Thermal Management System with Passive Cooling Modules

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1. Background

The chip-maker industry needs a temperature controlled environment for processor debugging, testing and validating. A temperature controlled environment is created by a so-called thermal management system or test validation tool which comprises of four parts: a host computer, a temperature control system (TCS), a thermal head (TH) and an active heat remover (chiller, house chilled water, fan, etc.). Fig. 1 shows a basic block diagram of a test validation tool.

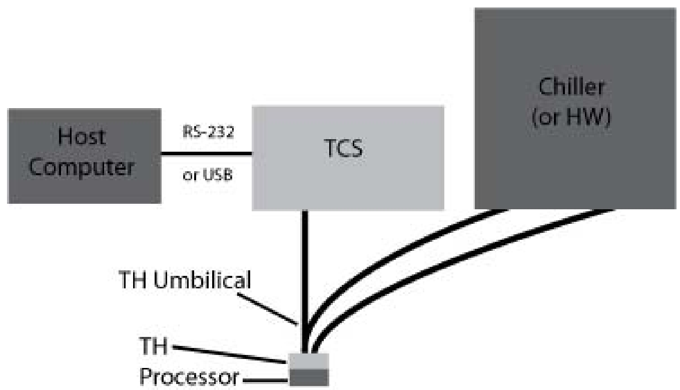

Fig. 1. TCS: temperature control system; TH: thermal head; HW: house water

A thermal management system is currently required to handle up to 200 Watts/cm^2 in the range of -50°C to 150°C for a chip or a processor. Such a thermal management system typically requires a fluid source such as a free-standing chiller or house chilled water system to cool the TH. The disadvantages of a chiller in a thermal management system environment are loud audio operational noise; high electrical power consumption; emission of heat into the environment; limited, adequately rated power-in outlets; as well as large footprint and space allocations. House chilled water is a very convenient and efficient fluid source; however, such systems are not usually available in the thermal management systems environment. Therefore, a thermal management system that does not require a chiller or a house chilled water fluid source is highly desirable. In this presentation, we will introduce a thermal management system which does not require a chiller or house chilled water. The system uses liquid-air cooling modules for heat removal. Each cooling module features scalability, low noise, low pressure and low energy consumption.

2. System Design

Fig. 2 is the block diagram of a new thermal management system with two so-called passive cooling systems (PCS). The PCS replaces the chiller or house chilled water required by the thermal management system. Two PCS cooling systems dissipate the heat generated by four, simultaneously operating, TH components to ambient. The Racked Integrated Thermal Management System (RITMS) in the figure is a smart temperature control system which controls and integrates the PCS and TH components to operate as a system.

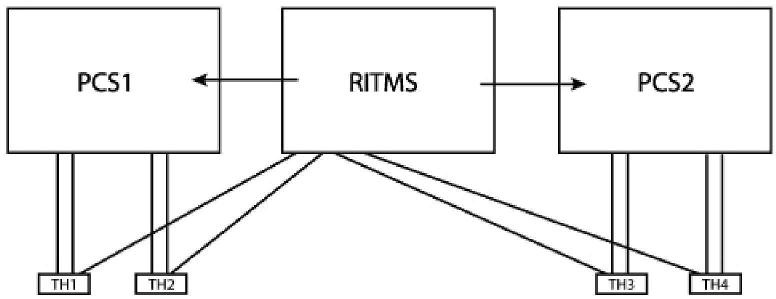

Fig. 2. Thermal management system with PCS units.
TH1...TH4: thermal heads; PCS1, PCS2: passive cooling system;

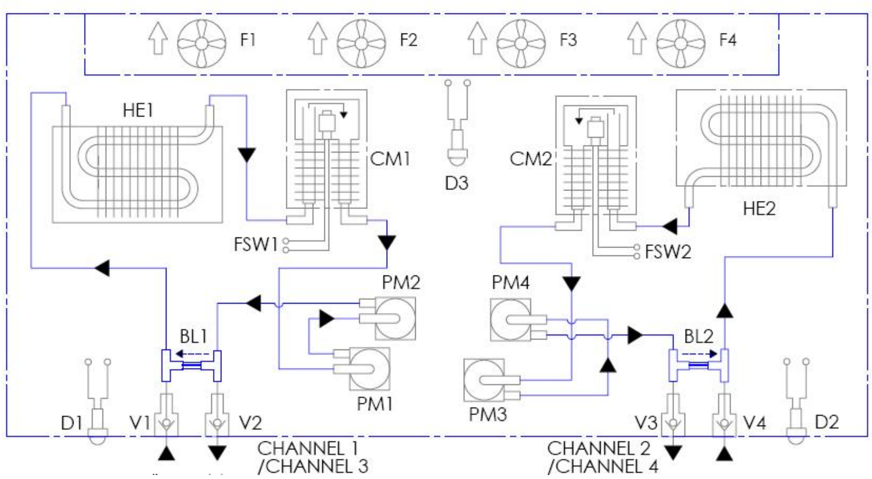

Fig. 3. Layout of a PCS unit.
CM1, CM2: cooling module; D1, D2: flashing LED assembly; D3: Kichler lamp holder;
F1…F4: fan, 12VDC, 120mm x 120mm x 38mm; FSW1, FSW2: liquid level switch;
HE1, HE2: heat exchanger; PM1…PM4: pump; BL1, BL2: bypass Line;
V1…V4: fitting, CPC.

A PCS unit has two independent channels; each one supplies fluid for one TH, as shown in Fig.4. Each channel comprises of two fans, one heat exchanger, one USTC cooling module (patent pending), two pumps fittings and connected hoses. The cooling module includes an air-liquid heat exchanger, a reservoir and a low liquid level sensor; its diagram is shown in Fig.4. The fans and pumps used in the PCS are low noise parts, which are operated with 12VDC; the heat exchanger and reservoir are integrated in compact form, so the overall PCS size is much smaller compared to a chiller. The PCS only consumes electrical power for pumps and fans which are low energy-consumption parts. As a result, the PCS requires much less power for operation than a chiller. The scalability of the PCS means a single or a multiple channels PCS can be configured. The PCS uses a low pressure pump, which increases overall long life reliability.

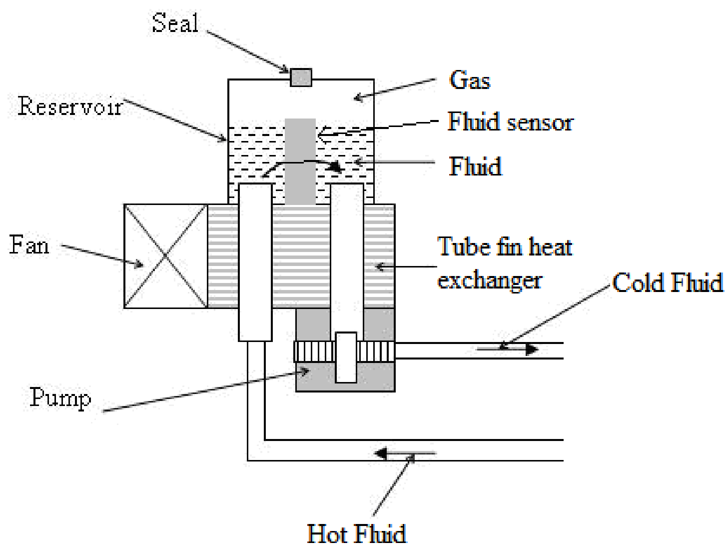

Fig.4 Schematic drawing of a cooling module

3. System Performance

Fig. 5 and Fig. 6 show the processor's temperature response when the processor's temperature setting is changed. In one case, the TH was cooled by a PCS, in a second case by a chiller, which corresponds to Fig. 5 and Fig. 6 respectively. The response time for a typical temperature change is less than one minute in both cases. Short response time (less than one minute) is also found when processor's power is switched from one level to another or vice versa in both cases. The difference in response time between the Chiller and the PCS cooled systems is small.

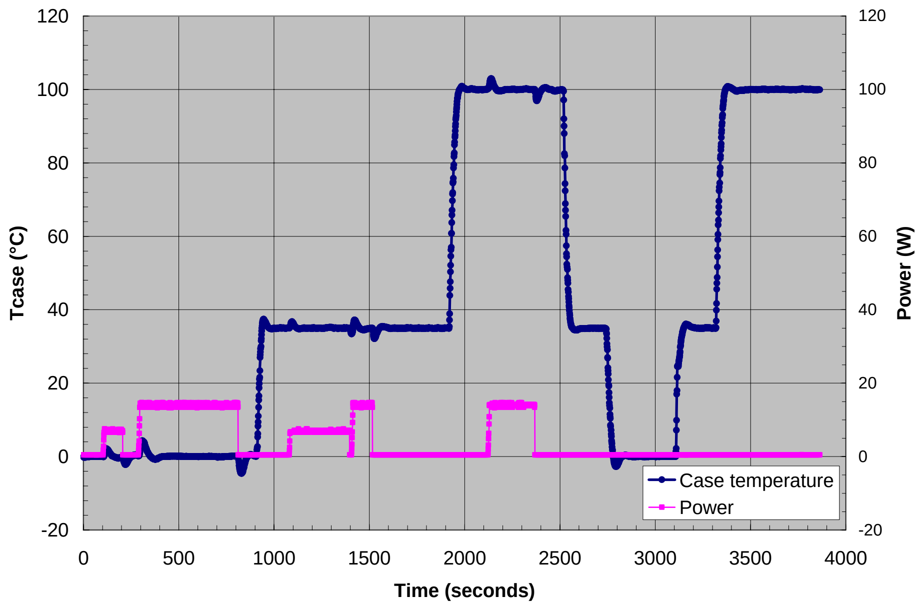

Fig.5 Temperature response when the case temperature setting is changed. The processor size is 10mmx10mm, and the TH was cooled by a PCS.

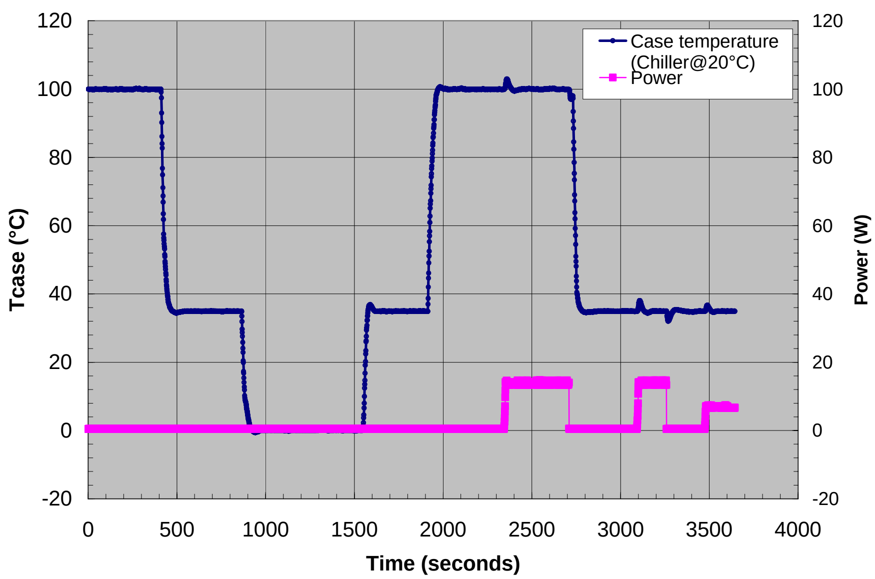

Fig.6 Temperature response when the case temperature setting is changed. The processor size is 10mmx10mm, and the TH was cooled by a chiller.

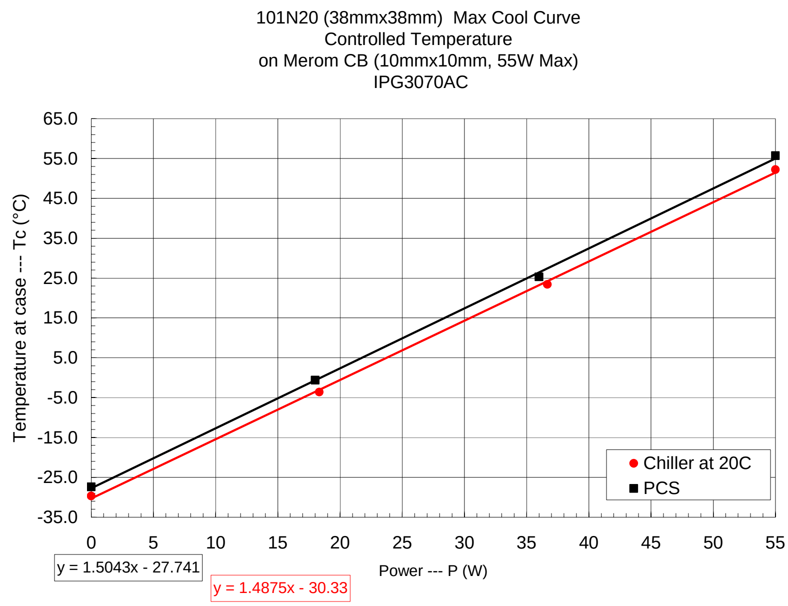

Fig.7 Maximum cooling curve comparison of a 38mmx38mm footprint of a TH cooled by a chiller or a PCS respectively. The processor's maximum temperature is 115°C. The processor has dimensions of 10mmx10mm.

Fig. 7 shows the lowest temperatures at different power levels of the processor cooled either by a chiller or by a PCS. We can control the temperature from 0°C to 115°C for a full running 17W processor which has 10mmx10mm in dimensions. The temperature uncertainty is less than 1°C. The difference in thermal performance between the Chiller and PCS cooled system is small.

Fig. 8 shows the maximum cooling capability for a TH which is cooled by a chiller and a PCS. The maximum power is 130W with a Multi-die processor (size: 2x10mmx10mm). From the performance curve, a PCS cooled system is also applicable to the temperature control of a high power processor.

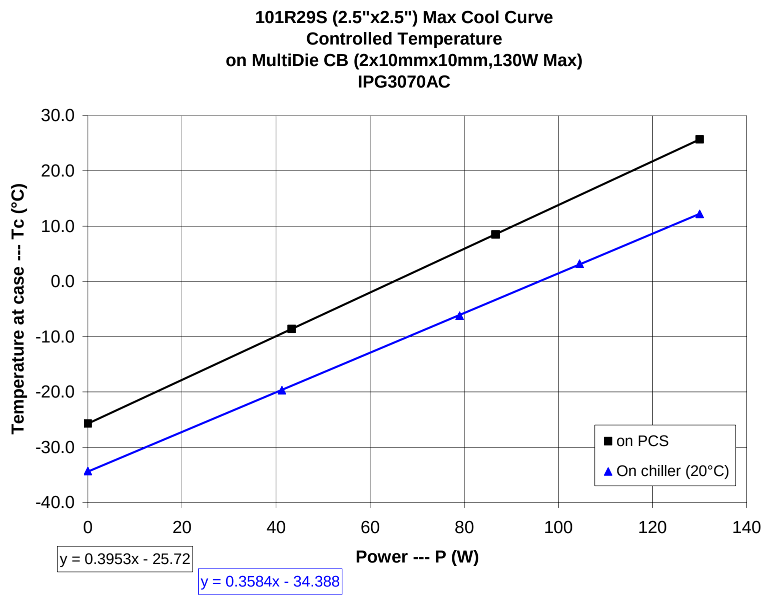

Fig.8 Maximum cooling curve comparison of a 64mmx64mm footprint of TH cooled by a chiller or a PCS respectively. The processor's maximum temperature is 115^{o}C. The processor has dimensions of 2x10mmx10mm.

4. Summary

In this presentation, a thermal management system without a chiller or a house chilled water system is designed. The thermal management system does not require a chiller or house chilled water. The system uses liquid-air cooling modules for heat removal. The cooling module features scalability, low noise, low pressure and low energy consumption.

Reference

[1] Spokoiny et al., "High Performance Test Validation Tool Design for Debugging Engineer in Chip-maker Industry", IMAPS Advanced Technology Workshop on Thermal Management, San Jose, California USA, September 24-27, 2007.