Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 4, No. 2, 2022

RF Thermal Simulation Design Based on Flotherm

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Abstract: As for the RF power supply, with the continuous expansion of the use field, the increasing integration and the substantial increase of the heat flow density in the chassis, the research on the thermal analysis and thermal design of the RF power supply is of great value. In the process of power supply development, the simulation method is used to analyze the temperature field of the power supply. The thermal design can significantly shorten the product development cycle, minimize the cost, and improve the reliability. Based on this background, this paper integrates the thermal simulation, thermal design and thermal test of RF power supply, uses thermal analysis software (Flotherm) to conduct thermal analysis of RF power supply, and conducts temperature experiment after designing internal cooling components. The experimental results show that after the thermal simulation and thermal design, the maximum internal temperature of the RF power supply is 127℃, the temperature of the key device power tube is 76.9℃, and the core temperature is 104℃, which are far below the maximum allowable temperature, meeting the thermal design requirements. This paper lays the foundation for mass manufacturing, standard formulation and serialization of RF power supply, and provides a reference for the integration of thermal analysis, thermal design and thermal test of power supply.

Keywords: RF power supply, Thermal simulation, Thermal design.

1. Introduction

In recent years, with the continuous progress of science and technology, RF power supply has developed rapidly and been widely used in many fields, especially in biomedical, medical instruments and other fields. With the continuous expansion of the field of use and the increasing degree of integration, the market demand for high frequency and small size has led to a sharp increase in the heat flow density and temperature in the electronic case. In the past design, engineers often rely on experience to design heat dissipation measures, and finally carry out prototype experiments. The benefits brought by such methods are often very low, and the cost of manpower, material resources and time is huge. As far as the RF power supply in this paper is concerned, the problem of heat density concentration has become the bottleneck of the development towards higher power and smaller volume. How to carry out efficient heat dissipation design for the RF power supply, quickly drain the heat generated by power loss to the external environment, and ensure that the internal temperature is far lower than the tolerance temperature of electronic components has great significance for its reliability improvement and long-term development.

The computer simulation technology for temperature can simulate the internal temperature field more realistically, and the discussion on the thermal problem of electronic equipment has gradually become a research hotspot at home and abroad. As early as the mid-1960s, foreign countries realized the importance of the heating problem of electronic equipment, and carried out research on it, thus developing technical means for temperature control such as thermal simulation, thermal testing, thermal control, and achieved fruitful results, accumulating rich experimental data and empirical formulas for designers [1]. In 1925, Cokroft [2] of the United States found a method to analyze the heat distribution in the transformer core, and proposed the theory of thermal analysis of electronic components. In 1992, John Ni Funk first proposed a semi analytical method with accuracy and speed comparable to the traditional finite element method [3]. This method creates differential and integral equations separately for the printed circuit board and the devices on it, and calculates the temperature when the printed circuit board is stable independently. Z. of Denmark Staliulionis created a thermal analysis model for the DC/DC power supply module by using the finite element analysis method. Through simulation and analysis of the mutual thermal coupling effects and temperature changes of components, it was found that the layout of components had a great impact on the life of the power supply [4];

Compared with the general situation of thermal design abroad, the research on thermal design was carried out late in China, but with the progress of science and technology, there is a higher requirement for the heat dissipation of electronic products, and some research has been carried out gradually in China, and some achievements have been made. Xu Xiaoting and others used Flotherm software to conduct thermal analysis on an electronic device, and on this basis improved the design of the heat dissipation measures of the electronic device, and obtained optimal design parameters that meet the heat dissipation requirements through numerical simulation [5]. Gao Xinxia studied the temperature fields of different types of high-power IGBT radiators with the help of ANSYS, and analyzed the influence of the basic parameters of the radiator on its heat dissipation capacity [6].

Domestic scholars have carried out a lot of research in the field of thermal design, but in terms of research on the combination of thermal analysis, thermal design and thermal test technology of power supply, domestic scholars have not really achieved the integration of thermal analysis, thermal design and thermal test of power supply. For the thermal design of power supply, using computer simulation analysis and verification, and using computer simulation assembly technology is the main development trend in the future [7].

2. Simulation Scheme

2.1. Initial and boundary conditions

The working environment temperature range of the RF power supply studied in this paper is 5℃~35℃. Since the ambient temperature is about 15℃ at the time of design, considering that the ambient temperature should be consistent with the ambient temperature for temperature experiment, the ambient temperature should be set as the middle value of 15℃, and the physical parameters of the air: thermal conductivity is 0.025W/m^2. ℃, viscosity1.85e^{-5}Ns/m^2, thermal expansion coefficient 0.003333k^{-1}. The boundary conditions for thermal measurement of RF power supply studied in this paper are as follows: the bottom surface of the packaging shell is the given ambient temperature of 15 ℃, the simulation is the temperature of the bottom of the RF power supply during operation, and the four sides and top surfaces of the shell are the heat exchange surfaces of the RF power supply during operation. Since the air flow outside the calculation area is very weak, it can be regarded as natural convection, and the natural convection heat transfer coefficient is generally 2~10 W/m^2.℃, combined with the working environment of RF power supply, the convection heat transfer coefficient is taken as 2 W/m^2.℃。

2.2. Mesh generation and solution

As a particularly important link in thermal simulation, grid generation cannot be ignored. Good grid generation can not only ensure the convergence of solution calculation, but also improve the efficiency of solution calculation [8]. In this paper, the grid division of key points in Flotherm is first used to ensure that the grid is created on the boundary of the object, and the grid refinement is carried out on the power device area to increase the solution accuracy. The model after grid division is shown in Fig. 1.

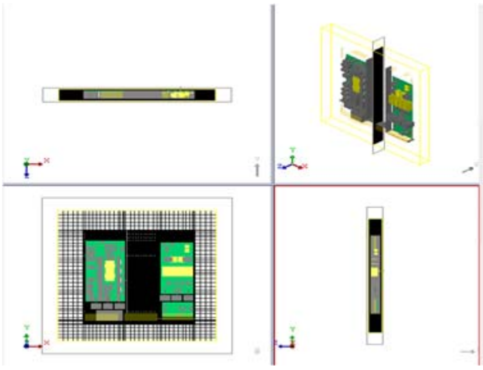

Figure 1. Key point grid generation

2.3. Thermal design of RF power supply

Firstly, the basic structure characteristics and working conditions of RF power supply are analyzed, and the power loss values of electrical components are calculated and estimated; Establish the initial simulation model of the chassis, conduct thermal simulation analysis on the RF power supply without any cooling measures, and obtain the temperature distribution cloud diagram, as shown in Fig. 2; Through heat source analysis, the main heat dissipation paths of heating components are obtained; Combined with simulation analysis and heat source analysis, the heat dissipation scheme is established as shown in Fig. 3: the whole machine adopts forced air cooling technology, and the finned radiator is installed on the main heating components.

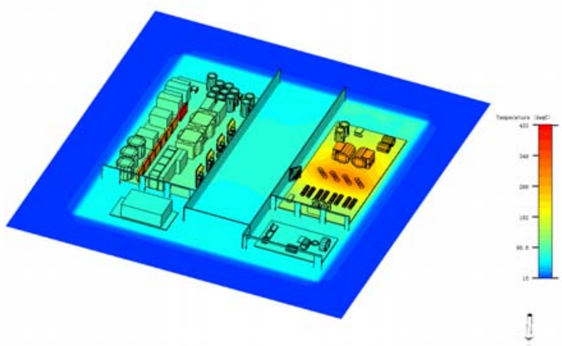

Figure 2. Initial Thermal Simulation

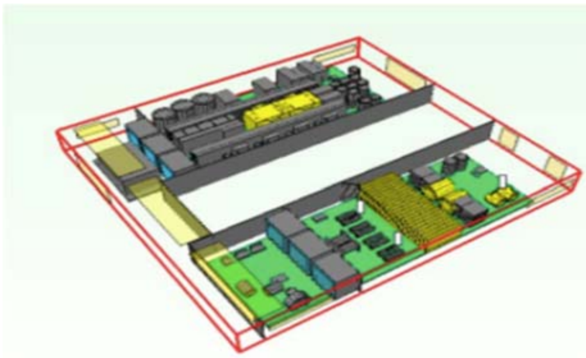

Figure 3. RF power cooling scheme

3. Experimental Results and Analysis

3.1. Simulation results with ambient temperature of 15 ℃

The radiator and fan model are added to the whole machine model for simplification, and the body is perforated according to the previously designed opening size. The opening area must meet the air volume demand. The whole machine simulation model is established again, and the solution is obtained after the local grid is densified. After the convergence, the maximum temperature, minimum temperature and temperature distribution of the model are obtained. The particle state of the fan is shown in Fig. 4, and the temperature nephogram in all directions is shown in Fig.

5. The red cross and green cross in the figure represent the highest and lowest temperature points respectively. The highest temperature point is the resistance on the power amplifier plate, and its maximum allowable temperature is 150℃.

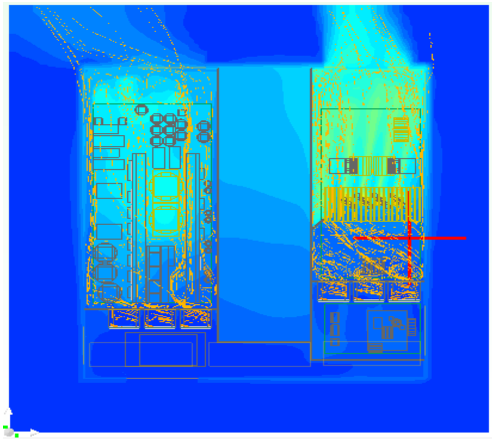

Figure 4. Fan particle status

Figure 5. Simulation Results

The maximum internal temperature of the RF power supply with preliminary heat dissipation design is the temperature of the resistance, which reaches 127℃. Since the maximum allowable temperature of the resistance is 150℃and it is not a key object, it can be ignored. The temperature of important components is shown in Table 1:

Table 1. Temperature of Important Devices

Device	Power tube	Magnetic core	Rectifier bridge	Resistance	Magnetic coil
Temperature (℃)	76.9	106	80.3	127	121
Maximum allowable temperature (℃)	150	150	150	150	200

The temperature change curve of several monitoring points set tends to be stable. The red curve represents the temperature change curve of the monitoring point at the power tube, the green curve represents the temperature change curve of the monitoring point of the MOSFET rectifier far from the fan end, the blue curve represents the temperature change curve of the monitoring point of the MOSFET rectifier near the fan end, and the black curve represents the temperature change curve of the monitoring point at the rectifier bridge. As shown in Fig. 6.

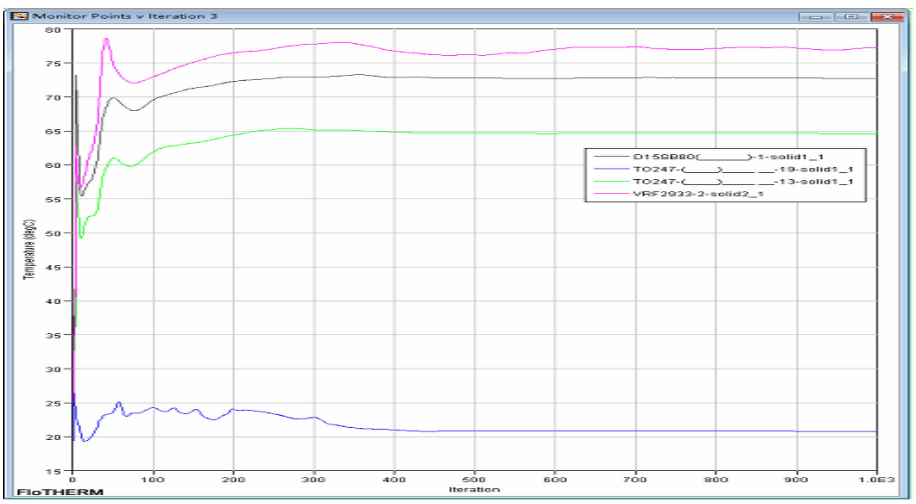

Figure 6. Temperature Change Curve of Monitoring Point

3.2. Prototype test

After the feasibility of heat dissipation measures is preliminarily verified by thermal simulation, a prototype of RF power supply is made according to the previous thermal design, a temperature experiment platform is established and temperature experiments are conducted.

3.2.1. Prototype test scheme

This RF power supply thermal test scheme: RF power supply connects a load output by an analog client to achieve the required power output, measure the temperature every 10 minutes and record the data until the temperature becomes stable, install thermocouples at the monitoring points near the power devices to measure the temperature, and the temperature data of other devices are obtained by the thermal imager. The prototype test platform and thermal imager are shown in Fig. 7 and Fig. 8.

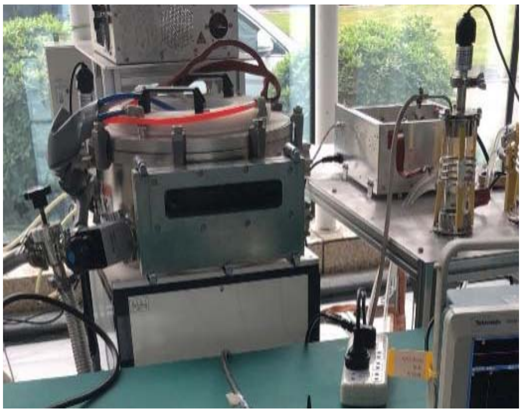

Figure 7. Prototype Test Platform

Figure 8. Thermal imager

3.2.2. Result analysis

After a series of experiments, the actual measured temperature data is obtained. After the experimental data is obtained, it is compared with the simulation data. The analysis results are shown in Table 2:

Table 2. Comparison between experimental data and simulation data

device	Test temperature (℃)	Simulated temperature (℃)	relative error (℃)	Maximum allowable temperature (℃)
Radiator teeth	69.5	67.1	+2.4	/
Power tube	78	77.1	+0.9	150
Magnetic core	104	97.3	+6.7	150
MOS	48	44.2	+3.8	120
CMOS	49.5	48.4	+1.1	120
Magnetic device	58	53.9	+4.1	120
Rectifier diode	32	28.5	+3.5	85
Rectifier bridge	75.7	72.4	+3.3	120

It can be seen from the above table that the maximum error is the temperature of the magnetic device, with a difference of 6.7℃. The main reason for this error may be that the radiator is complex in modeling, and there is a difference between the simplified model and the actual one. In addition, in the process of temperature measurement in this experiment, temperature data can be obtained directly from the monitoring point embedded with thermocouple, The temperature measurement of other radiator surfaces and some devices with high temperature resistance are measured by using thermal imager with the cover removed. There are certain errors, but the errors are within 10%, which verifies the feasibility of this simulation method.

4. Summary

Through the research on the thermal simulation and thermal design of RF power supply, the main conclusions of this paper are as follows:

(1) Based on the analysis of RF power supply structure and working conditions, a simplified model of RF power supply without any heat dissipation measures is made, and the power supply temperature field is simulated and analyzed using finite element analysis technology and related software Flotherm . The conclusion that the internal temperature distribution is centralized and the temperature rise is too high is obtained. On this basis, the main heating devices and the existing heat dissipation problems are analyzed, It provides reference and theoretical basis for the thermal design of RF power supply.

(2) Based on the analysis results, a heat dissipation scheme combining forced air cooling and air cooling radiator is developed for the whole machine; The radiator of the main heating components is designed theoretically, and the power supply of the initial design cooling scheme is analyzed by secondary thermal simulation. The temperature nephogram of each component is obtained when the ambient temperature is 15℃. The results show that the temperature is lower than its maximum allowable temperature, and the maximum temperature is reduced to 129℃, which can meet the heat dissipation requirements of RF power supply, verify the feasibility of the heat dissipation scheme, and achieve the original design intention of small volume RF power supply.

(3) Formulate a prototype experiment scheme to conduct temperature experiments, and compare the experimental data with the simulation results. The results show that the relative error between the experimental data and the simulation results is within 10%. The results verify the reliability of the simulation data. At the same time, it shows that Flotherm software has important significance in the practical application of the thermal design of RF power supply, and verify the reliability and practicality of the thermal simulation results of Flotherm software.

References

[1] Ding Lianfen, et al. Translated and proofread, Reliability Thermal Design Manual of Electronic Equipment [M]. China: Electronic Industry Press, 1989.

[2] Cockcroft JD. The temperature distribution in a transformer or other laminated core of rectangular cross section in which heat is generated at a uniform rate[J]. Mathematical Proceedings of the Cambridge Philosophical Society, 1925, 22(5):759-772.

[3] Funk, J.N, Menguc, M.P, Tagavi, K.A. A semi-analytical method to predict printed circuit board package temperatures[J]. IEEE Transactions on Components Hybrids & Manufacturing Technology, 1992, 15(5):675-684.

[4] Z Staliulionis, Z Zhang, R Pittini, MAE Andersen, A Noreika Thermal Modelling and Design of On-board DC-DC Power Converter using Finite Element Method ELEKTRONIK IRELEKTROTECHNIKA,ISSN 1392-1215, VOL. 20, NO.7, 2014.

[5] Xu Xiaoting, Zhu Minbo, Yang Yanni Thermal simulation analysis and software application of electronic equipment [J] Electronic Process Technology, 2006 (05): 20-23.

[6] Bai Lin, Liu Juan Thermal design of high-power electronic components and equipment structures [J] Science and Technology Innovation and Application, 2015 (25): 44-45.

[7] Xiao Jianfeng Thermal design of a high power density power module [D]. Shanghai Jiaotong University, 2018.

[8] Wang Xucheng Fundamentals and numerical methods of finite element method [M] Tsinghua University Press, 1997.