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The Electromagnetic Interference Model Analysis of the Power Switching Devices

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Abstract

The switching device turn-on and turn-off process will produce high-frequency electromagnetic interference, based on the finite element method ANSYS software with powerful computing capabilities, has been widely used in complex electromagnetic field calculations. In this paper, ANSYS software to model and analyze the insulated gate bipolar transistor (IGBT) and quantitative distribution of electromagnetic interference (EMI), and for the staff and scientists doing research in electromagnetic field analysis provides an effective reference program.

Keywords: *IGBT, electromagnetic interference, finite element method, power switching devices*

1. Introduction

The trends of the switching power supply is small size, light weight, high efficiency, high power density. The emergence of the power device so that the switching power supply capacity is increasing. In switching power supply use some nonlinear power switching devices, which can increase the frequency of the switching power supply, but subsequently increases the switching losses and electromagnetic interference also increases,for the switching power supply itself constitutes a large source of interference.Therefore, analysis of electromagnetic interference model of power switching devices must be taken into account in the design of the power problem. Insulated gate bipolar transistor IGBT usually was used in power devices[1-2].

IGBT as both a power MOSFET high-speed switching performance and a bipolar transistor high voltage, large current handling capability of the new components, with the advantages of high current density, small drive power, in power electronic converters and power transmissionthe large number of applications is an inevitable trend. The high voltage and high current is the main source of high-frequency electromagnetic interference in the IGBT turn-on and turn-off transient processing. Therefore, the analysis of its dynamic characteristics of electromagnetic interference model has some practical value.

For IGBT need to build its simulation models. The IGBT's model has three typies of that Behavioral model, Mathematicalphysical model and 3-dimensional solid model. Behavior model based on the equivalent circuit, the simple model, the simulation results are not accurate enough.The mathematical model based on the physical structure and mechanism of the IGBT as its base, using the mathematical equations to describe the physical characteristics of the device, such models can be precisely described the physical characteristics of the IGBT, but the dynamic electromagnetic field distribution of the IGBT can not reflect. The solid model is based on the physical structure and mechanism of the IGBT, and in the appropriate location using the same size and the corresponding filling material, made of the high precision of the IGBT solid model. Such models to overcome the shortcomings of the above-mentioned two models, the simulation accuracy, and can reflect the the IGBT surrounding electromagnetic field distribution. This paper, using ANSYS software based on the finite element method for IGBT 3D modeling, and analysis of the surrounding electromagnetic field distribution [3-5].

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2. Structure, working principle and characteristics of the IGBT
2.1 Structure of the IGBT

IGBT is a three-terminal devicem,it was of a gate G, the collector C and the emitter E. Figure 1 shows a schematic block diagram of an N-channel IGBT, it is a field controller parts, the gate and the emitter of the voltage between the UGE is positive and greater than the turn-on voltage the UGE (th), the IGBT is turned; UGE Equal 0 or less, the IGBT off. Which is configured as shown in Figure 1.

2.2 Working principle of the IGBT

The switching action of the IGBT by the addition of a positive gate voltage form a channel， so that the IGBT is turned on to provide base current to the PNP transistor. Conversely, plus reverse gate voltage to eliminate channel flowing through the reverse base current of the IGBT is turned off. The driving method of the IGBT and the MOSFET are basically the same, the only control input pole of N-channel MOSFET, has a high input impedance characteristic[6].

When the the MOSFET channel forming, from P + base is injected into the N-layer of the hole (minority carrier), the conductivity modulation of the N layer, to reduce the resistance of the N layer of the IGBT at high voltage, and also has a low on-state voltage.

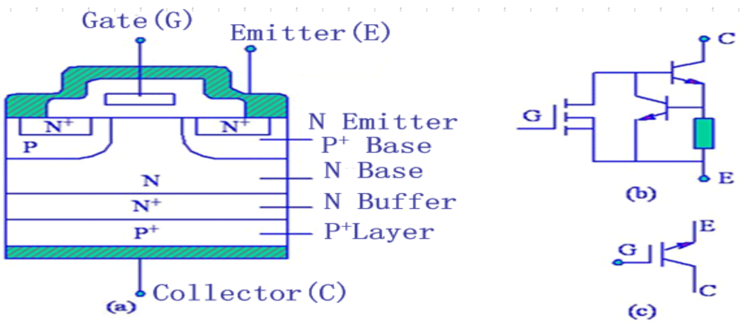
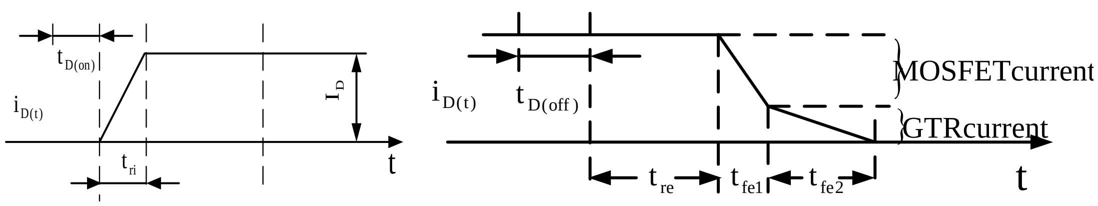


Figure 1. Basic structure of IGBT and symbol

2.3 Characteristics of the IGBT

IGBT characteristics include static and dynamic two types, here focuses on the dynamic operating characteristics. IGBT characteristics include static and dynamic two types, here focuses on the dynamic operating characteristics.IGBT in the opening process, most of the time is to run as a MOSFET, the drain-source voltage Uds down later in the process, the PNP transistor enlarged area to saturation, but also increase the time delay. td (on) turn-on delay time, tri current rise time. The practical application by the drain current of given opening time ton is TD (on) and of Tri. The decline of drain-source voltage the time by tfe1 and tfe2 composition. As shown in Figure 2.



(a) IGBT turn-on current (b) IGBT turn-off current

Figure 2. IGBT turn-on current and turn-off current waveform

3. IGBT Modeling and Simulation
3.1 Solid modeling
For the basic structure of Figure 1, to create the corresponding solid finite element model of the IGBT shown in Figure 3. The IGBT internal structure more complex, using ANSYS software to build 3D solid modeling, the combination of layers can be used according to the layers of segments of different functions, each corresponding part is set based on different materials appropriate relative magnetic permeability and resistivity rate [11].

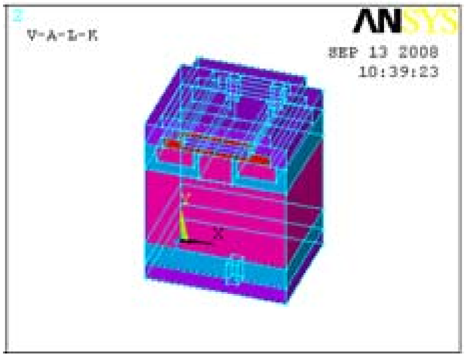


Figure 3. Solid model of IGBT

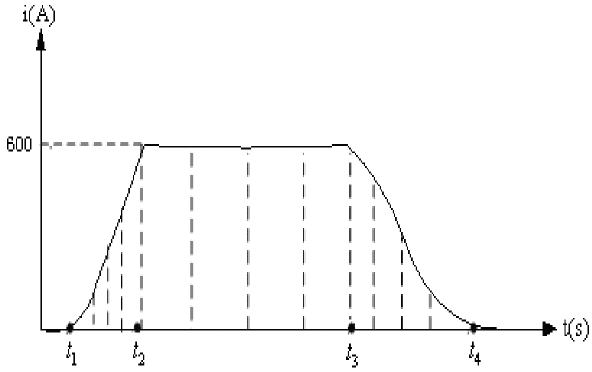


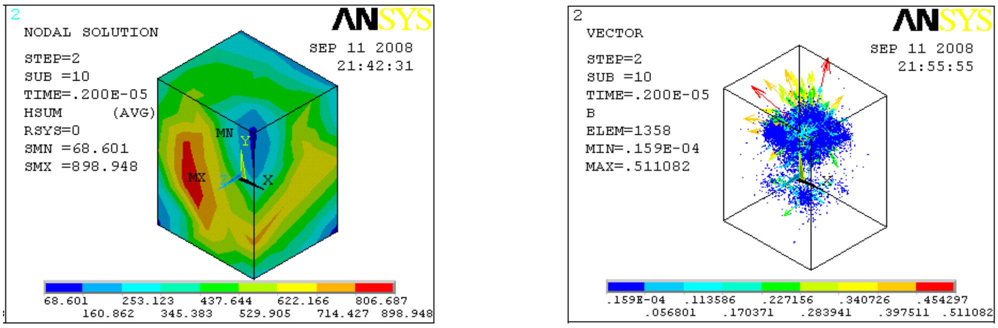
Figure 4. Example of load division

3.2 Finite Element Simulation[7-11]
ANSYS software simulation of the switching device IGBT adopt transient loading mode, the load applied to the current density. 3D transient analysis, boundary conditions and loads are applied to a function of time. Therefore required to load the physical quantity changes with time of divided into a plurality of periods, and were analyzed for each time segment and then gradually. There are three ways of loading step, ramp and automatic time step, here the selection ramp load. Depending on the speed of the load current trend, is divided into different time intervals, the the IGBT actual opened off the current waveform simulation close to the actual waveform of the load form.The turn-on and turn-off waveform painting together, as shown in Figure 4 of the IGBT specific current waveform is applied in the switching process.

It should be noted that the time substep select appropriate, load not pitch, is divided into different sub-step according to the changes of the current load, dividing time sub-step should carefully weigh its advantages and disadvantages. The substep excessive, slow computing speed, high precision calculations, the increased demand for memory space. Substep is too small, the calculation speed, accuracy, and make useful information is lost and can not accurately reflect the true results. The IGBT internal each layer be of different the current density, According to each layer section calculated load amount for each part of the area before the load, after solving and post-processing.

Through the general postprocessor observation IGBT simulation results. Figure 5 (a) and (b) are a perspective view of the IGBT of the magnetic field strength and the magnetic induction intensity of the simulation results. As can be seen from the results in the pin at the magnetic field strength and the magnetic induction intensity is stronger, and from which it is clear that the distribution of the magnetic field, different colors represent different nameplate size of the magnetic field strength in Figure 5.

4. Analysis of simulation results
From the IGBT model equal distance, but orientation of the different nodes of simulation data shown in Table 1 shown by the time course of post-processor Statistics. Comparative multiple sets of data shows that the IGBT through a certain load, the size of the electromagnetic field generated around different.In order to compare the size of the different orientations of the magnetic field in a more intuitive manner, the line chart in Figure 6 in the figure is a more clear contrast data of Table 1.



(a) Magnetic field strength contours (b) Magnetic induction

Figure 5. Magnetic field distribution view of IGBT

Table 1. Electromagnetic field data

Node	H(A/m)	B(T*E-6)
11711	261.374	328
11712	145.621	278.9
11713	163.606	2056
11714	226.828	285
11715	372.397	468
11716	136.16	171.1
11718	348.939	468
7891	7501.32	9426
8132	6978.32	8769
8105	8582.35	10784.9
8062	3212.59	4037
1691	13378.2	16815
1131	12452.6	15651

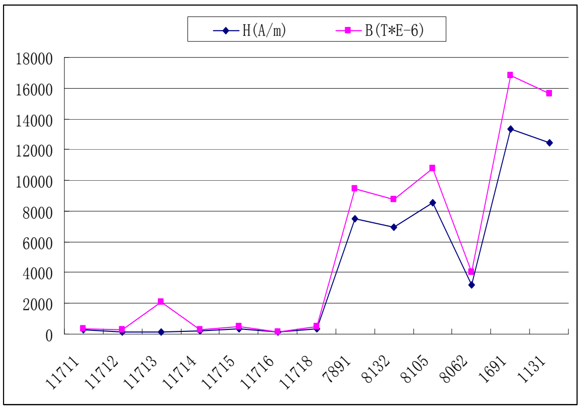


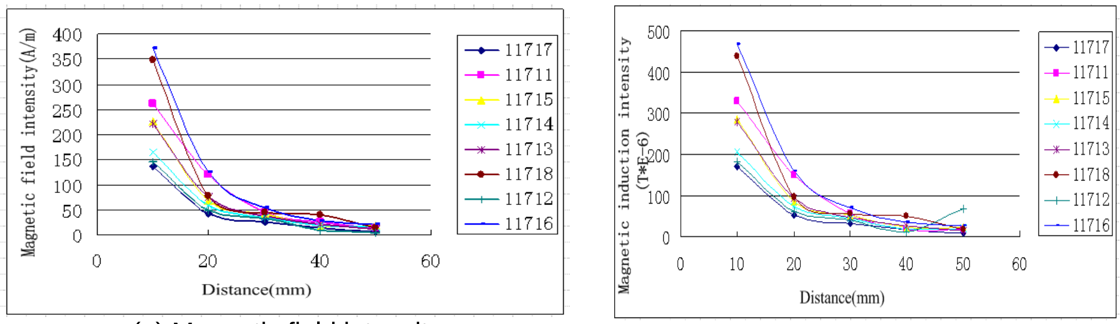
Figure 6. Comparing electromagnetic data of IGBT in different directions

Table 2 is taken in from the IGBT distance gradually increasing part of the simulation data of the node values of the different orientations. The comparison results from the data in the table can be clearly concluded that the different nodes, into a non-linear proportional decrease with increasing distance IGBT distance, and as the distance increases, the increasing rate of change of the magnetic field strength and the magnetic induction intensity small.

Table 2. Electromagnetic fields simulation results of IGBT at different distance

Distance (mm) / H/B[(A/m)/T] / Node	10	20	30	40	50
11717	136.16/0.0001711	42.1353/5.2948E-5	26.4907/3.3289E-5	15.1959/1.9095E-5	7.5644/9.5057E-6
11711	261.374/0.0003284	119.974/15.0727E-5	45.4538/5.7119E-5	26.455/1.9095E-5	13.3544/1.6781E-5
11715	226.828/0.000285	68.524/8.6109E-5	42.464/5.3361E-5	18.8295/2.3661E-5	19.4116/2.4393E-5
11714	163.606/0.0002056	59.6532/7.4962E-5	36.2571/4.5562E-5	19.7314/1.9095E-5	16.4143/2.0626E-5
11713	221.916/0.0002789	75.4893/9.4863E-5	38.2534/4.8070E-5	21.6688/2.7229E-5	12.6568/1.5905E-5
11718	348.939/0.000438	78.2481/9.8329E-5	44.0064/5.5300E-5	40.2875/5.0627E-5	13.6251/1.7121E-5
11712	145.621/0.000183	50.0839/6.2937E-5	32.8941/4.1336E-5	9.3528/1.1753E-5	5.4366/6.8318E-5
11716	372.397/0.0004680	125.523/0.0001577	55.0329/6.9156E-5	28.9566/3.6387E-5	20.4534/2.5702E-5

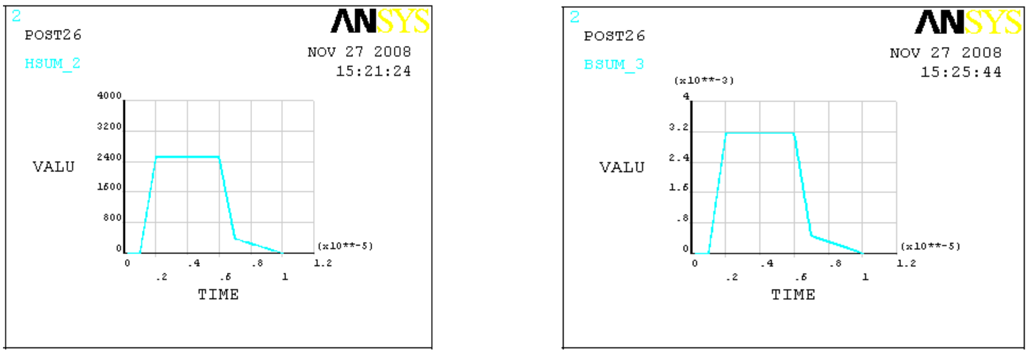
The line chart in Figure 7 (a) and (b) directly reflects the change in magnetic field of table 1 simplify the processing, the trend of the polyline.



(a) Magnetic field intensity (b) Magnetic induction intensity

Figure 7. Magnetic field polylines comparison of IGBT

On the face of the different nodes to do a comparison, Figure 8 (a) and (b) is taken around the IGBT pin about 7 mm is a node of the magnetic field strength and the magnetic induction intensity changes with time, can be seen the IGBT around transient magnetic fieldthe strength and the size of the magnetic induction in line with the change of load.



(a) transient magnetic field intensity (b) transient magnetic induction intensity

Figure 8. Transient magnetic field change of IGBT

5. Conclusion

Most analyzes switching power electromagnetic field distribution only for qualitative analysis, and can not be quantitatively the size of the specific analysis of the electromagnetic field of a point. In this paper, the IGBT model in ANSYS environment Quantitative analysis of the electromagnetic field distribution, with the theoretical calculation of the data is consistent. Using ANSYS software to analyze switching power supply electromagnetic field distribution law is an effective method for accurate modeling of the switching power supply difficulties. By a series of articles on the switching power supply components and switching power supply typical circuit analysis and experimental results verify the correctness of the analysis.

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