Simulation analysis and system testing of multi-core processor 16-channel high-density computer software made in China

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Abstract

Godson 3A processor is China's first quad-core CPU with completely independent intellectual property rights, and the outstanding performance of Godson 3A makes it have broad prospect of application in products including high-performance computers, high-performance pcs, servers, low-energy-consumption data center, high-throughput computing application, high-end embedded applications, and digital signal processing, etc. In order to study the reliability of high-density computer design and the balance between functions and performance, high-density computer with Godson 3A processor as the core design is selected in this paper to make simulation analysis of its design, and emulation software is used for printed emulation simulation, mainly testing its heat dissipation and system performance, and comparing with high-density computers of other types. It has been verified through system testing that high-density computers based on Godson 3A quad-core processor and designed with balance design method are superior in energy consumption, heat dissipation and space.

Keywords: multi-core processor made in China, high-density computer, simulation

1 Godson 3A multi-core processor made in China

Godson 3A processor is developed independently by China, and four GS464 high-performance processor cores of 64-bit four-issue superscalar of 9 flow main frequency 1GHz are integrated within the chip, and compared with the central processors designed by Intel and AMD, they have the advantages of low energy consumption, safe and controllable [1, 2].

Grudin has proposed the concept "cooperative work supported by computer", and Stanford University's PACT and other projects have achieved some results. Currently, there has already been the cooperative design about electronic device's heat dissipation and electromagnetic compatibility, but for high-density computers, the relationships between application demands, physical techniques and designing targets are constantly changing, involving computation theory, system structures, physical techniques, and many other fields [3,4], and many aspects like performance, energy consumption and size are needed to be involved. So how to carry out balance optimization design still needs to be studied.

Some auxiliary design software tries to provide a collaborative environment including thermal analysis and structural design, but the designers' balance design require the corresponding auxiliary tools to have effective methods with more fundamental meaning.

2 Balance design of high-density computer

Reliability, function and performance are the three main goals to be considered and involved in design, because in the implementation on common main board structure and case structure, the three can supplement each other and restrict each other. Only by considering all these aspects comprehensively in the entire design process can overall optimization be realized, instead of caring for this and losing that. A comprehensive design like this is called balance [5-7]. The starting points to consider these goals comprehensively in design process are called balance points.

Generally, the target set is set as $Objects = \{O_1, ..., O_n\}$, links of design are the sequence $Steps =< S_1, ..., S_m >$, then the balance design on the link $S_i (i = 1, ..., m)$ is expressed as $Tr(S_i) = Trade-off\,(Objects, S_i, C_i)$, C_i is the design status given at present, $C_i = Tr(S_{i-1})$, and the final result of design is $Tr(S_m)$.

If function, performance, heat dissipation, structure and other designs are carried out in serial, and design space is narrowed gradually, conventional low-density computers may satisfy the basic requirements, but due to the lack of collaborative time sequence in this design process, it may be impossible to form multi-goal comprehensively optimum balance design for the complex system of high-density computer [8-10]. This is because the design plan with relatively more functions and relatively high performance would bring relatively higher requirement for space and relatively larger energy consumption as well as heat dissipation pressure. If they can be considered after the design of function and performance, it may lead to relatively smaller function and performance gains after paying relatively larger heat dissipation and structural design.

An important indicator affecting the reliability of computers is the operating temperature. Improved function and performance make the amount of chips and energy rate increase constantly, leading to the rapid increase of main board's energy consumption and heating rate, thus increasing the probability of failure of electronic devices. Even if too high operating temperature does not cause the failure, some performance may be lost because many components cannot work properly with high temperature. Reliability is associated with nearly every component of the system, and due to limited space, the discussion of reliability in this paper is only focused on the part of thermal design.

3 Simulation analysis of high-density computers' structure

3.1 COMPUTERS' STRUCTURE

In building a supercomputer, modular structure is needed to design the computation nodes. In terms of a single computation node of particular performance targets, it is a design problem as whether high-density design or the loose design is used physically [11].

From the functional perspective, low-density design, like the Tower Server, allow more use of commercially available devices with the design space needed to realize more functions, and there are more types of design to be chosen, which is beneficial to reduce the difficulty of implementation.

From the perspective of performance, for the system and the bus, due to the reason of power and signal to noise ratio, its link has the limitation of the maximum line length, and meanwhile, the delay of line's transmission increases with the increase of line length, if high-density design is used, it is beneficial to maintain the integrity of bus signals and shorten the transmission delay.

From the perspective of heat dissipation and structure, high-density design like the blade nodes can be closely arranged in physical space, which saves time, and easy to manage and for physical extension. However, the resulting high density has increased the difficulty of heat design, and meanwhile space constraints increases the difficulties in the realization of multi-function.

Balanced from the above aspects, the design of Godson 3A high-density computer is rack type and can be combined with the advantages of tower type and blade server.

3.2 PRINTED CIRCUIT BOARD LAYOUT

In terms of function, feasibility and convenience of wiring are considered; in terms of performance, the impact on the design of system's structure is considered to obtain optimum total routing delay; and in terms of reliability, completeness of signals and uniformity of printed boards' density are considered.

In the process of concept design and simulation design, system design team need to change between the function module schematic diagrams, physical layout model and thermal analysis results of the circuit board in balance design. Changes made in any diagram should be timely reflected on other diagrams so as to make the whole design team "keep in pace" and its design improvement in various aspects can be timely reflected to the entire development process. Since problems in function, electrical performance, mechanical structure and heat dissipation can be solved before the detailed design, optimization efficiency of the design has been improved.

On the basis that the type and scale of processor interconnect network to be designed, type of processor, and type of enclosure are basically determined, a few alternative main board layout schemes can be raised from the perspectives of heat dissipation and structure design.

As shown in Figure 1, the layout A can be divided into three parts: main board, fan and power supply. The main board is two symmetrical boards both at the left end and at the right end, and they are connected indirectly to each other by 4 plugins. Two sets of power supply are located at the right side and the left side of the main board. The fan is located at the front end of the main board, and I/O interfaces like InfiniBand are at the back end of the main board. In order to improve the yielding rate of printed circuit board, they are designed after divided into two plates: the right one and the left one, and high-speed connector is adopted for the interconnection between boards. Each board includes 8 pieces of CPU, and is divided into the upper group and the lower group with each group connected by 4 pieces of CPUs, forming a direction as "one".

As shown in Figure 2, the main difference between layout B and layout A lies in: the main board is one upper printed circuit board and one lower circuit board symmetric to each other; 16 pieces of CPU are divided into 8 rows with two pieces per row, forming the shape of "Zhi" with total 3 columns.

Advantages of layout A lie: regular layout, smooth air and heat dissipation way. Clear lines with few crosses and without cross between the hypertransport (HT) connection and processor and memory lines. And there is only cross between HT0 and HT1 (used for the interconnection between cc-NUMA structure) used for the internal interconnection between cc-NUMA structure.

The drawbacks are: the processors are lined vertically and transversely with the longitudinal ones longer, increasing the complexity of wiring and PCB processing. So it can be considered that the right and left boards in this scheme can be changed into the upper ones and lower ones. There is a longer HT bus in the connection between 4 CPUs within each cc-NUMA, leading different CPU has different delay rate of access memory and local memory, which may influence the performance. The No.0 cc-NUMA CPUs on each printed circuit board are relatively far froom each other, so it is not easy to realize the two public modules of cc-NUMA.

Advantages of layout B is: 3 columns of CPU and main board's heat flux density has been decreased.

The advantages and disadvantages of two layouts are integrated as shown in Table 1.

The main board is segmented horizontally with moderate area, which is convenient for making boards. HTOs are connected evenly and the four pieces of processors of each cc-NUMA are distributed symmetrically, which is beneficial for the performance. No.0 processor of each cc-NUMA has relatively large space around it, facilitating for arranging other devices. On the same main board, No.0 CPUs of two cc-NUMAs are relatively close to each other, which makes it easy to realize the public modules of two cc-NUMAs.

Its drawbacks are: there are many crosses between the processor, the memory connection line and HT1 connection line, and they need to be allocated to the multilayer printed circuit board. Besides, the average length of HT1 connection line is longer than layout A.

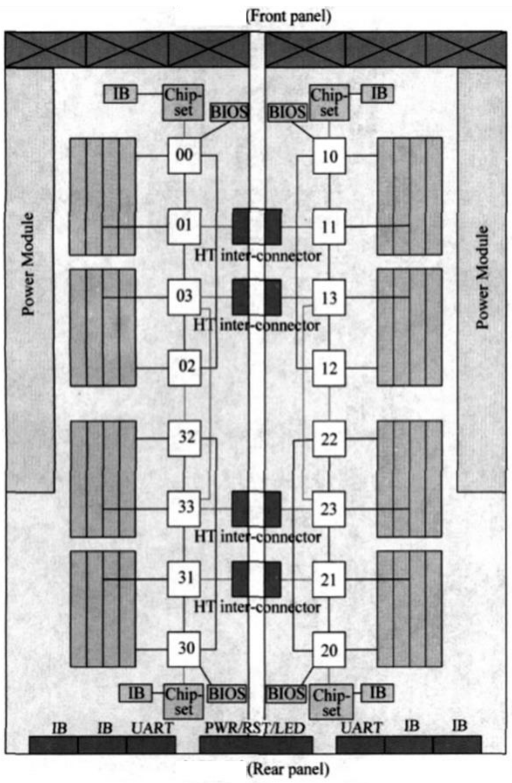

FIGURE 1 Layout A

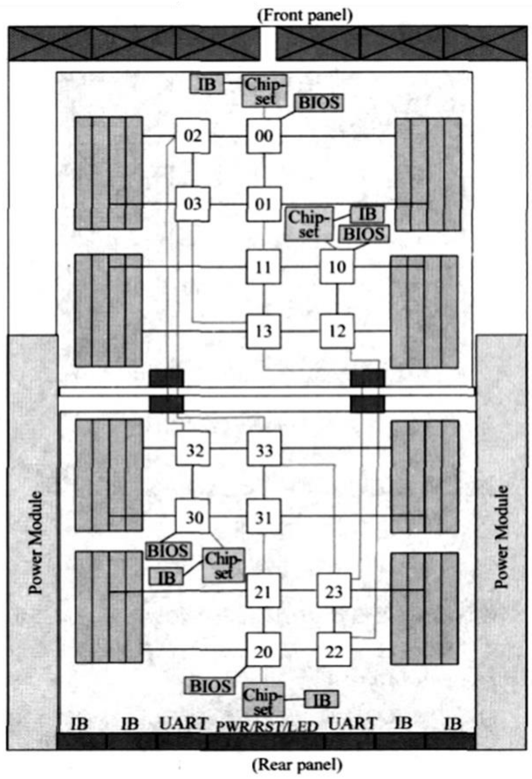

FIGURE 2 Layout B

TABLE 1 the micro-system structure parameters of SpMT WaveCache

	Layout A	**Layout B**
Heat Dissipation	More CPUs with single wind path and cooling effect is obvious	Heat dissipation is a little better than layout A
cc-NUMA Internal Symmetry	cc-NUMA Internal Asymmetry	cc-NUMA internal symmetry
Processing of PCB	PCB is horizontally narrow and vertically longer with complex processing	Without problems in layout A
Layout	Relatively neat with clear lines	Neat degree is slightly worse than layout A
Lines	Less line-to-line cross	Several crosses between processor and memory connection and HT

3.3 SELECTION OF CHIP TYPES

Chip is the functional implementer and also a heating source. On the basis of meeting the function, the performance, energy consumption and size of chips should also be considered. For example, communication chips, can select the performance difference controlling the different amount of chips on the premise of providing network connectivity. Meanwhile, two chips with different energy consumption and volume indexes have the similar performance and different features.

The key balance point of function, performance and heat dissipation balance design is generally the selected type of processor, communication chips, power conversion chip and chip group, etc.

4 System test and results

Good balance design embodies the multi-function, high performance and high reliability expected to be achieved, and has good stability.

16-way 1U Rack high-density computer occupies 0.46m2, the peak performance value is 256GFlops, peek energy consumption is 226W/U, and computation/energy consumption rate is about 0.853GPlops/W.

Measure the energy consumption and temperature of sample Linpack mechanism on a large scale, and the unit CPU energy consumption and temperature measurement range are no higher than 10.2W and 32°C. Heat dissipation simulation effects of thermal design of the whole mechanism of different energy consumption are shown in Table 2.

TABLE 2 Heat dissipation simulation effects of thermal design of different CPU energy consumption

Energy Consumption of Unit CPU /W	Highest Temperature/(°C)	Lowest Temperature/(°C)	Average Value/(°C)
20	**54.98**	**42.12**	**42.94**
30	**64.50**	**55.53**	**62.64**
40	79.81	63.90	72.29
50	92.11	72.33	79.80

On the market, computation nodes are mainly two-way, and there are few four-way nodes or more-than-four-way nodes. As shown in Table 3, compared with IBM and some other mainstream high-performance computation nodes, it has the characteristics of relatively high density and occupying small area.

This shows that the whole design realizes complex functions, and meanwhile reflects the characteristics of low energy consumption and high energy efficiency. Structure and thermal design are a kind of efficient solution that can adapt to higher thermal stresses.

The energy consumption of Godson 3B 8-core CPU is estimated to be less than 25W, while the encapsulation is the same as Godson 3A CPU, so from the perspective of CPU upgrade, the current thermal design basically keeps unchanged, that is, has good scalability.

TABLE 3 Comparison of relevant computers

Objects to be Compared	Density, performance, energy consumption characteristics
High-density Computer in this paper	Support 16 4-core 1.0GHz Godson 3A processor, occupies 1U with energy rate at about 226W.
IBM BladeCenter ® JS20 Blade Server	Support two 2.2GHz IBM PowerPC970 processors. Peak performance is about 17.6GFlops, occupies about 1/2U with energy rate at about 395W.
IBM BladeCenter ® JS22 Express Blade Server	Support four 2-core 4.00GHz processors, occupies about 1/2U with energy rate at about 350W.
TYAN GT62B8230-LE and rack server	Support two AMD 2.1GHz 12-core Opteron6100 processors, occupies 1U with energy rate at about 350W and peak performance at about 201.6GFlops.

5 Conclusion

Godson 3A processor is China's first quad-core CPU with completely independent intellectual property rights, and the outstanding performance of Godson 3A makes it have broad prospect of application in products including high-performance computers, high-performance pcs, servers, low-energy-consumption data center, high-throughput computing application, high-end embedded applications, and digital signal processing, etc.

Balance design method is adopted in this paper to analyze the design process combined with the 16 way high-density computer research based on Godson 3A processor, based on which, the machine structure of high-density computer is analyzed and simulation software is used to make printed circuit boards of different layouts and compared them. Finally, by testing the energy consumption and heat dissipation of sample machine by using large-scale Linpack, and comparing with computers of the same type, the design of the whole machine not only realizes complex functions, but also has excellent characteristics of low energy consumption and high efficiency at the same time.

Make multi-goal design of high-density computation nodes of supercomputer's core components. The reliability, functionality and performance trade-off analysis in the process of the design have provided ideas and experiences.

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