Power Supply, Cooling and Mechanical Technologies for Green IT

● Yoshinori Uzuka ● Kazuhiko Itakura ● Nobuyoshi Yamaoka
● Tomoyoshi Kitamura

There is an emerging trend for green IT on servers. This trend includes the enhanced Top Runner Program in Japan, new requirements of EuP Lot 3 in the EU, and the ENERGY STAR program for computer servers in the US. These have focused customers' attention on reducing environmental load when using servers. Fujitsu has been working to develop servers that have a lower environmental load. It is doing this by introducing green IT technologies to reduce power consumption, save resources and improve the recycling rate. This paper describes specific examples of Fujitsu's efforts in the areas of power supply, cooling and mechanical technologies for green IT on servers.

1. Introduction

There is an emerging trend for companies to reduce their total cost of ownership (TCO). Substantial improvements have been observed in various regulations and guidelines for promoting energy conservation. To address these trends, Fujitsu is emphasizing the development of green IT technologies to reduce energy consumption.

This paper describes specific examples of Fujitsu's efforts in the areas of power supply, cooling and mechanical technologies for green IT.

2. Power supply technologies

Currently, the power consumption (power conversion loss) of a server's power supply occupies about 30% of the power it uses. In response to increasing market demands for green IT, there has been a drastic improvement in efficiency. Further, there are some other initiatives to promote high efficacy power. These include an increased awareness of third-party accreditation systems for power efficiency (e.g. 80 PLUS) and the establishment of rules on efficient power conversion in power supply units in the US ENERGY STAR Program (Server Version) that came into effect in May 2009.

Technologies for high-efficiency power supplies can be categorized as below:

1) Technologies to improve the characteristics of power devices
2) Technologies to improve power conversion circuits

The Fujitsu Group is conducting original investigations and research, aiming to introduce GaN High Electron Mobility Transistors (GaN-HEMTs) in power devices, and to optimize the soft-switching control method for GaN-HEMTs.

In addition to the technologies used inside servers, Fujitsu is also developing technologies to improve the power supply efficiency of a data center as a whole such as Higher Voltage DC (HVdc).

We will detail these efforts in the following section.

2.1 Novel power device: Development of GaN-HEMT

We investigated the distribution of power conversion loss inside a power supply. This investigation revealed that about 40% of the loss is attributable to the switching device. Namely, improving the characteristics of the switching device is considered to be one of the essential points in realizing a high efficiency power supply. The dominant type of switching device currently used is a Metal Oxide Semiconductor Field Effect Transistor (MOS-FET). However, the trend of decreasing the on-resistance has come to its limit (the current on-resistance is 40–190 mΩ) and no significant reduction can be expected in future.

Taking advantage of its experience with GaN-HEMT development, the Fujitsu Group is committed to developing a power device that can drastically reduce on-resistance compared with the on-resistance of MOS-FET. It aims to do this by sophisticating GaN-HEMT technology and developing an innovative power device. Aiming to increase the conduction electron density, a novel crystal structure and unique gate configuration were adopted to handle high-level current. Further, devices with switching specifications that meant they could easily replace the conventional MOS-FET were achieved by improving insulators and the like. Our future target is to have the highest efficiency in the industry by integrating GaN-HEMTs in power supplies for Fujitsu's servers.

2.2 Saving of stand-by power

Another important issue to tackle in improving the power efficiency of servers is to reduce the consumption of stand-by power. Generally, the power supply of a server consists of high-efficiency main power and low-efficiency stand-by power. Stand-by power is less efficient than the main power in most cases due to the inability to improve efficiency by having additional circuits because of limited space and cost. Therefore, our team commercialized a novel method to ensure stand-by power by using only high-efficiency main power to decrease power consumption in stand-by mode.

Normally, the printed circuit board of the mission critical server is equipped with a slow start circuit to prevent the in-rush current by hot-swap. Therefore, this slow start circuit is constructed so that it shall switch on and off in tandem with the switching on and off of the server. In addition, when stand-by power is necessary the power should be supplied directly upstream from the slow start circuit. Through this approach, it is possible to use only high-efficiency main power. In mission critical IA servers (the PRIMEQUEST series), the consumption of stand-by power could be drastically reduced from 18% to 6%.

2.3 Higher Voltage DC supply system: HVdc technology

As an approach to reduce the overall power consumption of a data center as a whole, HVdc is attracting public attention.

In a conventional power supply, after receiving commercial AC power from outside, the voltage is transformed twice inside the uninterrupted power supply (UPS) unit and also twice inside the ICT unit to which the current is supplied (four times in total). With HVdc, voltage is transformed only twice, where a DC high voltage current is supplied directly to the ICT unit (**Figure 1**). By reducing the transforming steps, energy loss is reduced and energy can be conserved in the whole power distribution system. Moreover, because a higher voltage is used, it becomes possible to have fewer components such as power distribution cables.

While there are high expectations for HVdc as a new way to conserve energy, there are some challenges to overcome. Particularly, it is imperative to ensure safety to prevent an electric shock. The team is promoting technology to shut off high voltage arc current as well as a high-speed shut-off technology to secure safety when

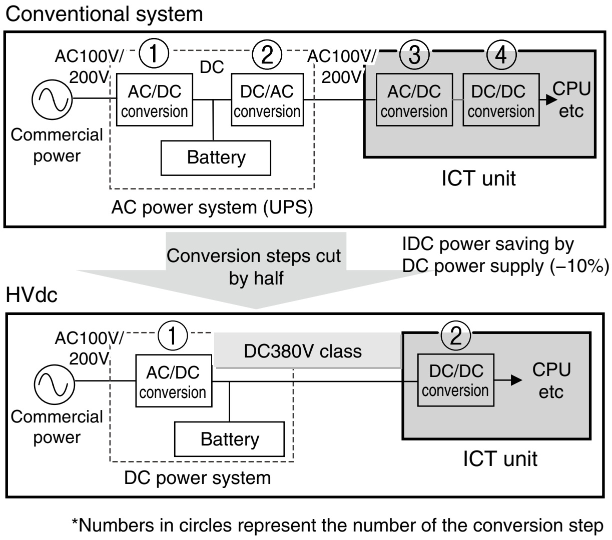


Figure 1
Comparison of distribution architecture of conventional and HVdc system.

power leaks.

3. Cooling technology

With the improved performance and downsizing of servers, power density is increasing year by year. Enhancing the cooling efficiency is one of the main emphases in green IT initiative. The points below should be considered when trying to achieve an efficient cooling design:

1) How to optimize a cooling system
2) How to efficiently eliminate heat from the generating source

To address these challenges, Fujitsu is involved in developing cooling technology and a cooling design by using various types of simulation technologies. Further, the team is making efforts to develop technologies for high-efficiency cooling components. These efforts are explained in detail in the following section based on Fujitsu's server cooling design.

3.1 Thermo-fluid dynamics simulation technology

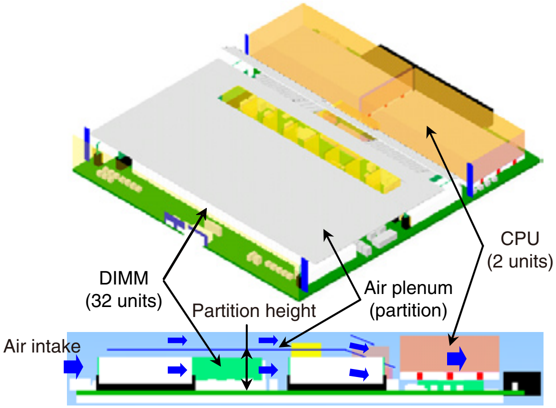
Running a thermo-fluid dynamics simulation is the key to optimizing a cooling system. Various patterns are available in general for cooling air channels in server packaging architectures to support optional configurations, such as redundant power supply, memory, CPU and I/O devices. In any architecture, it is essential to run highly accurate thermo-fluid dynamics simulations from the early design phase to ensure optimal cooling air. Fujitsu has secured computing power dedicated to thermo-fluid dynamics simulations that allows fast and accurate package simulations for a whole unit to help produce optimized cooling designs for servers.

3.2 Thermo-fluid dynamics simulation for next-generation IA server

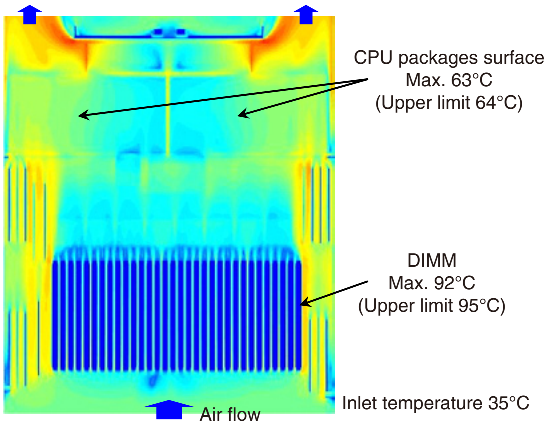
This equipment adopts air cooling technology in its system board unit (W 420 mm × D 478 mm × H 68 mm) illustrated in **Figure 2 (a)**. The air flows from the dual inline memory module (DIMM) to the CPU. These components generate a lot of heat (total heat generation of approximately 500 W when combining the heat from the DIMM and CPU). Special consideration should be given to the air flow and configuration of the heat generating components to suppress any elevation in the CPU's temperature in the downstream side. Fujitsu designed partition architecture to enable the optimal distribution of air flow to the CPU and DIMM based on the results of running simulations. Further, it was able to successfully keep the CPU temperature below the allowable limit under conditions of limited air flow. The analysis result is indicated in **Figure 2 (b)**.

Fujitsu has contributed to promoting green IT with the optimized cooling method mentioned above.

Further, to address an issue related to the decreased air flow that occurs when the fan fails and the air flow makes a detour, a simulation was used to develop an open and closing shutter mechanism (**Figure 3**). Because the shutter mechanism closes automatically when there is fan trouble, it is possible to maintain the cooling



(a) Simulation model overview (system board)



(b) Distributions of air flow rate and key component temperature

Figure 2
Overview of simulation model, temperature of system board and distribution of airflow.

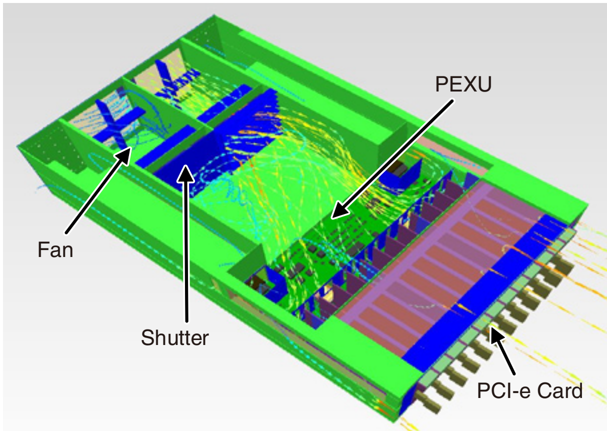


Figure 3
Preventing airflow from turning round with shutter to open and close.

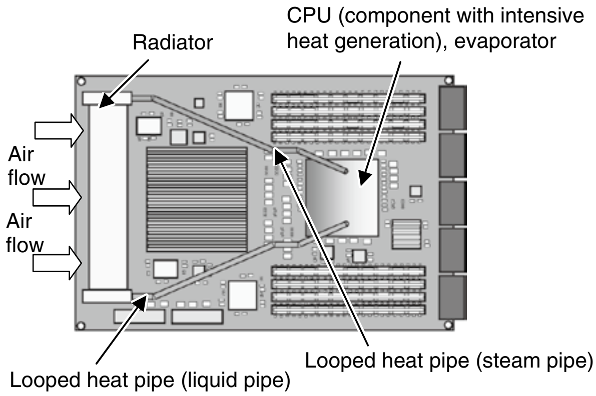


Figure 4
Unit with looped heat pipe.

performance without increasing the fan capacity.

3.3 Looped heat pipe

Technology to transfer heat is very useful if, owing to configuration restrictions or such like, it is difficult to supply optimal cooling air to areas such as the CPU that generate intense heat. In this case, the heat is transferred to the area inside the unit where more effective cooling is possible. In the conventional approach, a heat pipe is used widely to achieve this objective. However, due to the high power density of servers, existing heat pipes cannot cover a sufficient distance or transfer enough calories.

Therefore, we are developing a looped heat pipe, a novel technology that enables efficient heat transfer on a semi-permanent basis without consuming electric power (**Figure 4**). The looped heat pipe is a two-phase fluid heat transfer device that transfers heat from a heat source to a heat radiation section by utilizing the capillary phenomenon. This mechanism enables greater heat transfer over a longer distance compared with the conventional heat pipes. It has a number of advantages including its simple mechanism, lightweight and ability to work without electric power. We plan to make further enhancements to the reliability and performance of this looped heat pipe and reduce its cost by for example improving the wicks.

3.4 Simulation for quieter cooling fans

Due to the high power density of servers, there are increasing needs to develop a compact cooling fan that has both a high heat radiation performance and low noise characteristics. A successful case of minimizing fan noise by flow dynamic simulation in a double inversion (counter-rotating) fan of 40 mm square integrated in a 1U server unit is described below.

Figure 5 indicates a schematic chart of the double inversion fan and the result of a flow dynamic simulation. The dynamic wings that rotate in mutually different directions are arranged serially and operated at approximately 10 000 rpm. A static wing was arranged between the front dynamic wing and rear dynamic wing. This allows part of the rotating flow generated by the front dynamic wing to be restored as a static pressure. The pressure distribution of the wing's cross section is indicated in **Figure 6**. Before the improvement [Figure 6 (a)], disturbed flow can be observed with separation in the rear wing. Meanwhile, the separation is eliminated after improving the wing's geometry, realizing an efficient flow [Figure 6 (b)]. The wing geometry was optimized by evaluating the fan's aerodynamic performance and repeatedly revising the wing geometry based on simulations. As a result, a noise reduction of approximately 6.0 dB (A) was possible compared with the wing in the initial design.

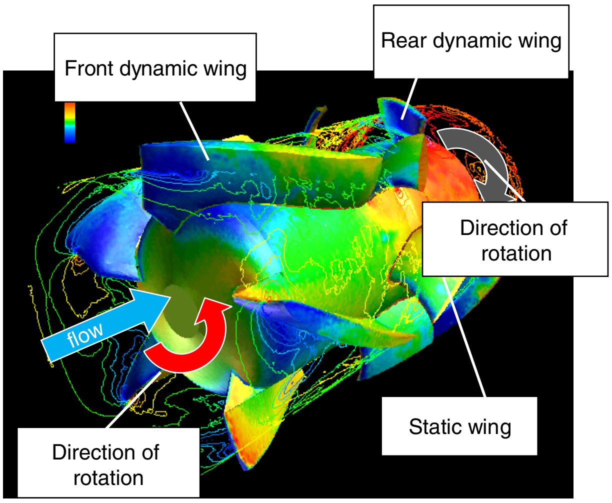


Figure 5
Schematic chart of double inversion fan and distribution of surface pressure.

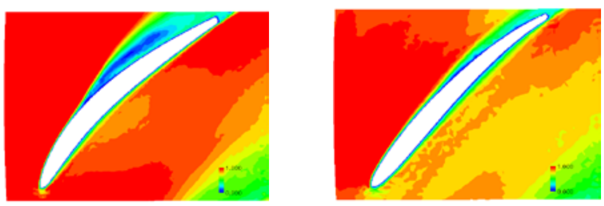
4. Mechanical technology

In this chapter, we will describe our approaches to realizing technology for green IT in terms of server chassis based on mechanical design using simulation technology.

It is essential to consider the whole life cycle of a product when introducing green IT to server chassis. Particularly, the following aspects should be considered:

1) Reducing the amount of materials and energy consumed in producing the equipment
2) Reducing the environmental load when transporting the equipment (reducing the weight)
3) Reducing the environmental load while the equipment is in service (reducing the installation space)
4) Increasing the recycling rate at disposal

Recent improvements in simulation technology have made it possible to run various types of simulation for the equipment as a whole. We are engaged in optimizing the materials to be used by actively running simulations in the design phase.



(a) Before improvement (b) After improvement

Figure 6
Improvement of wing.

4.1 Vibration simulation

This section refers to a vibration simulation for the chassis of a floor stand server.

To evaluate the anti-seismic performance of the equipment, Fujitsu is running a vibration test by simulating vibrations equivalent to 1000 Gal or a Japan Meteorological Agency seismic intensity scale of 6 Upper. We carried out a vibration simulation of the chassis as a whole in the design phase. The simulation result is indicated in **Figure 7**. A dynamic vibration simulation was conducted with approximately 5000 components and about 300 000 meshes to compute the resonance frequency and stress distribution. In this case, we can see that the stress concentrates on the corner of the lower shelf and the support root sections. Considering the simulation result and physical characteristics of the chassis materials, we reviewed the thickness of the metal plate and reinforcement structure. These review results were then reflected in the design. Green IT is realized by optimizing and reducing the weight of the materials used for the chassis.

Further, by actively running simulations, the number of prototypes made and their assessments can be reduced.

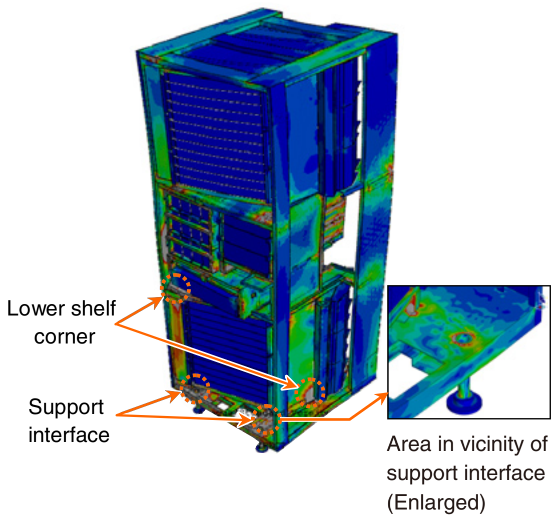


Figure 7
Stress distribution in floor stand frame.

4.2 Package drop simulation

This section refers to a drop shock simulation conducted on the package of a rack mount server.

The package drop evaluation is carried out in conformance to JIS Z 0202. When rack mount servers are shipped, they are protected by some cushioning material in a corrugated cardboard box. The package drop test can confirm that the package materials protect the product from any shock when they are dropped. However, it is difficult to judge whether or not the package materials offer optimal protection for the product. Therefore, simulations are used to optimize the package materials.

To improve the accuracy of package drop simulations, it is essential to correctly define the physical characteristics of the foam material and cardboard and then carry out appropriate modeling. Data about the foam material and cardboard expressed as a stress-strain diagram were obtained by measuring actual material test pieces. A simulation was then conducted by modeling the cardboard as anisotropic material.

Figure 8 indicates an example of a simulation on when a package is dropped. The shock of the drop crushes the foam material and deformation is observed on part of the product. In this case, any damage to the product was successfully avoided by changing the cushioning material.

This type of simulation enables the equipment packaging to be optimized, which also contributes to green IT by avoiding any excessive use of packaging materials.

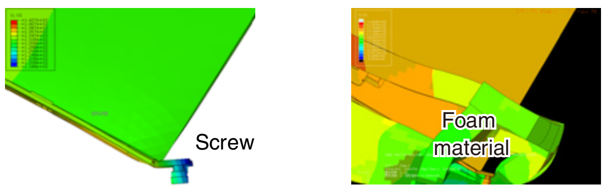


Figure 8
Deformation of UNIX server parts when dropped.

5. Conclusion

This paper described specific examples of Fujitsu's efforts in the areas of power supply, cooling and mechanical technologies for green IT on servers.

By developing and commercializing these technologies, the Fujitsu Group supplies servers that meet customers' request for reduced TCO and conform to various regulatory requirements and guidelines related to energy conservation. The Fujitsu Group will help to further reduce environmental load in the whole of society by continuously promoting green IT in the server sector.

Yoshinori Uzuka
Fujitsu Ltd.
Mr. Uzuka is engaged in the development of cooling technology and design for servers.

Nobuyoshi Yamaoka
Fujitsu Advanced Technologies Ltd.
Mr. Yamaoka is engaged in the development of structural and thermal simulation technology supporting device development and promotion of product design applications.

Kazuhiko Itakura
Fujitsu Ltd.
Mr. Itakura is engaged in the development of power supply technology for servers.

Tomoyoshi Kitamura
Fujitsu Advanced Technologies Ltd.
Mr. Kitamura is engaged in the development of unit power supplies for ICT equipment and the development of common technology for power supplies.