Research on Thermal Design of Server Structure Based on LRM Mode

Lu Ju, Shiying Men*, Huan Liu, Yaozhong Chen and Jinfeng Qiao
Norinco Group North Information Control Institute Group Co., Ltd.

*Corresponding author email: 498809990@qq.com

Abstract. Aiming at the module heat dissipation problem of a military domestic LRM mode server, a thermal design which can improve the module cooling efficiency and equipment integration is proposed. The design can realize the easy heat dissipation and high integration of on-board equipment. Through the design of fan device, module cooling and heat pipe, the heat dissipation efficiency of the server was improved, and the heat dissipation capacity of the module was improved. Thus the integration degree of on-board equipment was improved. The designed server was thermally analyzed and tested at +65 ℃. By comparing the experimental results with the thermal analysis results, the conclusion proved the correctness and feasibility of the research content in this paper.

Keywords: Server; LRM; Thermal design analysis; On-board equipment.

1. Introduction
There are many factors affecting the reliability of ground military electronic products, one of which is the heat dissipation performance. Due to the high reliability requirements of equipment, harsh service conditions and harsh environment, these conditions put forward strict requirements for thermal design. With the development of science and technology and the demand of information war, the miniaturization and integration of electronic products have increased, which has brought great difficulties to the heat dissipation design. The quality of heat dissipation structure affects the product performance. On the other hand, in order to comply with the localization situation of weapons and equipment, domestic components are widely used in electronic products, which leads to the geometric multiple growth of the working heat of electronic products in unit volume relative to imported components, and also puts forward higher requirements for the heat dissipation structure. How to solve the problem of heat dissipation of electronic devices in a limited space has become a difficult problem restricting the development of electronic technology. In order to ensure the rapid cooling of products in high temperature environment and high-frequency operation of electronic devices, and ensure the stable and reliable operation of electronic products, it is very necessary to study its heat dissipation technology. Common thermal control methods include natural heat dissipation, forced air cooling, heat pipe heat dissipation, immersion cooling and cold plate cooling. Natural heat dissipation uses the natural gap between electronic components and the natural conduction, convection and radiation of the chassis shell to achieve the purpose of equipment cooling. Forced air cooling is to use the fan to blow or extract air to improve the air flow speed inside the equipment to achieve the purpose of heat dissipation. Immersion cooling is a heat dissipation method using fluid medium with high cooling efficiency for heat exchange, which belongs to the category of direct liquid cooling. Cold plate cooling is an indirect cooling method. Heat is transferred to the coolant through the heat-conducting material, heat-conducting insulating
adhesive film or heat-conducting adhesive and cold plate. The coolant absorbing heat flows through the radiator air liquid radiator or liquid fuel radiator and is dispersed into the air or dissipated into the fuel.

2. Basic Principle of Heat Pipe Heat Dissipation

Heat pipe is an efficient heat transfer element which uses capillary action to maintain the working liquid circulation to achieve the purpose of heat dissipation. A typical heat pipe is composed of shell, core and working medium. The working principle of heat pipe is shown in Figure 1 [6]. It is a slender, hollow metal tube with closed ends. The capillary material on the inner wall of the tube is filled with working liquid water, methanol, ammonia, diketone, freon, etc. the heating element contacts the evaporation section of the heat pipe to transfer heat to the liquid working medium through the tube wall. The working medium becomes steam after absorbing heat, the latent heat of vaporization is released in the condensation section, and these heat is transmitted to the surrounding air with the help of a larger radiator, so as to achieve the purpose of long-distance and efficient heat transmission under a very small temperature difference.

![Figure 1. Schematic diagram of working principle of heat pipe.](image)

Although the heat pipe does not need external input power, it has many advantages, such as simple structure, low noise, reversible heat transfer direction and excellent thermal response. However, the manufacturing process of heat pipe is complex and the cost is high. Air cooling heat dissipation equipment is required to cooperate with heat dissipation, and it is limited by viscosity limit, sound velocity limit, carrying limit, boiling limit, capillary limit and so on. At present, it is only widely used in notebook and desktop computer heat dissipation, nuclear power supply temperature control, metallurgy, light textile and other civil industrial fields. In addition, because its heat transfer principle is based on the principle of gravity assistance and capillary force, it is very sensitive to gravity and difficult to start at low temperature. In military fields such as aerospace, many factors such as ambient temperature range, acceleration and installation inclination limit its wide use, but the research in this field is still in-depth.

3. The Working Principle of LRM Mode Server

A military localized LRM mode server is composed of power supply, storage, data exchange, data processing, video and audio and other functional units, as shown in Figure 2.

![Figure 2. Server diagram.](image)
The server is mainly composed of damping device, module fixing bracket, LRM module, fan device, locking structure, etc.

(1) Damping device
The damping device mainly absorbs most of the energy generated by environmental vibration through the damping device to reduce the resonance amplitude and vibration acceleration in the mechanical structure of the server, so as to reduce the damage caused by vibration to the equipment.

(2) Module fixed rack
The module fixed frame is installed on the top of the damping device in an L-shape and is composed of a bottom plate and a back plate, as shown in Figure 2B. The inner side of the upper support of the backplane is used to support the installation of each LRM module. The inner side of the backplane integrates the interface of the LRM module to realize the functions of high-speed communication bus and expansion interface after the calculation and processing module. The support base plate and the back plate are connected through stiffeners on both sides to ensure that the server meets the stiffness and strength requirements.

(3) LRM module unit
LRM module unit adopts standard 6U size independent sealing reinforcement design and is fixed on the module fixing support through locking structure. This type of module unit has the advantages of convenient installation, reliable locking, easy plugging and maintenance.

4. LRM Mode Server Thermal Design
Based on the analysis in Section 3, it can be seen that each functional unit has small volume, high integration and complex working environment. In addition, all internal core chips are made of domestic products such as Feiteng, jingjiawei and Ziguang Guoxin. The chip power consumption is generally higher than that of imported ones, and the integration of structure and function modularization will inevitably produce a high power density on the packaging of electronic modules at all levels. If there is no new heat management method, the component junction temperature will increase significantly, resulting in a serious decline in reliability, even lead to the failure of component function, so that the whole system cannot work normally, which puts forward higher requirements for heat dissipation performance.

The data exchange, data processing, storage and other units of domestic LRM mode server are the main heating components, which will generate large heat during operation, which shall be dissipated, and the power consumption shall be calculated according to 85W.

4.1. Thermal Design of External Structure
In addition to supporting, the supports on both sides of the module fixed rack can also be used as the air flow guiding structure of the lower fan device to guide the air flow under the working state of the fan to the module installation area. A 5mm space shall be reserved between two adjacent module units on the module fixing support to ensure the heat exchange space outside the module unit. A fan device is set directly below the module unit, and the system fan disk is arranged, as shown in Figure 3. The system fan panel adopts a 3 + 6 layout and is installed under the module according to the reverse air suction mode. This arrangement not only enhances the heat dissipation effect, but also makes the structure more compact. The fan device supports hot plug. On the left side of the fan panel are three jxh5015b12 fans with a speed of 6000 rpm and an air volume of 17.49 CFM. 2 on the right × 3 layout, 6 jxh6015b12 fans in total, rotating speed 5400 rpm, air volume 21.7 CFM. After the fan is started, the heat from the inside of the module to the shell can be dissipated quickly and evenly through the cooling slot.
4.2. Thermal Design of Internal Structure

The shell of LRM structure is the heat dissipation part of the whole module unit. Each module unit is composed of shell and cover plate, which are made of aluminum alloy. The design of heat dissipation channel is the key to the realization of LRM air cooling function. There is a heat dissipation groove structure outside the shell and cover plate. The design of heat dissipation groove increases the heat dissipation area of the surface by more than 40%. The module shell structure is shown in Figure 4. The internal heat dissipation structure of the module is shown in Figure 5. A heat pipe is added between the chip of each service unit and the cover plate. Its good thermal conductivity can quickly transfer the heat generated inside the module to the outside of the cover plate. Heat conductive silicone grease (thermal conductivity 3W / m • K) is filled between the upper surface of the chip and the heat pipe to maintain air-free bonding between the chip and the heat pipe. The shell of the power supply module inside the module is made of aluminum alloy. Due to its small power, the temperature equalizing plate is not used. Instead, a heat conduction boss that can contact the heating device is added on the shell to directly transmit the heat emitted by the device to the shell, and then the heat is transmitted to the heat dissipation groove outside the shell through the shell, as shown in Figure 6.

Figure 3. Schematic diagram of fan panel of backplane system.

Figure 4. Module shell structure.

Figure 5. Internal heat dissipation structure of high power module.
5. Server Thermal Simulation Analysis and Experiment

5.1. Thermal Simulation Analysis

5.1.1. Geometric model establishment. The CAD model of LRM mode server is simplified and imported into Icepak module of ANSYS Workbench. The completed thermal simulation model is shown in Figure 7.

5.1.2. Setting of boundary conditions. After establishing the thermal analysis model in 5.1.1, it is also necessary to set the boundary conditions of each module in the model. In this paper, the module is placed in indoor and engineering vehicle trunk and other environments during normal operation. In order to ensure that the heat dissipation performance of the radiator can meet the requirements to the greatest extent, the external environment of the radiator must be set as a windless ordinary atmospheric environment. Therefore, during simulation analysis, the six side wall types of the cabinet need to be set as openings. In addition, you need to set the radiator type to complex type and set the material of frame and module housing to aluminum 2A12-T4. Because the server in this paper mainly relies on heat conduction and heat radiation between and air for heat dissipation, heat radiation has a great impact on heat dissipation, so it is necessary to turn on the heat radiation switch. Finally, define the heating power of the heat source and turn on the heat radiation switch.

5.1.3. Thermal simulation results. After the boundary conditions are set, the thermal analysis model needs to be meshed and the grid quality should be checked. The divided grid fully conforms to the solution standard of Icepak thermal simulation software module. After meshing, the solution parameters are set and solved. This paper will not repeat this process. The results after solution are shown in Figure 8.

Figure 6. Internal heat dissipation structure of low power module.

Figure 7. Thermal simulation model.
5.2. Experimental Test and Conclusion of Prototype Working

Place the LRM mode server in the high and low temperature box, observe its working condition at the ambient temperature of +65 °C, and determine the positions of 5 test points according to the thermal analysis results. See Table 1 for specific test data.

**Table 1.** Test point temperature when the server operates at an ambient temperature of +65 °C.

| Test point number | 1  | 2  | 3  | 4  | 5  |
|-------------------|----|----|----|----|----|
| Temperature(°C)   | 73.4 | 74.7 | 82.8 | 85.5 | 89.1 |

The simulation results show that the LRM mode server works at the ambient temperature of +65 °C, and the system fan starts to exchange the air with higher temperature in the heat sink with the air with ambient temperature, so as to achieve the purpose of external heat dissipation. Under the condition of full load operation, the fan runs at full speed, and the maximum temperature of three 85W unit modules is about +55.5 °C. When the ambient temperature rises to +65 °C, the maximum temperature of the unit module reaches +89.1 °C, which is less than the junction temperature of +100 °C of the processor, and the domestic on-board server can work normally.

5.3. Comparison between Experimental Data and Thermal Analysis

Through thermal simulation analysis, the steady-state temperature distribution of each module structure in the LRM mode server is obtained when the ambient temperature is +65 °C. Now it is compared with the actual data obtained from engineering experiments. See Table 2 for the specific data.

**Table 2.** Comparison of measured temperature data between thermal design analysis and engineering experiment.

| Number | Specific location | Thermal analysis temperature(°C) | Experimental test temperature(°C) | Error comparison(%) |
|--------|------------------|---------------------------------|----------------------------------|--------------------|
| 1      | Module 1         | 73.4                            | 75.2                             | +2.4               |
| 2      | Module 2         | 74.7                            | 72.9                             | -2.5               |
| 3      | Module 4         | 82.8                            | 85.1                             | +2.7               |
| 4      | Module 5a        | 85.5                            | 82.2                             | -4                 |
| 5      | Module 5b        | 89.1                            | 86.6                             | -2.9               |
From the comparison results, it can be seen that the error between the temperature data obtained by thermal design analysis and the actual temperature data measured by engineering experiments is controlled within 5%, and the thermal design method meets the design index requirements.

6. Conclusion

It can be seen from the above chapters that the LRM mode server adopts the combination of air cooling of the whole machine, module cooling and liquid cooling, which can improve the heat dissipation capacity by XX% on the basis of the traditional heat dissipation mode. At the ambient temperature of +65℃, when working at full load, the core stable temperature is only 86℃, which can ensure reliable and stable operation for a long time; Due to the combination of complete machine air cooling, module cooling and heat pipe, the LRM mode server frame design has better stiffness and strength, which can meet the environmental adaptability requirements of impact and vibration of military products.

References

[1] Yan Ni, Guan Zhihong, Liu Zhengwei, etc. The design and verification of the high heat dissipation structure of the air-cooled frame on board[J]. Electronic Mechanical Engineering, 2021, 37(1):28-34.

[2] He Jiang, Miao Jianyin, etc. Research status and development trend of spacecraft deep-low temperature heat pipe technology[J]. Vacuum and Cryogenics, 2018, 24(1):1-8.

[3] Wang Yulong, Ning Meng. Discussion on heat dissipation of military ruggedized computers based on TRIZ theory[J].2020,33(1):102-105/4, Zhang Rong. Application of heat pipe cold plate in conduction cooling LRM module[J]. Mechanics and Electronics, 2017, 35(6): 22-25.

[4] Chen Aihua, Zhang Yue, etc. Heat transfer performance test of gravity vertical radial heat pipe[J]. Mechanical Design and Manufacturing Engineering, 2017,46(5):59-62.

[5] Dou Zhihai, Lv Hongtao, etc. Analysis of the heat transfer performance of a miniature flat heat pipe[J]. Journal of Aeronautical Dynamics, 017,32(2):275-279.

[6] Dou Zhihai, Liu Chenxi, etc. Experimental research on the heat transfer characteristics of a flat heat pipe radiator[J]. Science Technology and Engineering, 2018,18(4):136-140.