as a monopole that cuts through a VLSI. Das and Roy test three models: ground plane monopole, ground plane monopole through a VSLI and element through a VSLI with a heat sink. From the

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experimental results Das and Roy concluded that the radiation emissions and resonant frequencies from cases one and two were similar. Case three had fairly similar results when the vertical dimension of the heat sink approached a fifth or a sixth of a wavelength. Case three had radiation emissions and resonant frequencies that were lower. Thus as a first approximation a monopole may model characteristics of a heat sink structure.

A. Traditional Heat Sink Model

In traditional heat sink model, the processor is closer to the heat sink than the ground plane. An image plane forms such that common mode currents from the processor can flow into the heat sink rather than be returned normally to the ground plane. That is, a conductive path is formed due to the stray capacitances. The defined model by IEEE EMC Challenging problems, TC-9, can be described as figure 1, which is called traditional heat sink model in this paper.



Figure 1. TC-9, traditional heat sink model.

B. Intel P4 CPU Heat Sink

Intel P4 processor has a different packaging and structure configuration compared with traditional CPU configurations, as shown in figure 2. In P4 configuration, a heat spreader is located on top of VSLI. The heat spreader is isolated form VSLI packaging. Therefore different numerical model will be used in computer simulation. A simplified model such as multi layered structure for P4 CPU is used as shown in figure 3, where Intel Pentium 4 Processor in the 478-Pin Package can be used for 1.40 GHz, 1.50 GHz, 1.60 GHz, 1.70 GHz, 1.80 GHz, 1.90 GHz, and 2GHz.







Figure 3. Computer model of P4 heat sink, where the materials are used as; IHS: copper, substrate: polyamide, patch: copper, heat sink: aluminium, ground plane: copper.

3. FEM based Simulation Results of CPU Heat Sinks

A. Traditional Heat Sink Model with Two Grounding Points

The simplified model of heat sink over a ground plane with two grounding points is presented in figure 4, where the excitation is vertical source extending from the ground plane to the base of the heat sink, and the

excitation source is slightly off centre to encourage propagation of different modes. It is offset by 1.27mm in the x- and ydirections from the center of the heat sink. The numerical model is solved by FEM in frequency domain program taking into account the absorbing boundary conditions. Figure 5 and 6 show the simulation results as a monopole radiator. The radiated emission is not that larger compared with wireless communication devices.



Figure 4. Simulation model using finite ground plane for two grounded heat sink.



Figure 5. Radiation pattern at frequency 3.15 GHz for E theta field when theta equal to 0 degree.



Figure 6. Return loss for two grounded heat sink.

B. Traditional Heat Sink Model with Four Corner Grounding Points

With four corner grounded heat sink as shown in figure 7, the different results can be obtained. Figure 8 and 9 show the simulation results of return loss and radiation pattern related to radiated emissions from heat sink.



Figure 7. Four corner grounded heat sink model.



Figure 8. Far field radiation pattern at frequency 1.83 GHz for E theta field when theta equal to 0 degree.



Figure 9. Return loss for the four corner grounded model.

C. P4 CUP Heat Sinking Simulation

The radiated emission from heat sink on high power microelectronics has recently become of interest due to higher power levels and faster clocking of digital circuits, such as Intel P4, AMD and other processors. In this paper we only consider the modelling of P4 CUP heat sink configuration as shown in figure 10. The excitation is vertical source extending from the ground plane to the base of patch and coupled with the heat sink through substrate. There is no grounding point for this P4 heat sink model. Figure 11 and 12 show the radiation pattern and return loss of P4 heat sink model. From the simulation results we can see that there is a significant radiated emission from this heat sink at 2.6 GHz compared with normal wireless communication devices.



Figure 10. P4 CPU heat sink model.



Figure 11. P4 heat sink radiation pattern at 2.6 GHz for the E theta field when theta equal to 0 degree.



Figure 12. Return loss of P4 CPU heat sink model.

4. Conclusions

The paper presented EMC computer modelling techniques and its application in CUP heat sink simulation. To compare the effect of grounding heat sink in various ways, or not grounding it, several heat sink configurations including P4 CPU heat sink are investigated. The grounded heat sink can still produce some radiated emission from heat sink. The isolated heat sink may produce less radiated emission. The future work is to minimize the radiated emission from heat sink using optimisation techniques.

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