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Abstract

A New Architecture for Avionics Thermal Management

Charles P. Minning
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

John H. Schroeder and Douglas W. Wolfe
Raytheon Electronic Systems
El Segundo, CA 90245

A new and innovative convective cooling scheme for compact avionics subsystems in airborne and space applications is presented. The basic physical configuration of the avionics subsystem consists of stacked multichip modules (MCMs) arranged such that both the pressure drop in the coolant stream and the weight and volume overhead for coolant distribution and manifolding are minimized.

The key to this cooling approach is the integration of a thin porous heat exchanger into the MCM substrate to significantly increase the heat transfer surface area in contact with the coolant. The resulting substrate consists of two layers: a thin non-porous layer for mounting and connecting electrical components and a porous heat exchanger. Substrates with this configuration have been fabricated as a single integral part without bondlines. Coolant flows through the MCM stack in the direction perpendicular to the interconnect planes of the individual MCMs. For a given MCM in the stack, coolant first flows through the porous heat exchanger and then exits through a series of small orifices in the non-porous layer containing interconnections between electrical components. Coolant exiting the orifice holes of one MCM then enters the porous section of the next MCM and so on for the entire stack. This coolant flow scheme permits high heat transfer rates at a minimal pressure drop.

This paper describes the methodology for demonstrating the feasibility of the cooling concept by means of mathematical models and appropriate experiments. Key to this effort was the prediction of the coolant pressure drop as it flows through a MCM. The performance of the porous heat exchanger is difficult to predict because the coolant velocity (both magnitude and direction) is unknown and varies with position due to channeling of the coolant caused by the orifices. However, a method was developed to predict the maximum and minimum expected pressure drop for gaseous coolants, and this method was verified by experiment. A discrete-element thermal model was developed to predict the thermal performance of a single MCM, again for gaseous coolants as well as for different substrate materials, and the results of this model were verified by experiment. A discrete-element thermal model for a typical airborne radar processing element consisting of a stack of 3 MCMs dissipating a total of 300 watts was then developed and the results compared with those of a conventionally air-cooled radar processing element. The results for the 3 MCM stack configuration were found to compare favorably with the conventionally air-cooled radar configuration.

The models for predicting both the pressure drop and thermal performance has been extended for liquid coolants, and these results are compared with those for gaseous coolants.