White Paper

Thermal Design and Management of Servers

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Overview

With the exponential growth of knowledge development, data needs to be stored, processed and secured so users can access the data quickly. Servers engage in a major role in this type of data-intensive business applications. The progressions in hardware, software and miniaturization technologies, along with the information development, has led to a huge increase in servers power densities and computing power. By developing thermal management in servers to remove the heat generated by the devices, it will improve the reliability and enhancement performance.

Green Data Centers

A data center is complied of computer servers usually controlled and maintained by an operation to accomplish server needs much greater than the capability of one machine. These centers run extremely scaled software applications with million of users. The demand for bigger and better data centers increase as they become the nerve centers of business and society. There is a rising need to generate the most computing power per square foot at the lowest possible cost in energy and resources, all of which is bringing new level of attention and challenges.

A green data center is essentially a repository for the storage, management, and dissemination of data. In the center, the mechanical, lighting, electrical and computer systems were developed to optimize energy efficiency and environmental impact. The operational scope of a green data center design for the IT industry must minimize the carbon footprints of buildings and use alternative energy technologies. A green data center focuses on two primary objectives, energy conservation and environmental safety. This is achieved through optimizing the performance of cooling systems using real-time sensing technology. To resolve this issue, green data centers perform sensor-based optimal cooling.

Thermal Challenges in Servers

The growth in power densities, performance, and reliability constraints will generate major obstacles for the thermal management of servers. These thermal challenges will change with different products and requirements. Such challenges faced in the servers consist of very high

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power dissipation, high ambient temperature, stringent thermal requirements, harsh environment, meeting strict standards and compliances, miniaturization, product design cycle time reduction, minimizing the thermal cost, and feasibility solution using available resources. The electronics cooling industry has put into consideration these challenges and has come up with path breaking innovative solutions time after time.

Innovative Cooling Solutions

Due to thermal challenges, it has led to solutions in thermal management. The latest technologies in the thermal management arena function in and around the basic heat transfer modes. The development has reached a point where the technologies overlap the fundamental functional industrial domains. The development of technologies is moving from single-phase heat transfer to multi-phase heat transfer, which has led to the design of advanced cooling solutions. Different technology types require different cooling techniques.

Conduction Cooling

Conduction: An important cooling technique where more heat will be transferred to surrounding ambient through the conduction heat transfer.

Advanced Cooling Technologies

Refrigerant Cooling: Used when sub-cooled temperatures are required in a system.

Hybrid Cooling: More than one coolant will be used. Cooling will achieved through more than two different modes of heat transfer.

Cold Plate Technologies: High conductive material with the flow passes will be in contact with the power dissipated components. Low melting point liquid will flow trough the passes and remove heat from the chip.

Smart Cooling Technologies

Spot Cooling: During this process, a cold fluid will be blown across the spots wherever hot spots are present, and cooling will be attained. This can be achieved directly or indirectly through a fan.

Heat Pipes/ Heat Super Conductors: The hollow tubes are filled with a low melting point liquid, with tube wall and liquid separated by a wick. The highly conductive material will help disburse the heat with low resistance. It is a very effective, noise-free technique which will remove heat from the processor chips.

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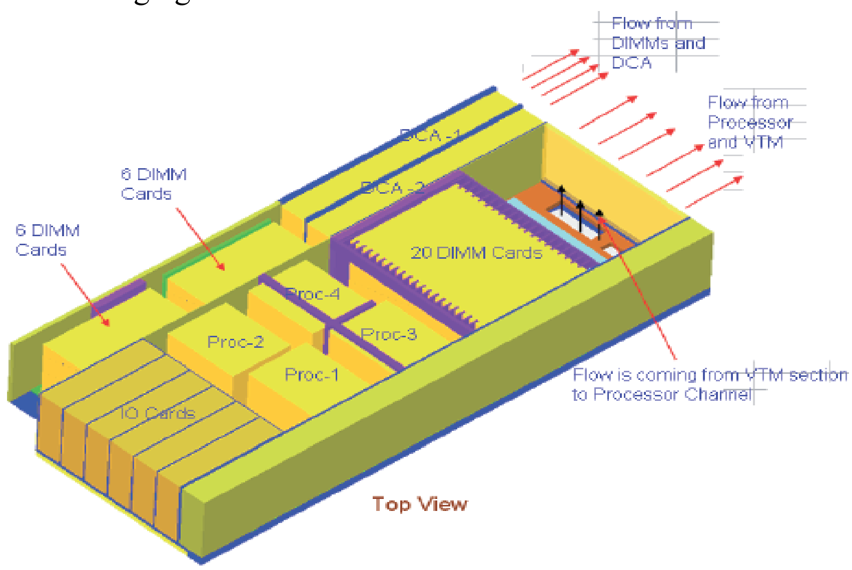
Compact Heat Exchangers: With the miniaturization in the place, heat will be removed from the system to ambient through compact heat exchangers.

eTECs (Embedded TECs): With multi-core processors where some of the cores may be very hot and the temperature must be brought down to allowable limit, TECs will be inscribed at a certain portion of the die, and these will take care of the die temperature.

Thermal Management of High End Server

A high end server comprises of as many as 13 sublevel nodes packed in a compact chassis in two rows. Each sublevel node consists of six IO cards, 32 DIMM cards, four multi-core processors, one voltage transformation module and two DCA channels. The total power dissipation of each node is 2.4kW and the total power dissipation of full high end server is 32.1kW. Providing a thermally feasible optimal solution to this high end server is very difficult and challenging.



Thermal Challenges

Multi-Core Processors Cooling

- Less space available and preheated air will flow across the processors, making the design more challenging
- Advanced cooling technologies is needed from the industry to cool these next generation processors
- Total power dissipation = 920W

DIMMs Cooling

- Less flow rate availability
- Space constraint between DIMMs
- Total power dissipation = 736W

Voltage Transformation Module (VTM) Channel Cooling

- Has one of the critical flow path designs in the server
- VTMs are placed in a narrow flow channel through which fluid enters the modules – this is one of the geometric constraints for the thermal design
- Second constraint is available flow rate to cool the modules
- Total power dissipation = 370W

System Pressure Drop Optimization

- Since it is a very high power dissipating system, there is a need to optimize the system in such a way that maximizes the heat transfer and minimizes the pressure drop.

Innovative Thermal Solutions

Multi-Core Processing Cooling

- Designed and optimized a customized heat sink fulfilling the thermal requirements.
- Heat sink has been designed so that it minimizes the weight and decrease the cost.
- Base and center fins of the heat sink were designed as copper, and extreme fins were made up of aluminum.
- Heat pipes were used to connect through the aluminum fins and the base of the heat sink.
- This combination of different heat sink materials and heat pipes is providing allowable temperature limit for processor
- This innovation design added value to the customer

DIMMs Cooling

- Nova chip which controls the DRAMs cooled with custom made optimized heat sink
- Nova chip heat sink was designed with a constraint on the height of the heat sink (distance between any two respective DIMMs was less) and the less available flow rate across the DIMMs
- The innovative design of Nova chip heat sinks across all DIMMs made thermal cooling possible for high dissipating DIMMs

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Voltage Transformation Module Channel Cooling

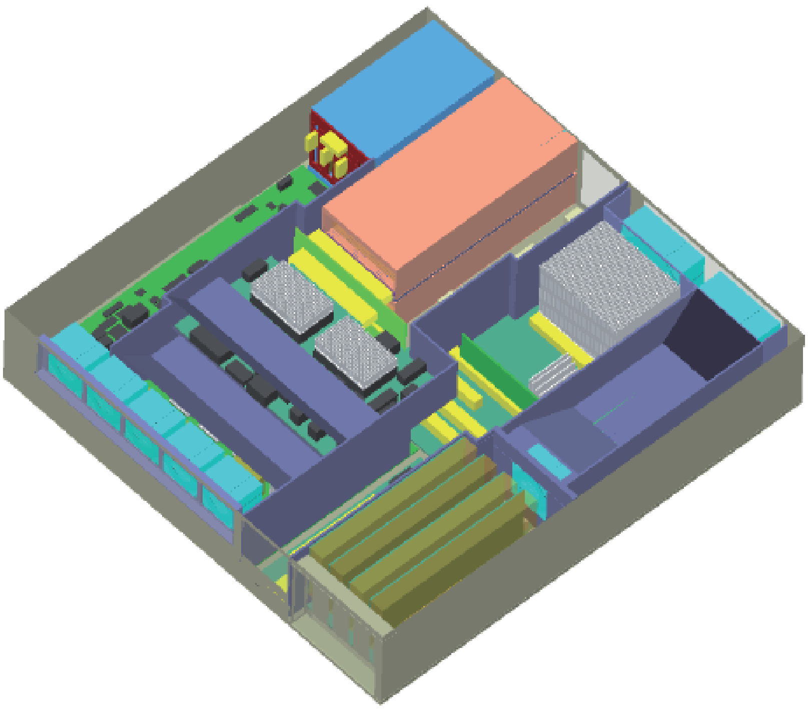
- Two different innovative concepts were proposed for VTM channel cooling
- One is a generic solution with innovative optimized individual heat sinks for each VTM within a narrow flow channel. These new heat sinks were fully custom made.
- The other is a novel concept in which we achieved a thermal solution with the available flow rate within a narrow flow channel. This is achieved fully wit conduction cooling and partly through convection cooling
- Optimal pressure drop is achieved to maximize the flow rate through the channel

System Pressure Drop Optimization

- From the start of the thermal solution, emphasis has been on the pressure drop for each and every module across the system
- Pressure drop optimization helped to reduce the acoustic related problems with fully utilizing the available flow rate across the system

Thermal Management of Rack Mount Server

A typical rack mount server consists of a power supply unit, hard disk, IO board, motherboard, network switching board, and a power distribution board. It contains 1U, 2U, 3U, and 4U rack.



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Thermal Challenges

- High ambient temperature
- Cooling HDDs
- Fan locations were fixed, most of the flow is taking the path of least resistance
- Providing a solution at high altitude conditions
- Meeting the strict compliances and standards of the product

Smart Cooling Solutions

- Flow deflectors/ducts were used to utilize the available flow across the unit
- Four dedicated flow channel were designed to control the flow behavior inside the system.
  - HDD air flow channel
    - HDDs were cooled with a flow duct, which will direct the flow from the fan to HDD without any preheat in the air
  - Network switch board and PDB flow channel
    - Custom made heat sinks were designed to cool the components on these two boards
  - CPU flow channel
    - Processor was cooled with a custom made heat sink with a heat pipe and hear sink advanced cooling option
  - IO Board flow channel

Conclusion

As servers are very important in data centers, thermal management of servers in data centers and green data centers was also highlighted with descriptions of the innovative cooling technologies which have evolved in the industry. Present thermal challenges faced by servers and the innovative solutions which emerged from the industry were discussed.

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