Effects of Power/Ground Via Distribution on the Power/Ground Performance of C4/BGA Packages

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Abstract

The effects of the distribution of power and ground vias in C4/BGA type of packages are studied. Two types of via distributions are evaluated. One type is that vias are concentrated in the core area. The other type is that vias are uniformly distributed across the package. The performances of power and ground supplies of packages are evaluated through their resonance characteristics, impedances and effective inductances. It is found that the lowest package resonant frequency is increased by adding power and ground vias in the package. It is also found that, there are no significant differences in the lowest resonant frequencies between the two types of via distributions, but the centered via distribution results in substantially lower effective inductance of the package.

Introduction

The distribution of power supply within a package must be done in a manner that provides a low impedance connection between the power and ground to the devices [1]. In high performance flip-chip and ball-grid-array (BGA) packages, multiple power and ground planes are often used in the package to keep the power supply noise low [2]. Meanwhile, many power and ground vias are used to connect those power and ground planes. A question is whether there are any effects of the distribution of these power and ground vias on the performance of the power and ground supply of the package.

Two distributions of the power and ground vias are studied in this paper. One is centered distribution which means that the power and ground vias are at the core area of the package. Another one is uniformed distribution which means that the power and ground vias are uniformly spread across the package. In this study, a fast electromagnetic field simulation tool, SPEED97 [3], is used to do the package analysis. From transient electromagnetic field simulation results, the input impedance and the effective inductance are calculated for the evaluation of package performance [4].

It is found that the lowest package resonant frequency is increased by adding power and ground vias in the package. There are no significant differences in the lowest resonant frequencies between the two types of via distributions. But the centered via distribution results in substantially lower effective inductance of the power and ground supply of the package.

Case Studies

The stack up of the packages to be studied is shown in figure 1. There are total two ground planes, two power planes in the package. Ground vias connect the ground planes and power vias connect power planes of the package. The power supply of the card is assumed to be ideal. So all the ground vias and power vias are connected to the ground plane of the card.

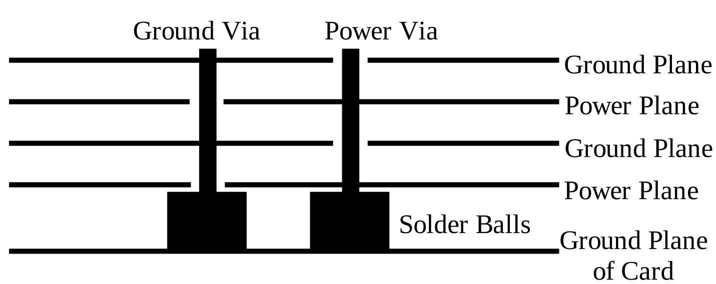

Figure 1. Stack up of the package studied.

The plane is 28.57 mm by 28.57 mm in size. The separation between two planes in the package is 400 μm. The dielectric constant of the medium between planes is 10.0. In the package, the via radius is 50 μm. Solder balls are modeled by vias of radius 400 μm. The height of the solder ball is 900 μm. The dielectric medium surrounding the solder balls is air. The pitch of the solder balls is 1.27 mm. There are total 22 by 22 solder balls under the package.

The two distributions of the power and ground vias are shown in figure 2. One is centered distribution shown in figure 2(a), where all the ground vias and power vias going down directly right below the chip. In the uniformed distribution shown in figure 2(b), all the ground vias and the power vias connected to the chip first going down to the upper ground plane and the upper power plane, then uniformly going downward. The question here is which distribution of the power and ground vias is better from the power/ground performance point of view.

For each via distribution, three cases are studied. The first case includes 32 pairs of power and ground vias in the package. Figure 2(1) shows the power and ground via arrangement for the centered distribution. Figure 2(2) is for the uniformed distribution. The vias in the central region of figure 2(2) are power vias passing through the top ground plane of the package. For both via distributions, there are 32 pairs of power and ground solder balls connected to the ground plane of the card.

In the second case, additional 40 pairs of power and ground vias are added into the package. These vias are not connected to the chip but are connected between planes inside the package. For centered distribution, the 40 pairs of vias are located at the corners of planes or at the middle of plane edges, as shown in figure 2(3). For the uniformed distribution, the 40 pairs of vias are uniformly distributed among the previous 32 pairs power and ground vias, as shown in figure 2(4). For both via distributions, there are 72 pairs of power and ground solder balls connected to the ground plane of the card.

In the third case, there is are additional power and ground solder balls compared to the second case, but more power and ground vias are added. Each power via of case 2 is surrounded by additional ground vias, and each ground via of case 2 is surrounded by additional power vias. The pitch of the vias inside the package is 0.635 mm, which is 25 mil. Figure 2(5) shows the via arrangement for the centered distribution. There are 225 power vias and 360 ground vias in the package. Figure 2(6) shows the arrangement for the

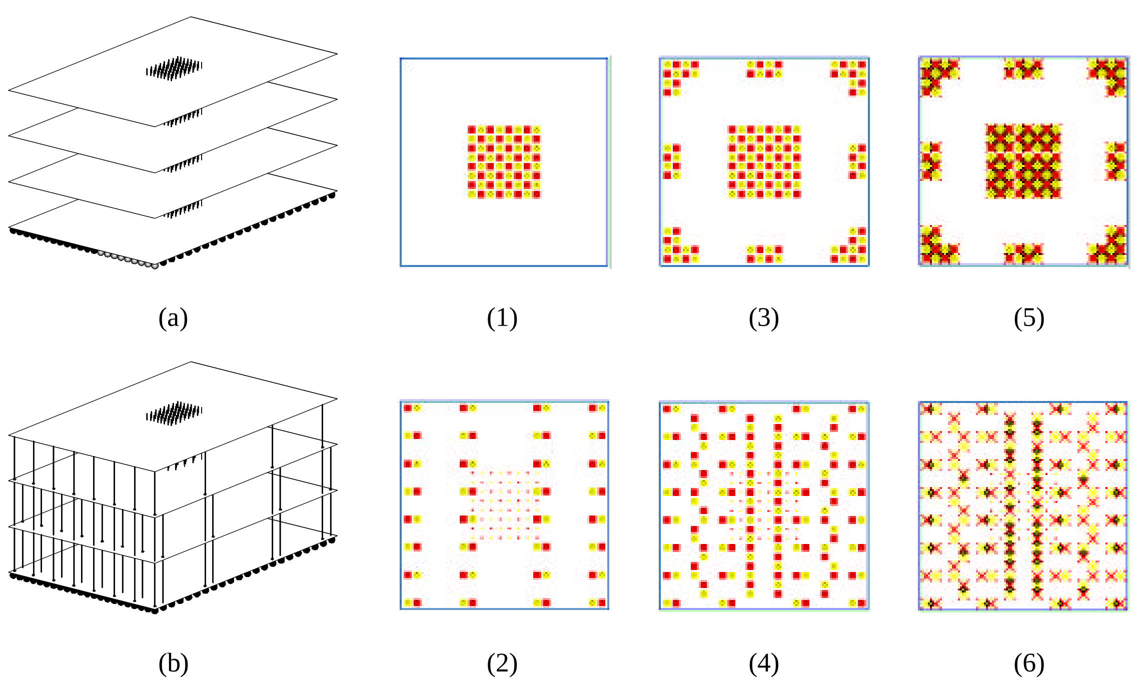

Figure 2. Package configuration for two different power and ground via distributions: (a) is for centered distribution; (b) is for uniformed distribution. (1) - (6) are top view of the power and ground via arrangements for case (1) - (6).

uniformed distribution where there are 378 power vias and 486 ground vias.

Simulation Results

With the software tool SPEED97, the input impedance as well as the effective inductance, looking into the package from the chip, of the power and ground system of the package is calculated and compared.

Figure 3 shows the magnitude of the input impedance for the six cases up to 2 GHz. The lowest package resonant frequency for each case is placed in the parenthesis of the legend of figure 3. For case 1 and case 2, one can see that the lowest package resonant frequency for the centered distribution is 42 MHz lower than that of the uniformed distribution. For case 3 and case 4, the lowest package resonant frequency for the centered distribution is 33 MHz higher than that of the uniformed distribution. For case 5 and case 6, the lowest package resonant frequency for the centered distribution is 6 MHz lower than that of the uniformed distribution. One can see that, with the same or comparable number of the power and ground vias, the lowest package resonant frequencies for two via distributions are close to each other.

For the first case of two via distributions, there are 32 pairs of power and ground vias in the package, the lowest resonant frequency of the package is around 1 GHz. After adding another 40 pairs of power and ground shorting vias into the package, the lowest package resonant frequency is increased to about 1.63 GHz. With additional power and ground vias as in case 3, the lowest package resonant frequency is shifted further up to about 1.81 GHz.

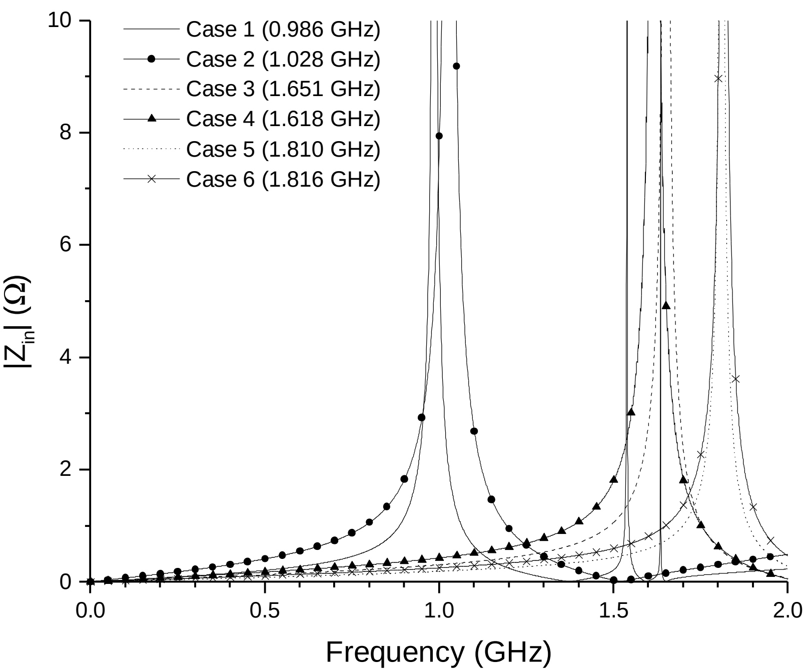

Figure 3. Input impedances of the package.

Figure 4 shows the effective inductance of the package for six cases. The dc effective inductance for each case is indicated in the parenthesis of the legend of figure 4. One can see that the effective inductance of the package with centered power and ground via distribution is always lower than that for the uniformed distribution. This is because that for centered power and ground via distribution, the current loop through power and ground vias is smaller than that of the uniformed distribution. For the first case of two distributions, the effective inductance for the centered power and ground via distribution is half of that for the uniformed distribution. By adding power and ground vias, for the centered power and ground via distribution, the effective inductance is reduced from 55 pH to 26 pH; and for the uniformed distribution, the effective inductance is decreased from 110 pH to 34 pH. So one can see that the centered power and ground via distribution can provide lower effective inductance than the uniformed distribution, even though the total number of power and ground vias for the centered distribution is less than that for the uniformed distribution.

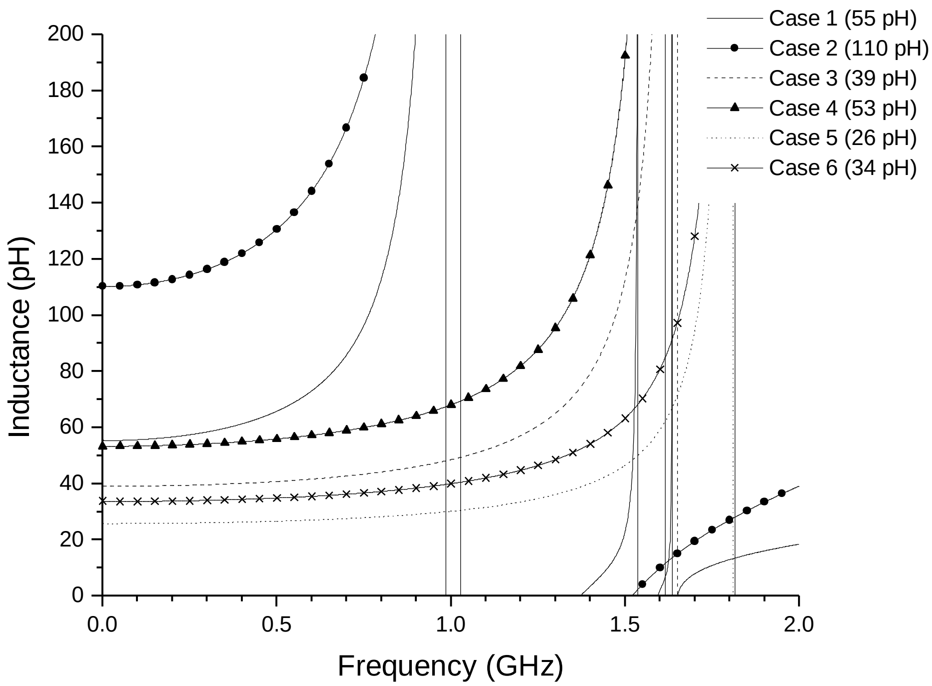

Figure 4. Effective inductances of the package.

Conclusion

Two types of distributions of power and ground vias in packages are studied. It is found that, with more power and ground vias, the lowest package resonant frequency can be moved higher. Among the two types of via distributions, there is no obvious difference in their lowest package resonant frequencies if the total number of vias are about the same, but the centered via distribution provides substantially lower effective inductance than the uniformed via distribution.

Acknowledgment

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