Integrated Protection Design of an Anti-harsh Environment Reinforcement Chassis

Miao Zhang(✉), Daoqing Qu, Jiangfeng Huang, and Shangyong Liang

The Computer Department, Jiangsu Automation Research Institute, Lianyungang, China
zm86325@126.com, {qudaoqing,huangjiangfeng, liangshangyong}@jari.cn

Abstract. As the main content of structural design for electronic equipment, chassis design has become an important part to achieve technical indicators. The paper discusses design ideas of an anti-harsh environment reinforcement chassis deeply, and describes particularly thermal design, electromagnetic compatibility design, anti-vibration and anti-impact design and so on. The methods and main structure diagram are given in each part of the design in this paper. The anti-harsh environment reinforcement chassis is taken environmental tests to make sure that it has good reliability and integrated protection capabilities, which provides a reference for similar engineering design.

Keywords: Reinforcement chassis · Integrated protection
Environmental tests · Reliability

1 Introduction

Chassis plays an important role in the life and work efficiency of electronic equipment, which makes sure the safety and stabilization of electronic components [1]. As modern military electronic equipment used in high-tech products, it is not only to meet equipment function, but also to meet the environmental requirements of the equipment. A well designed electronic chassis is the basis of improving the reliability of the modern electronic equipment, which can withstand the strong vibration shock and electromagnetic interference, as well as the harsh weather conditions [2, 3]. With the rapid development of electronic information, the performance of the anti-harsh environment computer is getting higher and higher. Therefore, the existing reinforcement computer has been unable to meet the cooling requirements of multiple high-performance main modules. The paper introduces an anti-harsh environment chassis, which elaborates the chassis design, thermal design, electromagnetic compatibility design, anti-vibration and anti-impact design and so on.

W. Xu et al. (Eds.): NCCET 2017, CCIS 600, pp. 86–95, 2018.
https://doi.org/10.1007/978-981-10-7844-6_9

2 Chassis Structure Design

As shown in Fig. 1, the reinforcement chassis is with five independent air ducts that are connected to the inlet and outlet. First of all, the ducts use a rectangular corrugated board. High-performance main modules are cooled by cold plate which is fit through the thermal pad and the side wall closely. It increases the heat dissipation area of each cooling channel and shortens the heat path. Then, it strengthens the fit of the cold plate with the side wall of the air duct through wedge locking device, which improves thermal efficiency. And then the high-power fan is used to pump air, which ensures every main module to be cooled through own independent air duct. High performance electrical connectors in the rear cover of the chassis are welded to signal transfer board. And main modules are inserted into the Compact Peripheral Component Interconnect socket of the printed circuit board [4]. The signal transfer board is connected to the printed circuit board through a flexible printed circuit board, which avoids compatibility between cables.

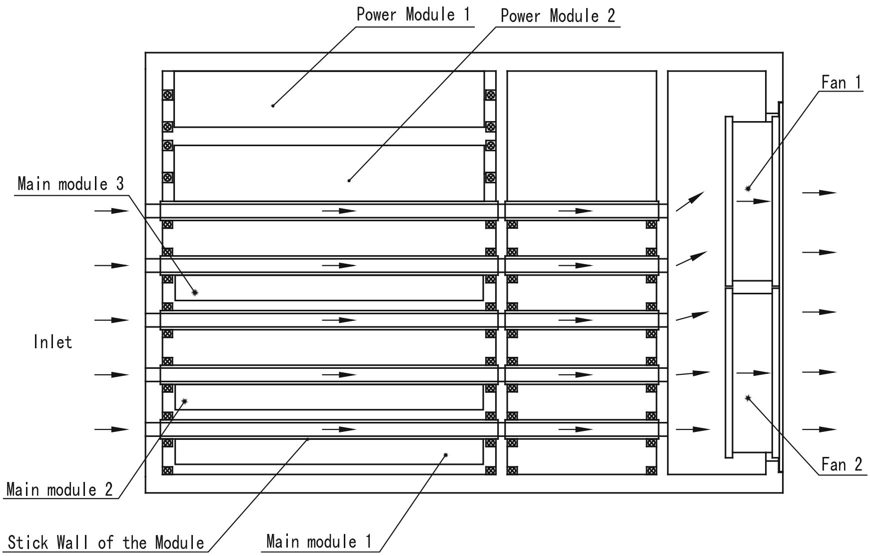

Fig. 1. The schematic diagram of multi-ducts cooling chassis

3 Thermal Design

3.1 Framework Design

In order to ensure that the reinforcement computer in a harsh environment can be stable and reliable work, it needs to takes the chassis to strengthen the fully enclosed structure. Five parallel ducts and corrugated boards are weld in the chassis through the vacuum brazing process, which can ensure that external ducts are isolated from internal modules and the printed circuit board. The technology of vacuum brazing can make the framework heat evenly and have small deformation. Furthermore, the vertical and parallelism of the board is good. The chassis framework is made of rust-proof aluminum plate because of its low density, corrosion resistance, high thermal conductivity and good electrical conductivity, which can improve the natural heat dissipation capacity of the chassis.

3.2 Cold Plate Design

The heat of the chassis is mainly from the components of the module, so it is the key to make it heat to the air. Figure 2 shows heat dissipation diagram of the traditional main module. The heat of components transfers through the thermal pad to the cold plate, and then conducts to the chassis slot board. Finally, the heat is forced to the outside of the chassis through ducts on the slab. It is designed to have a long heat conduction path and a small thermal conductivity area. The existing main module cooling schematic diagram is shown in Fig. 3. The heat generated on the printed circuit board transfers through the thermal pad to the cold plate, and then conducts to the air duct through the large cold plate, which can put the heat of the aluminum plate out of the chassis and can also scatter the concentrated heat evenly. By reducing the heat path and increasing the cooling area, the heat of the key components can be cooled effectively.

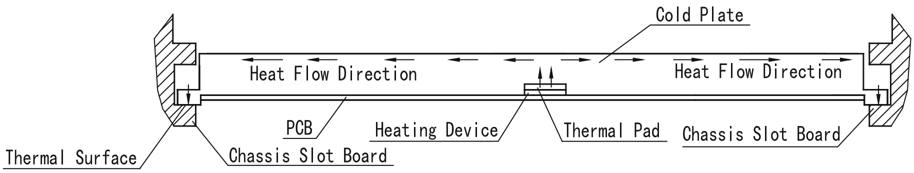

Fig. 2. The cooling schematic diagram of traditional main module

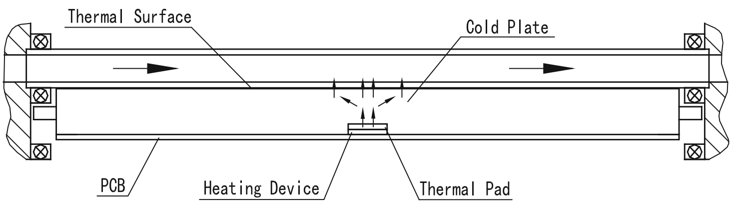

Fig. 3. The cooling schematic diagram of existing main module

In the process of electronic equipment cooling, the interface filler material is an important link in the thermal conduction path, which affects the overall thermal resistance of the whole heat conduction path directly. The thinner the interface filler material is, the smaller the thermal resistance is, which the better the thermal conductivity is. However, the thinner interface filler material has greater stress to electronic device in the assembly process, because the thinner interface filler material has the smaller compression deformation. But the stress between electronic devices and the cold plate in the assembly process is weakened mainly through the compression deformation of the interface filling material, it is necessary to balance the relationship between heat and external stress. In order to reduce the equivalent thermal resistance of the heating device to the cold plate, on the one hand, a new type of flexible thermal pad is select that the thermal conductivity is up to 15 (W/m·K), the other hand, the gap between heating devices and the cold plate is minimized as far as possible if the amount of compression and the stress of components are permitted.

3.3 Thermal Resistance Analysis

Thermal resistance is the integrated parameters to prevent the heat transfer capacity. The greater the thermal resistance is, the worse the thermal conductivity is. In a certain ambient temperature and motherboard power, the surface temperature of chips is lower in the conductive path of the small thermal resistance of. The cold plate of the main module is made up of the aluminum alloy and the heat of chips on the printed circuit board transfers to the duct shown in Fig. 3, which will encounter a variety of thermal resistance in the transmission process. The process can be analyzed in the method of electric simulation. Assumptions:

(1) Ignore heat conduction and radiation of the air gap;
(2) The thermal resistance of the thermal pad between the chip and the aluminum cold plate is equal to the one between the processor CPU and the aluminum cold plate. The size of thermal pad is 10 mm × 22 mm × 1 mm, and the thermal conductivity of pad is 15 W/(m·K).
(3) Thermal conductivity of the aluminum cold plate is 180 W/(m·K).

According to the formula $R = \delta/KA$ [5]:

$\delta_1 = 0.7 \times 10^{-3}$m, δ_1 is the thickness of the CPU thermal pad after compression;

$A_1 = 15 \times 10 \times 22 \times 10^{-6}\text{m}^2 = 3.3 \times 10^{-3}\text{m}^2$, A_1 is the cross-sectional area of the CPU thermal pad;

$$R_1 = \delta_1/KA_1 = 0.21°\text{C/W}$$

$\delta_2 = 4 \times 10^{-3}$m, δ_2 is the thickness of the aluminum plate;

$A_2 = 180 \times 135 \times 233 \times 10^{-6}\text{m}^2 = 5.66\,\text{m}^2$, A_2 is the cross-sectional area of the aluminum cold plate;

$$R_2 = \delta_2/KA_2 = 7.06 \times 10^{-4}\,°\text{C/W}$$

Where δ is the thickness of the object, A is the cross-sectional area perpendicular to the direction of heat conduction, R_1 is the thermal resistance between the chip and the aluminum cold plate, and R_2 is the thermal resistance of the aluminum cold plate.

In the adhesive cooling chassis, the total thermal resistance of the chip in the thermal conduction path is 2.3 °C/W.

The traditional thermal resistance is generally about 6 °C/W, obviously, in the anti-harsh environment reinforced chassis the method of adhesive heat dissipation based on ducts reduces significantly the main module chip thermal resistance, enhanced the main module external cooling capacity greatly, which solves the problem of high power dissipation.

3.4 Fan Selection

The heat power consumption of the reinforcement chassis is less than 300 W, according to the heat balance equation [5], the whole ventilation Q_f:

$$Q_f = \varphi / \rho C_p \Delta t \tag{1}$$

Where ρ is the density of air, kg/m^3; C_p is the specific heat of air, J/(kg·°C); φ is the total loss power, W; Δt is the temperature difference between outlet and inlet of the cooling air, °C.

The total loss power of the chassis is 300 W, the density of the air is 1.093 kg/m^3, the specific heat of the air is 1005 J/(kg·°C), the temperature of the cooling air inlet and the outlet is 10 °C, according to Formula (1), Q_f = 0.027 m^3/s = 0.027 × 35.3147 60 = 57.2 CFM. Taking into account the internal thermal resistance and loss of air, the required air volume is 103 CFM according to 1.8 times the redundancy design. According to the results, the main parameters of the selected axial fan are: voltage 24 VDC, power 5 W, air flow 100 CFM, wind pressure 0.28 in H_2O. As the chassis volume is large, and the heat should be discharged evenly, two fans are used in parallel way.

4 Electromagnetic Compatibility Design

Electromagnetic compatibility means that the equipment and the system can perform the coexistence of the respective functions together under the limited space, time and frequency resources [6]. Electromagnetic compatibility design is an important technical indicator of the system design of electronic equipment, and its purpose is to make the circuit module noninterference with each other, at the same time, the equipment within the system does not interfere with each other and can meet the requirements of electromagnetic compatibility.

4.1 Rigid and Flexible Printed Circuit Board Design

At present, the vast majority of the reinforcement chassis leads the signal line to the electrical connector by cable bundle welding, which needs to take up the larger space and is difficult to control the cable position accurately. Because of the limited chassis space and a large number of different types of cable, it will lead to electromagnetic compatibility problems interfering with each other easily. Through the technology of the flexible printed circuit board, the bottom plate is connected to the signal board to avoid electromagnetic compatibility issues caused by complex traces. As shown in

Fig. 4, the printed circuit board connectors are installed to the rigid part of the printed circuit board (signal exchange board), but do not weld, and then the electrical connectors are fixed to the chassis panel through the screws to fasten the panel and electrical connectors, and then the signal board is fixed to panel through the studs, and finally the electrical connectors are weld. The interface surface of the panel and chassis is installed with conductive rubber ropes to enhance the overall shielding effectiveness of the chassis.

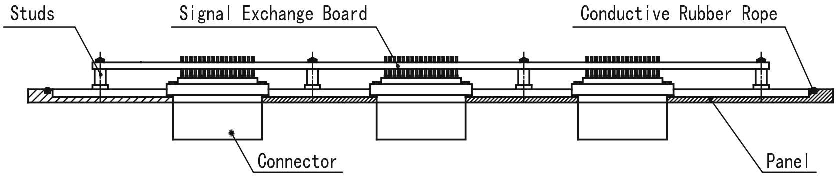

Fig. 4. The installation schematic diagram of connectors

4.2 Seams Shielding of Cover and Chassis

Shielding is an effective measure that limits the electromagnetic energy within a certain range to suppress radiation interference using conductive or magnetic materials. According to the principle of electromagnetic shielding, a seamless, non-hole and closed box has the best shielding performance [7].

The reinforcement chassis will have a combination of panels generally that cannot be contacted fully, only at some contact point, which constitutes a hole array called the seam [8]. The seam is one of the main factors that affect the shielding performance of the chassis, so it is vital importance to improve the electrical contact of these seams to the chassis design.

In order to reduce the seams of structural parts, the reinforcement chassis will be designed into a whole. Double-layer conductive rubber strips are installation on the cover of the chassis and the box (shown in Fig. 5) to ensure the electromagnetic compatibility and sealing of the chassis. It is made of silicone, silicone fluorine and other adhesives and silver, silver-plated copper and silver-plated nickel and other filler composition, which can be completed environmental seals and electromagnetic seals at the same time. Conductive rubber strips have excellent compression characteristics in a wide temperature range, which meet the US military standard wet test standard MIL-STD-810 [9]. From Fig. 5, the cover plate is fixed to the box with fastening screws, and the groove of the lower end of the screw is matched with the boss above the cover. It is provided with a flexible gasket between the groove and the boss. The contact part of the cover plate and the box is equipped with a dovetail groove for the installation of “B” type conductive rubber strip. The outer seal in the form of the whole circle is to ensure the reliability of environment sealed.

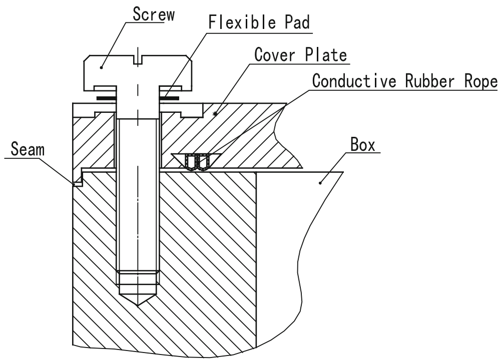

Fig. 5. The seam schematic diagram of cover plate and box

4.3 Shielding of Hole

It needs process holes to install switches, power supplies and fuses and other components in the panel, however, a metal shield covering switches and fuses can prevent electromagnetic leakage of such holes. Double-shielded structure can improve significantly the shielding effectiveness in the case of the volume of small cases that is shown in Fig. 6. An electromagnetic seal between the shield and the panel reduces the gap and improves electrical contact. A rectangular shielded socket on the side of the shield leads the switch, the fuse wire to the rectangular shield socket directly, which achieves the integration of shielded filter.

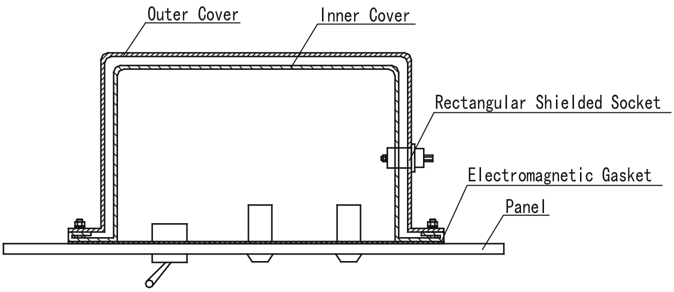

Fig. 6. The schematic diagram of double shield

The network port and other external interfaces on the panel are closed with a door, the contact surface of the door and the panel filled conductive shielding ropes forms a good conductor. The power cord and the signal line are wind cable shield secured connector sheath, and seams of connectors with electromagnetic shielding function and the chassis are installed conductive rubbers. Connectors, cable shield, and the chassis constitute a complete shield, effectively preventing electromagnetic interference coupled to the wire or through the installation hole into the chassis.

4.4 Filter and Ground

Figure 7 shows installation diagram of the filter. The power filter with a ground terminal and the signal filter are installed on both sides of the partition with screws. The electromagnetic of the chassis integrated power filter and signal filter compatibility is improved. Grounding is one of the important means of suppressing electromagnetic noise and preventing interference. For an ideal grounding system, the potential reference for each part is kept at zero potential [5]. The filter and connectors are connected to the chassis with conductive gaskets, which forms a conductor with the chassis. The cover of the chassis is equipped with a shell-mounted screw combination structure shown in Fig. 8, which is connected with ground to achieve the chassis shell ground. The contact between the screw and the panel is conductive and enhances the conductivity of it.

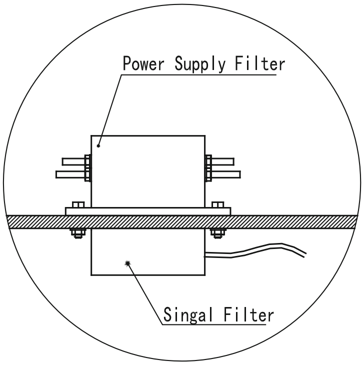

Fig. 7. A installation schematic diagram of the filter

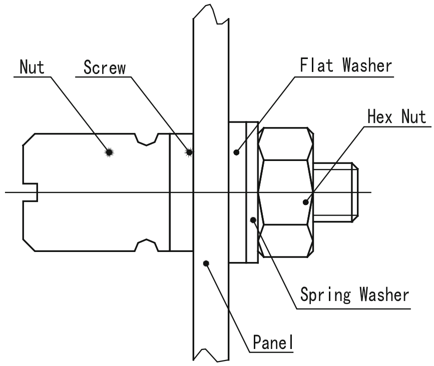

Fig. 8. The shell-mounted screw combination structure

5 Anti-vibration and Anti-impact Design

The hazards caused by the vibration and impact are: the larger resonance is occurred at a certain frequency of excitation; subjected to long-term vibration and shock is easy to make electronic equipment fatigue damage [10]. Vibration shock will increase the mechanical stress of the computer, resulting in poor contact, component deformation and so on.

In order to improve the vibration resistance of the whole machine, the hydraulic shock absorber is installed at the bottom of the reinforcement chassis. The main advantage of this type of shock absorber is that the performance of vibration reduction is good and the installation is convenient.

Panels of the chassis using vacuum brazing technology form a whole, before and after the cover plate are connected to the box through screws, which forms a closed whole to improve the anti-vibration impact capability of the chassis. It takes anti-loose measures to fixing screws, and pan head screws are generally with spring washers and flat washers, and countersunk screws plus thread glue for anti-loose treatment.

The module in the chassis is in the form of plug that the capability of anti-vibration impact is weak. Therefore, the wedge locking mechanism is designed as shown in Fig. 9, which consists of a front slider, a wedge block, a rear slider and a screw. The block contacted with the wedge block is designed as a bevel, which makes the locking structure riveted to the left and right sides of the printed board by rivets. The module is inserted into the groove of the chassis vertically, and the tightening force is applied to the screw clockwise, then the slider will move along the wedge-shaped surface, which contacts with the guide groove surface in the left and right direction to until the lock.

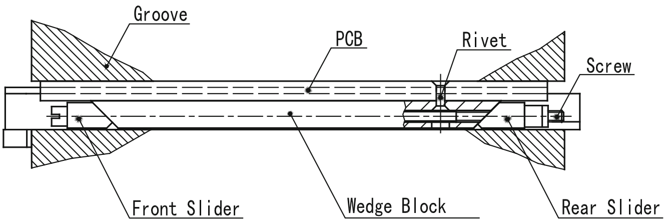

Fig. 9. Wedge locking mechanism

6 Experimental Verification

6.1 High Temperature Test

In accordance with the program of thermal design in the second section of this article, the reinforcement computer completing the assembly and commissioning passes successfully the high and low temperature tests and 120 h reliability assessment in the conditions of 55 °C ambient temperature. Using the Automation Test System ATM2400 and AccuSense UTS1000 thermocouple sensors, the test points are set up in the key components of the main module of the reinforcement chassis. The temperatures of key devices are shown in Table 1.

Table 1. Temperature of key devices (Unit: °C)

Serial number	Test points	Main module 1	Main module 2	Main module 3
1	CPU	80.3	84	82.3
2	Video card	75.4	78.8	77.2
3	North Bridge	71.5	73.4	72.6

As can be seen from the data in Table 1, the CPU shell temperature in the main module 2 is 84 °C and the CPU shell temperature in the main module 1 is 80.3 °C. As can be seen from shell temperatures, three main modules can work normally and meet thermal design requirements. Therefore, results of the test show that the structure of anti-harsh environment reinforcement is reasonable and can meet the machine’s cooling needs.

6.2 Vibration Test

In order to verify the adaptability and structural integrity of the reinforcement chassis in the condition of vibration, the vibration test of the reinforcement chassis is carried out strictly in accordance with the requirements of GJB322A-98. The chassis will be librated for 2 h at a frequency of 160 Hz, acceleration 2.5 g, and the chassis is without significant deformation, as well as cracks and shedding phenomenon, and functional indicators are normal, which meets the needs of a variety of harsh environments fully.

7 Conclusion

The reinforcement chassis passes not only high and low temperature tests and electromagnetic compatibility test, but also a series of tests such as vibration. The results show that the structure of the chassis, the strength of the design and thermal design are reasonable. The chassis is compact, lightweight, as well as high space utilization, and the functional modules of the cabinet arrange neatly and clearly. On the basis of ensuring the function of the device, its appearance is simple and generous, which gets the user's praise.

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