Thermal Management in Embedded Systems Using MEMS

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The objective of the ITEM (Integrated ThErmal Management) project is to specifically address thermal management of high-density embedded systems by developing a set of innovative scalable techniques that provide:

1. a flexible thermal management system with the capability to remain viable for several generations of increased microprocessor performance and power,
2. simplification of the packaging, by eliminating the cooling core concept and replacing it with an innovative "self-ducting" design based on 3-D stacking of computational nodes,
3. microelectromechanical structures (MEMS) that allow active, dynamic management of localized heat dissipation by directly adjusting the fluid boundary layer,
4. integrated thermal instrumentation circuits to monitor and control the local environment (e.g., microcells for chips and simple die for systems), and
5. embedded algorithms for intelligent and robust thermal management.

We are currently building a demonstration system to investigate the feasibility of the third goal, i.e., the effectiveness of magnetically actuated flipper MEMS in increasing the heat transfer ability of cooling fins by introducing highly localized turbulence. The hardware basis of this system is a carefully constructed test chamber for channeling air flow over extensions of a heat spreader, which form heat transfer fins and have MEMS flippers mounted on them (see Figure 1). The heat spreader is attached to the top of the Router Interface (RIF) single-chip module (SCM), a custom VLSI component designed for the Package-Driven Scalable Systems (PDSS) project. The RIF SCM is mounted on a PCB containing additional circuitry for exercising and monitoring the RIF routing function.

Due to the expected sensitivity of the measurements and the magnitude of the data to be taken, the evaluation procedure will be performed using closely controlled air flow rates. The air source will be supplied from an accumulator tank equipped with a self-contained air compressor. The air flow will be measured using an appropriate anemometer.

The clock frequency and input data of the RIF will determine the energy dissipated. If necessary, additional thermal energy will be supplied to the heat spreader via a strip heater. Other independent variables in this process are the actuator magnetic field characteristics and the air flow rate. A number of strategically placed thermocouples will be used to accurately measure temperature.

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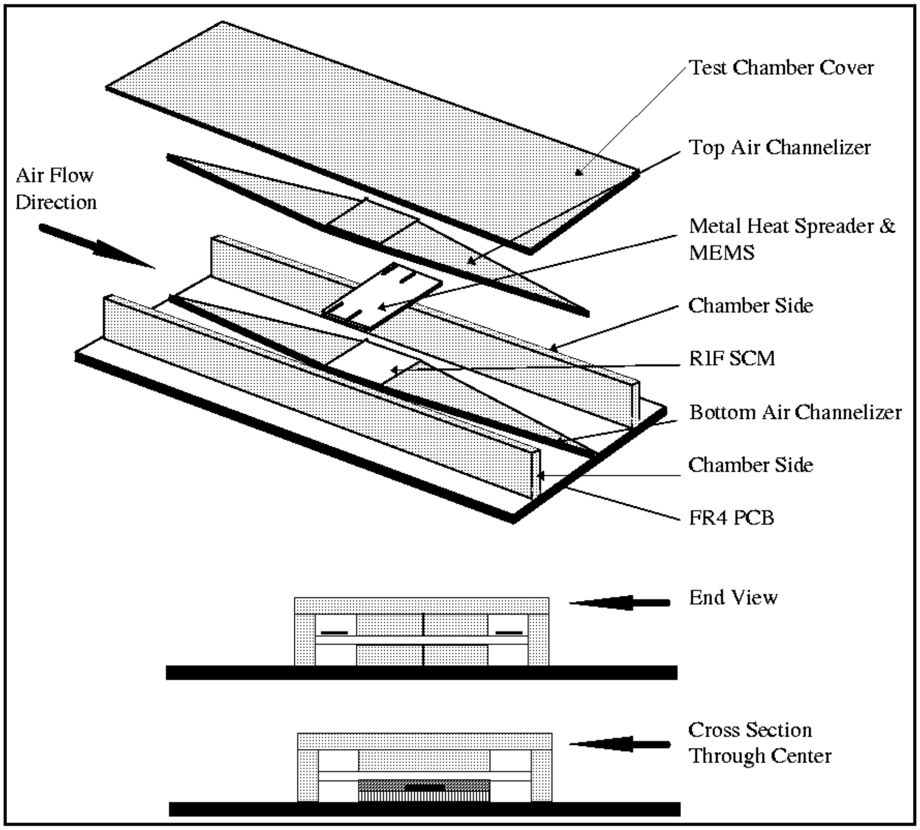

Fig. 1. MEMS Test/Evaluation Chamber

Although these temperature measures alone will provide useful information, by integrating the RIF component into this demonstration system, we intend to show the impact of the MEMS flippers on the functionality of "real" components. Furthermore, this interaction is of interest since the RIF is an essential component of the final ITEM system, a high-density version of the PDSS architecture which will be the densest system (in terms of FLOPS/volume) ever built.

The PCB is currently in the layout phase. Initial system assembly is expected to be completed by the middle of February with data gathering commencing near the end of February.

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