Analysis Research of the IGBT's radiator based on ICEPAK

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ABSTRACT: With the rapid development of power electronic devices, high-power IGBT is increasingly popular, It is used as a switching device in SVG static var generator. Due to the large switching losses, we need to design a suitable radiator, to maintain the highest temperature of 80˚C in working condition, then we can ensure the performance of the circuit devices and materials don't influenced by the heat stress. In this paper, we take infineon FF450R17ME4-B11 as an example, the software of ANSYS ICEPAK is using to do thermal simulation of the heat source, Optimally design the size of the radiator, keeping it work under the temperature of 80˚C.Then conclude some rules in the process of radiator design.

INTRODUCTION

With the rapid development of electronic technology, the miniaturization of electronic components is smaller while the power consumption is increasing, which has caused the heat flux of components and equipment increase sharply. Statistics point out that more than 55% of the failure of electronic products are caused by poor cooling system design. As the temperature increases, component failure rate increases exponentially. Therefore it is necessary to take reasonable thermal control technology to ensure the reliability of electronic components and equipment. Thermal analysis software systems can be more realistic simulation of thermal conditions, simulate the heat in the product design stage, and determine the highest point of the temperature in the model. By modifying the model or taking the necessary cooling measures, the heat problem can be eliminated, so that the maximum temperature can be in the permissible temperature range to meet the design requirements, which can reduce the cost of the design, manufacture, re-engineering and reproduction, improve the success rate of products in the first time; and improve the performance of electronic products and product reliability, shorten time to market products.

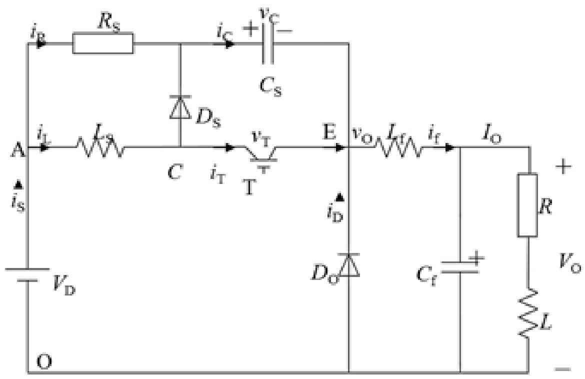
ANSYS ICEPAK is a thermal analysis software, which can combine radiators, fans, vents, water-cooled devices and other single or mixed cooling mode together, to analyse the overall thermal effect. This paper uses a single radiator cooling mode and optimize optimum shape design of the radiator, to make heat dissipation for IGBT power components simply and efficiently.

THE CALCULATIONS IGBT SWITCHING LOSS

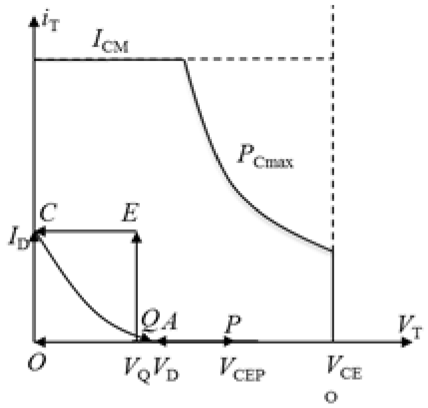
IGBT turn-buffering

The opening-shutdown process of IGBT is shown in Figure 1. A capacitor C is paralleled at the switch, which can make the terminal voltage v_t rise slowly during i_T is reduced from Io to zero in the process so that the turn-off loss can also be reduced.

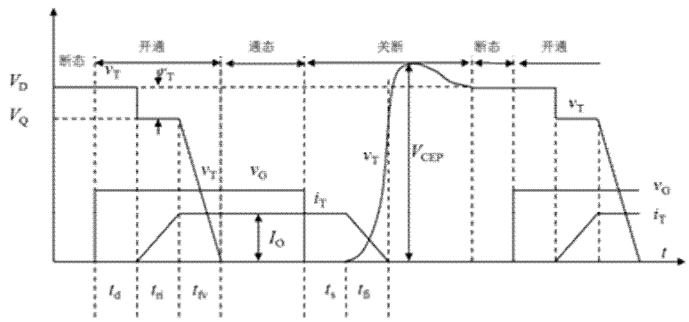
A buffer inductance L is in series with the switch, so that the terminal voltage v_t and opening loss are reduced during it rises from zero to Io in the process, which is the most basic measure to improve the opening process. It is specified that the current upper time is t_r, the voltage drop time is t_f, the switching frequency is 20KHz.



(a)electric circuit



(b) switch locus



(c) the waveform of the opening-shutdown process

Figure 1. The opening process of IGBT

The calculations of IGBT power loss

For example of FF450R17ME4_B11, it contains a half-bridge circuit, which means it contains two switches and two diodes. The basic properties are shown in Table 1.

Table 1. The parameter of IGBT.

Name	Condition	Value
The maximum emitter voltage V_{CES}	T_{vj} =25°C	1700 V
The maximum Collector Current I_C	T_C=25°C, T_{vj} =175 °C	450A
The maximum power dissipation P_{tot}	T_C=25°C, T_{vj} =175°C	2500 W
Rise Time t_r	I_C=450A, V_{CE}=900V	0.11us
Fall Time t_f	I_C=450A, V_{CE}=900V	0.3us

According to the waveform of switch's turn-on and turn-off, the calculation method of switching losses can be pushed, which means that the calculation method of opening loss *Pon* and turn-off loss *Poff* can be pushed.

$$P_{on} = \frac{1}{2} V_Q I_o \ (tr + tf) fs \qquad (1)$$

$$P_{off} = \frac{1}{12} V_D I_0 t_f f_s \qquad (2)$$

Among them, t_r is the rise time, t_f is the fall time, V_Q is the turn-on voltage, I_o is the conduction current, f_s is the switching frequency. Under extreme circumstances, the maximum IGBT switching losses is calculated to 1800W.

DESIGN OF IGBT RADIATOR

The cooling method of ANSYS ICEPAK

ICEPAK available cooling methods include natural convection air cooling, forced convection air cooling, infiltration cooling, boiling cooling, cooling tube, thermoelectric cooling and so on. Among them, the most common method used on radiators and fans is forced convection air cooling, which is the most simple and economical method.

The establishment of radiation model

This design focuses on single-phase full-bridge inverter circuit. Since a FF450R17ME4-B11 is a half-bridge circuit, so to form a full bridge circuit, need two FF450R17ME4-B11s, which means two heat sources. Each heat source is set that the maximum power total loss is 1800W, the distance between two heat sources is set to 120mm. The heat source is placed on the block, and the heat transfer coefficient of the block material is 1W/K-m^2. There are enough holes around the material to keep the full-bridge circuit unclosed. The final model is shown in Fig 2.

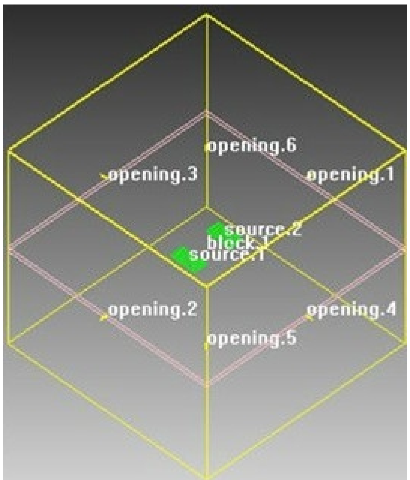


Figure 2. The opening process of IGBT

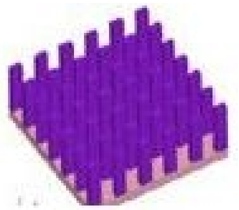
The design of the radiator

Typography for references

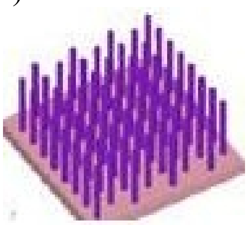
The radiators can be classified into simple types and detailed types; The simple types of the radiator use pressure loss coefficient to consider the flow pressure loss effect during the fluid flow through the rediating fins, and increase the local thermal conductivity of the fluid to consider heat exchange in the fins, which can reduce the difficulty of the simulation and design.

The detailed types of the radiator include extruded ,cross-extruded, cylindrical pin, coupled fins, shown in Figure 3.

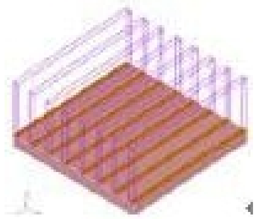
(a)extruded



(b)cross-extruded



(c)cylindrical pin



(d)coupled

Figure 3. The shape of the radiator

When the model is set up, it is necessary to consider the number, thickness, distribution, wind flow direction and other factors of fin for extruded ,cross-extruded and coupled fin in the design. Among them, coupled fins use contacts damping plate to set up a model at the interface, and extruded fins use thermal sheet to set up a model. In the design of the cylindrical pin fins, the fins' number ,radius and type need to be considered in both directions.

Radiator selection

Simple type radiator is not required for high-power IGBT. Therefore, the need to use detailed design radiator occured. Since needle columnar radiator is inserted inside the power element so that it is not suitable to cool IGBT, coupled radiator to consider contacting damping ,and the cross-extrusion radiator is too difficult to be made, the squeeze radiator is selected in this paper to achieve the simple and efficient purpose. The thermal resistance of the heat sink material is 1C / W. The final model is shown in Figure 4.

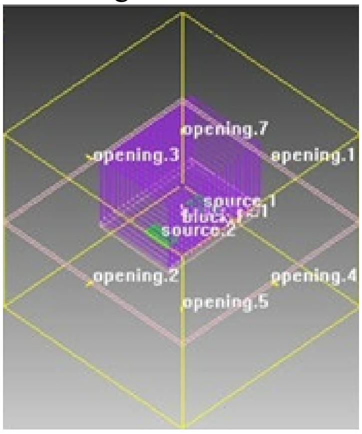
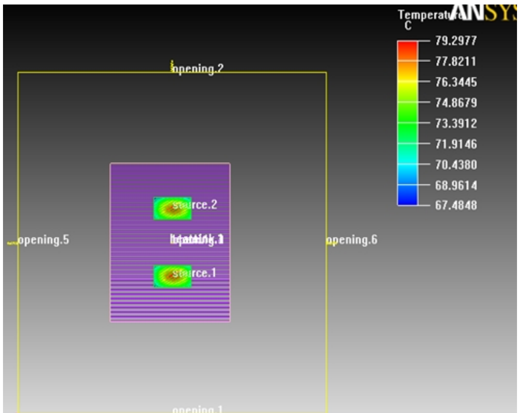


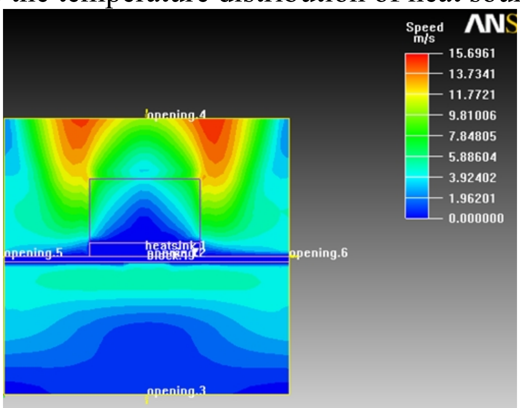
Figure. 4 The model chart of the radiator

The radiator design optimization

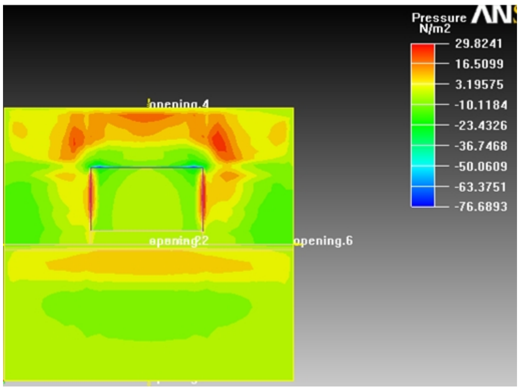
The primary goal of the thermal analysis is to control the source temperature under 80 degrees, which is its maximum safe operating temperature. The final result shows that the highest temperature of the full bridge circuit is the center of the two heat sources. Air and heat flow are primarily along the top of the heat and spread. In addition, when the heat sink fins distributed along the X direction, the cooling effect is better than that in the Z direction. Figure 5 is the simulation results when the number of the fins is 40, the base height is 0.05, the total height of the fin is 0.28 and the fin total thickness is 0.0045.



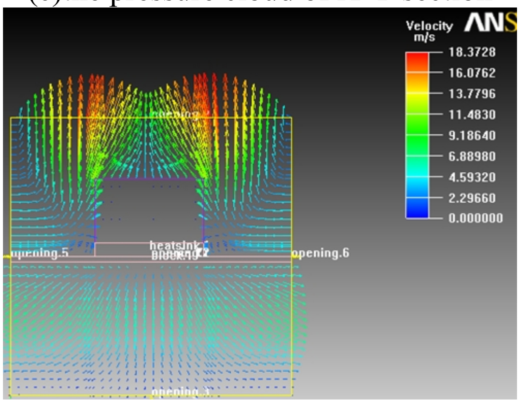
(a) the temperature distribution of heat source



(b)the air velocity of X-Y section



(c)the pressure cloud of X-Y section



（d）the velocity vector of X-Y section

Figure. 5 Simulation results

In this case the maximum temperature was 79 degrees, with the critical parameters to control the temperature below 80 degrees. The temperature around can be reduced more by adjusting the number of radiator fins, the base height of the radiator, the fin height of the radiator, radiator thickness and other parameters. From the optimization simulation result in the table in Appendix 2, it can be found that the cooling effect for IGBT is the base height, the number of fins, fin thickness and fin height in the order from from darkly to lightly.

CONCLUSION

Thermal methods vary in the thermal design of high-power power electronic devices. If cooling area and other parameters are well designed, a good cooling effect can be achieved.

Through the analysis above, extruded fins in the detailed radiator are recommended in this paper to construct IGBT radiator. In addition, when the fins are distributed along the x direction, the cooling effect is better than it along the Z direction. For extruded fins, it is not the more fins, the better effects, it is also important whether there is enough space to spread heat.

Fin height and fin thickness are the most important factors to the thermal effect, it is no good for cooling that the fin height is too high or too low, or the fin thickness is too thick or too thin .So it is necessary to find the most suitable size. The best cooling parameters are showed in table 13 for full bridge circuit consisting of two Infineon FF450R17ME4-B11

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