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Mitigate Voltage Regulator Switching Noise Coupling in the Frequency and Time Domains

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Abstract

The voltage regulator switching noise is an unavoidable problem in the server system. It degrades the signal integrity of the signal trace nearby the VR area. Two effective ways to reduce VR noise are shortening the distance and making back-drill. This paper verified these two ways by simulating three cases: power plane coupling, VR vias coupling to signal line, and VR vias coupling to signal vias. Finally, it shows that shortening distance and making back-drill significantly reduce crosstalk in the frequency and time domains.

1 Introduction

The rapid switching voltage regulator (VR) and non-ideal power delivery network produce high-frequency noise; the unavoidable primary noise source in the server system degrades the high-speed signal. Hence, this paper presents two main ways to reduce noise coupling: shortening the distance and making back-drill. Furthermore, these two ways are verified in three different cases, including broadside coupling (power plane coupling), orthogonal coupling (the VR vias coupling to the signal line), and vertical coupling (the VR vias coupling to the signal transmission via) [1].

The proposed way is expected in the prior art, but there are only offered simulation results in the frequency domain, and it is hard to estimate the impact in the pre-simulation stage [1]. Despite the other studies proposing that the crosstalk results only focus on VR switching noise coupling signal lines, different coupling paths are needed to consider nowadays [2, 3]. Thus, in this paper, we proposed simulation results, including the S-parameter and crosstalk magnitude, which means there are simulations of the frequency and time domain. We also focused on the three coupling methods mentioned above that could cause severe coupling effects on nearby signals.

Figure 1 shows the three coupling methods. First is the power plane coupling; even if there is a metal plane between the signal line and the noisy VR voltage plane, VR switching noise still affects the signal line by the potential difference in practice. Second is the noisy VR vias coupling to the signal traces. The detail of the coupling mechanism is introduced in [3]. The last is noisy VR vias coupling to the signal vias, and the current loop causes the central coupling [2]. According to the previous studies, we can suppress the crosstalk by increasing distance separation and applying back drilling. Both ways have a good effect on solving the VR coupling problems. The following sections will give simulation results in the frequency and time domains. The frequency domain results are simulated in ANSYS HFSS, and the ADS schematic obtains the time domain results.

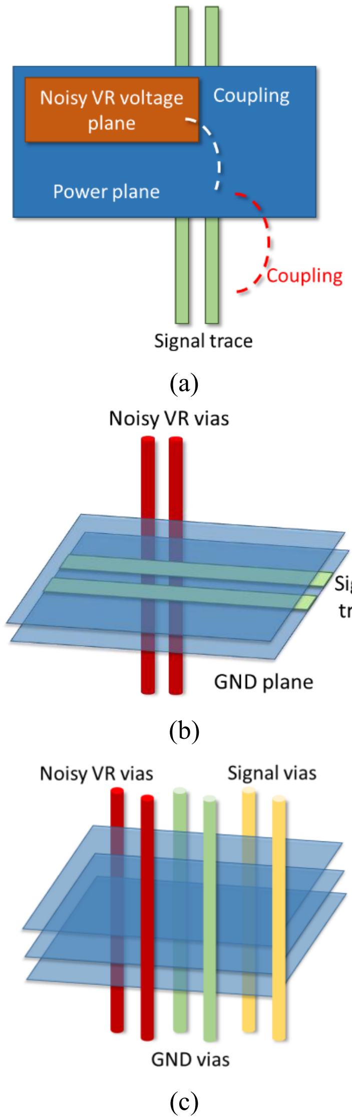


Figure 1. (a) Broadside coupling; (b) orthogonal coupling; (c) vertical coupling.

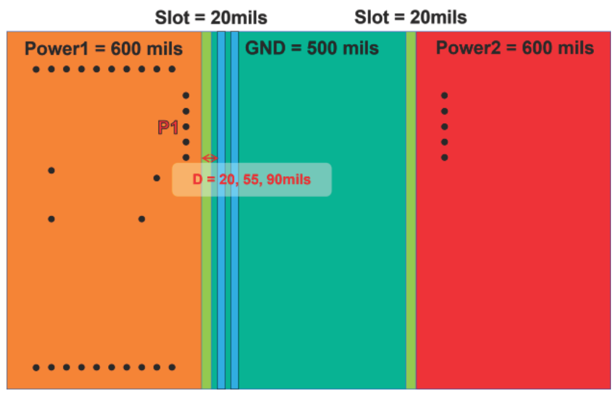
2 VR Switching Noise Coupling Mitigation

This section proposes the mitigation method and results of the three above-mentioned cases in the frequency and time domains.

2.1 Broadside coupling

Broadside coupling means the VR switching noise couples to the signal traces through the power or ground plane. In this case, we adjust the distance between the power/ground plane and the signal trace; the length is 20, 55, and 90 mils, respectively, as shown in Figure 2.

Figure 3 shows that the longer distance, the minor crosstalk in the frequency domain. Furthermore, the crosstalk magnitude in the time domain is also verified in Figure 4. So, distance is an essential factor in keeping signal integrity near the VR area and changing the signal traces to another layer is an effective method. Hence, the differential signal traces change to the below layer in the following two cases to confirm slight crosstalk from the power/ground plane.



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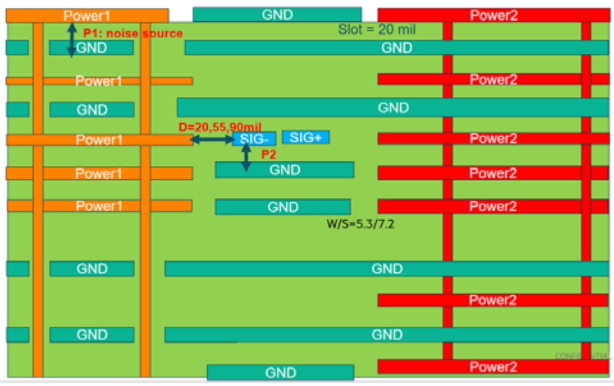


(b)

Figure 2. (a) Top view; (b) cross-sectional view.

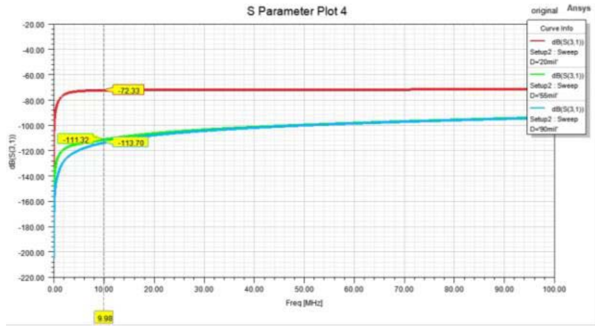
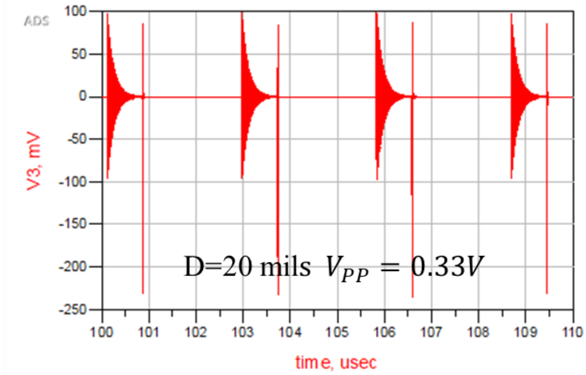


Figure 3. The crosstalk magnitude in the frequency domain. Depends on the distance between the power/ground plane and signal trace is (a) 20 mils, (b) 55 mils, (c) 90 mils



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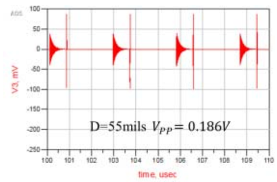
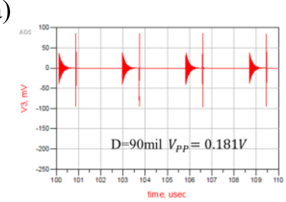




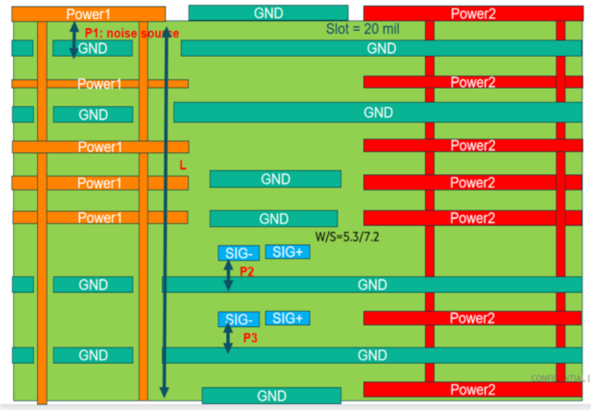
(b) (c)

Figure 4. The crosstalk magnitude in the time domain. Depends on the distance between the power/ground plane and signal trace is (a) 20 mils, (b) 55 mils, (c) 90 mils

2.2 Orthogonal coupling

The second case is to show the impact of back-drill. Even if broadside coupling noise is slight here, there is still noise from VR vias. Figure 5 (a) is the original structure, (b) is back-drilled VR vias, and the victim differential signal traces are P2 and P3. The distance

Figure 6 (a) is crosstalk from P1 to P2, and (b) is crosstalk from P1 to P3. Furthermore, Figure 7 shows crosstalk in the time domain. According to the results, the crosstalk decreases unremarkably at P2 because a stub of the VR vias can't be removed in practice. It still excites the electromagnetic wave and crosstalk to the P2 by the multi-layer stack. However, the crosstalk of P3 is decreased by 14 % in the time domain.



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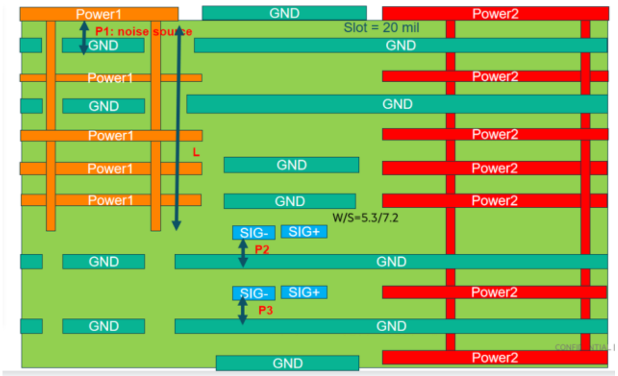
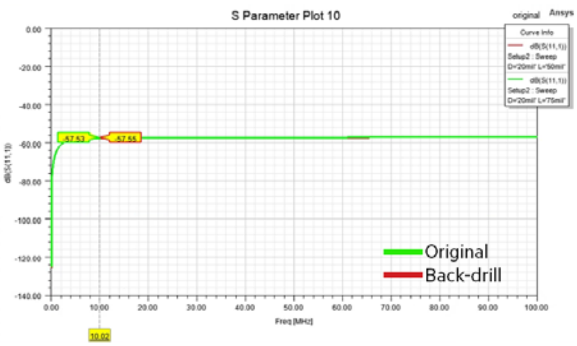


(b)

Figure 5. (a) Original structure; (b) back-drilled VR via.



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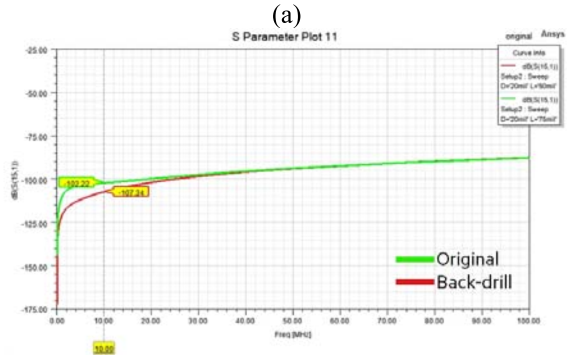
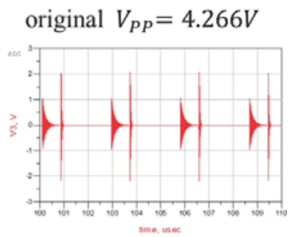
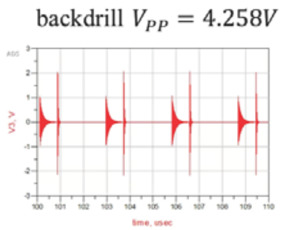


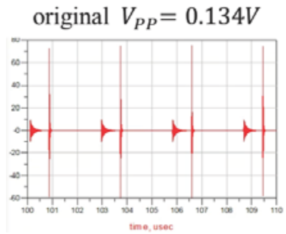
(b)

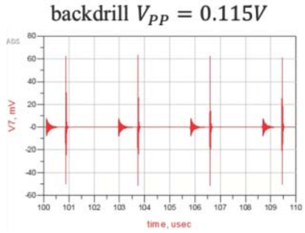
Figure 6. (a) Crosstalk from P1 to P2; (b) crosstalk from P1 to P3.





(a) (b)



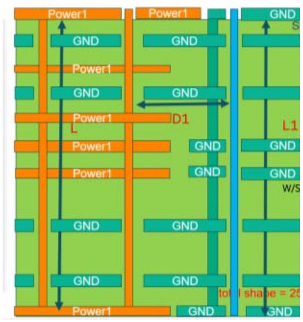


(c) (d)

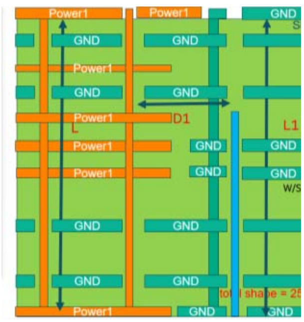
Figure 7. (a) Crosstalk from P1 to P2 for the original structure, (b) for the back-drilled VR vias structure. (c) Crosstalk from P1 to P3 for the original structure, (d) for the back-drilled VR vias structure.

2.3 Vertical coupling

The VR vias excite the noise and which is picked up by the signal vias, which is called vertical coupling. Figure 8 shows four cases to verify that the back-drilled vias mitigate the VR switching noise crosstalk. The results show that vias back-drilled signal and VR are the best results. If signal and VR vias are back drilled, the crosstalk almost being eliminated, as shown in Figures 9 and 10



(a)



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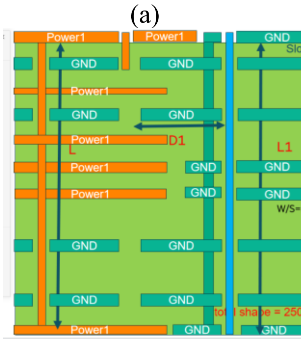

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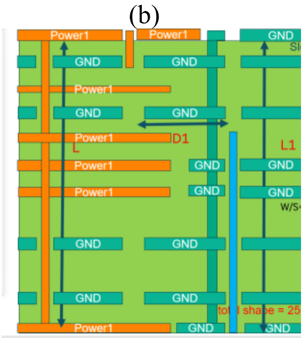

(d)

Figure 8. (a) case1: no back-drilled; (b) case2: only signal via back-drill; (c) case3: only VR vias back-drilled; (d) case4: both back-drilled.

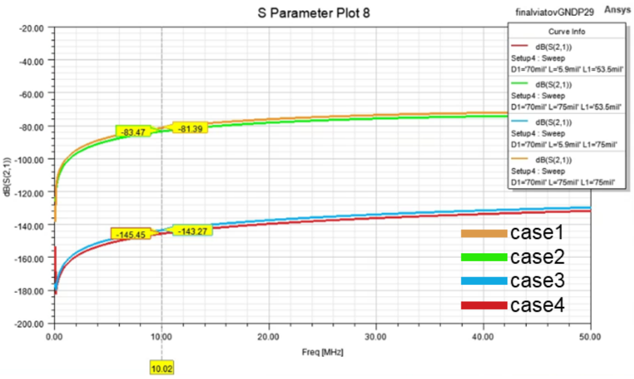

Figure 9. Crosstalk magnitude of four cases in the frequency domain.

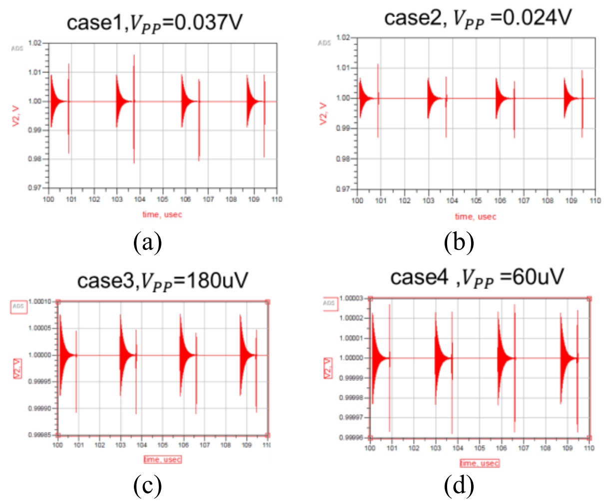

Figure 10. Crosstalk magnitude of four cases in the time domain.

Summary

This paper proposes the mitigation method of VR switching noise in three cases and verifies them in the frequency and time domains. First, keep the change between the signal traces and VR noisy area. The effective method is changing the signal traces to different layers to avoid broadside coupling. Second, the back-drilled VR vias orthogonally couple to the signal traces by the stub. This condition must be needed to prevent because the crosstalk is significant here. Ultimately, the vertical orthogonal coupling is the primary coupling mechanism. If the vias are not back drilled, the crosstalk is more than the other two coupling in the same distance. Therefore, the back-drilled VR and signal vias must be used nearby the VR area.

Acknowledgments

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