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L-type heat pipes application in electronic cooling system

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ABSTRACT

This paper describes the design, modeling, and test of a heat sink with embedded L-shaped heat pipes and plate fins. This type of heat sink is particularly well suited for cooling electronic components such as microprocessors using forced convection. The mathematical model includes all major components from the thermal interface through the heat pipes and fins. It is augmented with measured values for the heat pipe thermal resistance. A Windows-based computer program uses an iterative superposition method to predict the thermal performance. Thermal performance testing shows that a representative heat sink with six heat pipes will carry 160 W and has reached a minimum thermal resistance of 0.22 °C/W. The computer software predicted a thermal resistance of 0.21 °C/W, which was within 5% of the measured value. The result of this work is a useful thermal management device along with a validated computer-aided tool to facilitate rapid design.

1. Introduction

Several types of heat sinks combine embedded heat pipes and a base plate and fins. Estimating the typical thermal solution for the heat dissipation of electronic components when installing a heat sink with a fan is important. For a heat sink with embedded heat pipes, a rapid, correct estimate of the individual thermal resistance and thermal performance of the microelectronic components is also a key issue for thermal management and control.

The use of embedded heat pipes enables the heat sink to rapidly transfer heat from the heat source to the fins, without increasing the surface area of the fins or increasing the speed of the fan, making it possible to reduce the total thermal resistance to under 0.3 °C/W. For example, Wang et al. [1] investigated an aluminum heat sink with two embedded 6 mm diameter heat pipes, finding that they can carry away 36% of the total dissipated heat from the CPU, and that the lowest value of the total thermal resistance is 0.27 °C/W at an input power of 140 W. In evaluating the heat performance of a heat sink, the total thermal resistance, including individual thermal resistance of thermal contact and constriction, is used to evaluate the thermal performance of a heat sink thermal module. Due to the high thermal conductivity and increased heat flux capability of the heat pipes, their thermal resistance is very low, roughly $10^{-1} \sim 10^{-3}$ °C/W [2–4].

Heat sinks and embedded heat pipes have been explored in a number of studies. Heat sinks with embedded heat pipes have been found to have good thermal performance and low manufacturing costs application in servers, PCs, and notebooks [5–7]. The embedded heat pipes result in high effective thermal conductivity [8]. Because of the capillary force of the wick structure, heat pipes work against gravity, and optimum designs have been obtained using a nonlinear programming approach [9,10]. The powder cluster wick has a much higher maximum mass transport rate, enabling higher capillary limitation for the heat pipe [11]. Empirical studies have modeled the transient thermal behavior of a complex testing system, including multiple fans, a mixing enclosure, copper inserts, and a leaded package, that dissipates large quantities of heat over a short period of time [12]. Xie et al. [13] investigated a 4 mm diameter heat pipe and a heat sink, achieving an optimum total thermal resistance of 0.29 °C/W. Legierski and Wiecek [14] pointed out that the thermal performance of the heat sink with embedded heat pipes is better than that of an ordinary heat sink, with an optimum total thermal resistance value of 0.25 °C/W. Gernert et al. [15] used a heat sink with heat pipes whose evaporator is on the flat end face of the cylinder instead of its circumference composed of a 25.4 mm diameter heat pipe and an aluminum heat sink; when the maximum heat flux was 285 W/cm^2, the minimum total thermal resistance value was 0.225 °C/W. Wang [16] investigated an aluminum heat sink in which were embedded sets of two and four 6 mm diameter heat pipes, finding that they can carry 36% and 48% of the total dissipated heat capacity from CPU, and that the total thermal resistance is under 0.24 °C/W. Clearly, a heat sink with embedded heat pipes is one of the best solutions to the problem of high heat generation in electronic components.

The heat sink with six embedded L-type heat pipes studied in this article is shown in Fig. 1. The overall dimensions of the heat sink are $117 \times 85 \times 83$ mm^3. One end of the heat pipes is inserted into the

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