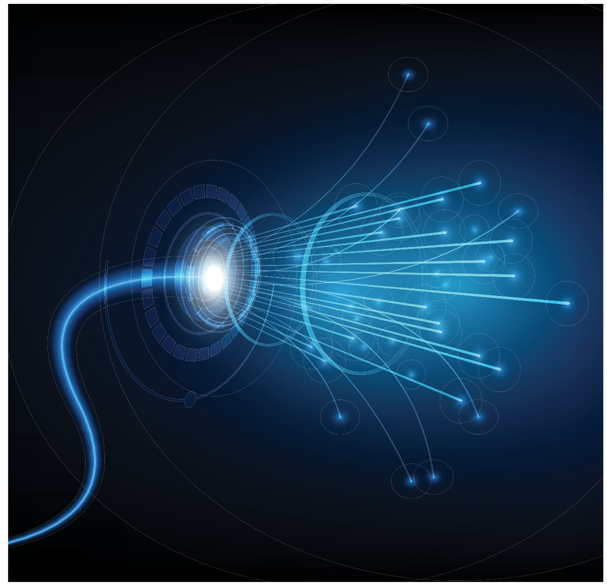
INNOVATIVE DESIGNS FOR OPTIMIZING 112G+ BGA FAN-OUT AND CONNECTOR FOOTPRINT CROSSTALK

Abstract

As the SerDes speed is reaching 112Gbps and beyond, crosstalk energy increases greatly. The reason is that crosstalk usually has higher coupling energy in the high-frequency region. The far-end crosstalk energy will decrease dramatically after attenuation through the system link. However, the near-end crosstalk energy will couple to the receiver almost without attenuation. The passive system crosstalk mainly comes from BGA component, addresses the optimization of line component and connector component. This paper aims at optimizing the crosstalk of BGA and connector component. The potential crosstalk sources in the BGA and connector area include the coupling of one differential-line to another differential-hole, the coupling of one differential-line to another differential-pad, and the coupling of one differential-hole to another differential-hole. As BGA pitch decreases, the noise generated by these crosstalk sources gradually increases. Therefore, it becomes an inevitable challenge to implement the 112G+ system. We propose a new routing structure which can reduce the coupling between transmission line and other passive components. We also propose a novel fan-out design, where the coupling between two pairs of differential holes is reduced.



1. Introduction

When the data rate reaches 112G+, the crosstalk noise index becomes more and more critical because of the following two reasons: First, compared with NRZ, the crosstalk noise of the PAM4 has a greater impact on COM (Channel Operating Margin), and it is more obvious in PAM6 and PAM8[1]. Secondly, with the increase of the baud rate fb, the ICN (Integrated Crosstalk Noise) value increases under the same crosstalk S parameter. Taking the ICN of FEXT equation (1-1)[2] as an example.

$$\sigma_{fx} = \left((A_{ft}^2 / 4 f_b) 2\Delta f \sum_{50M}^{0.75fb} \sin c^2 (f / f_b) \left[\frac{1}{1+(f/f_{ft})^4} \right] \left[\frac{1}{1+(f/f_r)^8} \right] 10^{-MDFEXT_{loss}(f_n)/10} \right)^{1/2} \quad (1\text{-}1)$$

Suppose that the integral item is constant C, the above formula can be changed to

$$\sigma_{fx} = \left((A_{ft}^2 / 4 f_b) 2\Delta f \, \frac{0.75fb - 50M}{\Delta f} \times C \right)^{1/2} \approx (0.75 A_{ft}^2 C / 2)^{1/2} \quad (1\text{-}2)$$

The fb of the signals above 112Gbps is much larger than 50M.
Therefore, formula (1-2) can be simplified as formula (1-3).

$$\sigma_{fx} \approx (0.75 A_{ft}^2 C / 2)^{1/2} \quad (1\text{-}3)$$

The value above is a constant. We only need to demonstrate that C increases with f_b. The amplitude of crosstalk increases with the increase of frequency[3]. Therefore, $10^{-MDFEXT_{loss}(f_n)/10}$ increases with the increase of frequency.

$$\text{PWF} = \operatorname{sinc}^2(f/f_b)\left[\frac{1}{1+(f/f_{ft})^4}\right]\left[\frac{1}{1+(f/f_r)^8}\right] \qquad (1\text{-}4)$$

As f_b changes, the figure below shows the relationship between PWF and frequency. As can be seen from Figure 1, the PWF function is an increasing function.

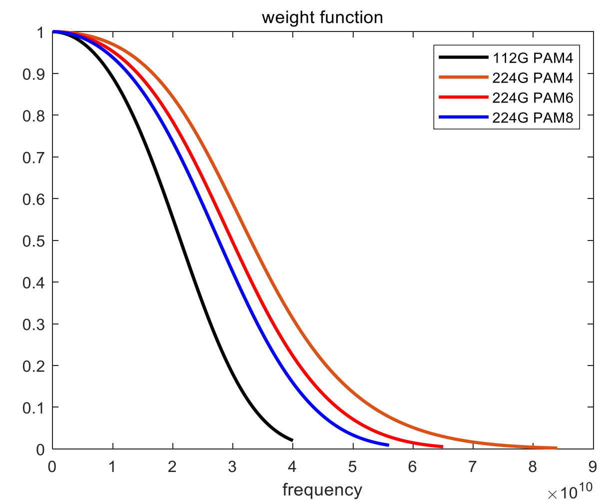


Figure 1 PWF function curve

This means that the expression in the integral item of equation (1-1) is an increasing function of f_b, so the same S parameter will increase with the increase of f_b.

The 224G PAM4, PAM6 and PAM8 systems have increased baud rate compared with the 112 G PAM4 system, and the increase of baud rate will lead to the increase of crosstalk ICN.

The main sources of crosstalk in the passive system are BGA footprint, connector body and connector footprint. The connector body is managed and controlled by the connector manufacturer. Therefore, BGA footprint and connector footprint are key challenges in system design.

The crosstalk sources in the BGA area and the connector area on the PCB can be divided into V2V (via to via) crosstalk, L2V (line to via) crosstalk, and L2P (line to pad) crosstalk. This paper introduces the way to optimizes these three crosstalk types, so that the 112G+ system can obtain a better ICN value.

2. Simulation and measurement of L2V crosstalk and L2P crosstalk

2.1. The simulation and optimization of BGA footprint

The coupling modes of L2P crosstalk and L2V crosstalk are similar. Therefore, this part mainly focuses on the simulation and optimization of L2P crosstalk, and then applies the same method to L2V coupling. The figure 2 shows L2P and L2V 3D structure.

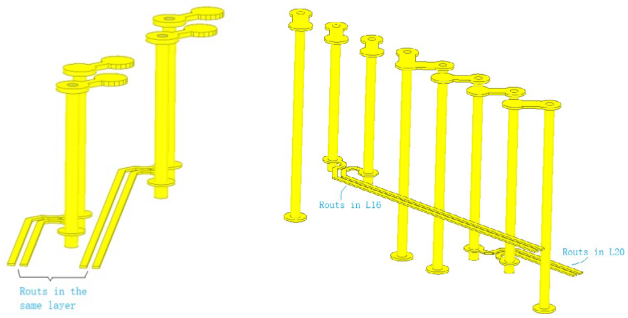


Figure 2 The 3D structure of L2P(right) and L2V (left)

In Figure 3 is a 2D structure of L2P, showing the parameters used in this simulation. Pad means the diameter of the pad. Drill means the diameter of the pre-plated via. Width means the width of the transmission line. Spacing means gap between the differential transmission line P and N. D2L means the gap between the drill and nearest transmission line. L2P means the gap between the transmission line and the pad of signals via.

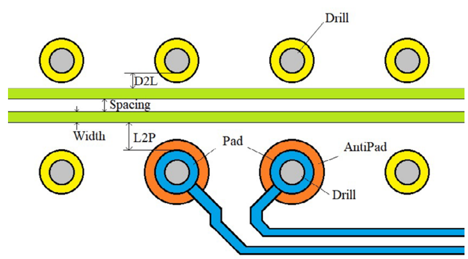


Figure 3 The 2D structure of L2P and D2L

The simulation of 1mm BGA

When the thickness of the copper is 0.5 oz., the Drill of 0.15 mm, the Width and Spacing of 2mil, the D2L of 6mil is the advanced processing capability corresponding to the 4 mm board thickness of the current board factory. If the thickness of the copper is increased to 1 oz., the Drill of 0.15 mm, the Width and Spacing of 2.5mil, the D2L of 6mil is the advanced processing capability corresponding to the 4 mm board thickness of the current board factory. Calculate the ICN by S parameter obtained through simulation and plot the ICN curves (the parameter configuration of 112G PAM4 adopts the recommended value in OIF[4]).

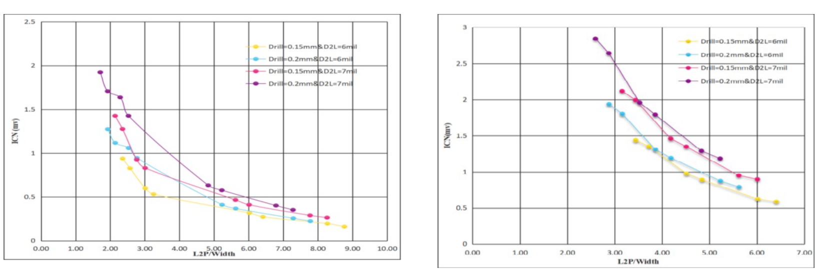


Figure 4 The changes of ICN (112G PAM4) with L2P / Width at 0.5oz. (left) and 1oz. (right)

As shown in Figure 4, as the L2P/width gradually decreases, the ICN almost increases exponentially. Therefore, the ICN of L2P is very sensitive to L2P/width. When the thickness of the copper foil is 0.5 oz. and L2P/width is greater than 5, the influence of the Drill and D2L value on ICN is not significant. When L2P/width is less than 5, the influence of Drill and D2L on ICN begins to be obvious. The smaller the L2P/width, the smaller the L2P. That is, the closer the line to the pad, the more electric field will be coupled to the via therefore, the influence of the Drill on ICN is more significant. The larger the Drill and the value of D2L, the larger the crosstalk. When the thickness of the copper is 1.0 oz. and D2L remains constant, the curve with Drill being 0.15 mm almost overlaps with the curve with Drill being 0.2 mm. This indicates that Drill has a weak influence on ICN. The L2P crosstalk of 1oz. is greater than that of 0.5oz.

When the thickness of copper foil is 1.0oz., and the structure of D2L is identical, the curve of drill 0.15mm coincides with the curve of drill 0.2mm, which indicates that the influence of drill on ICN is little and the crosstalk from D2L is greater than 0.5oz.

Figure 5 shows the comparison of 0.5oz. and 1oz. Data. The ICN value at 1 oz. is about twice than that at 0.5 oz. under the same condition.

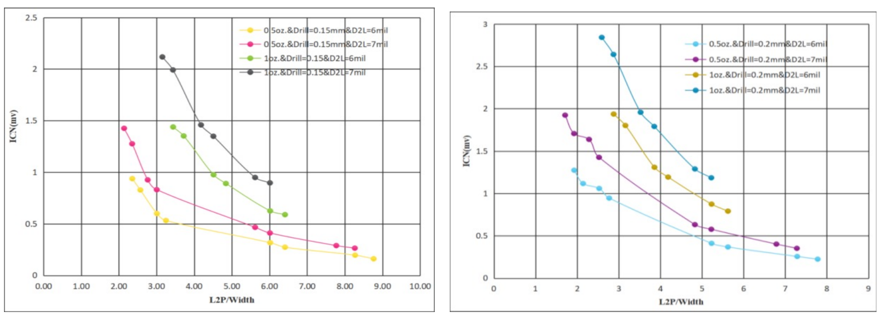


Figure 5 The comparison of crosstalk ICN (112G pam4) with 0.5oz. copper thickness and 1oz. copper thickness when drill is 0.15mm (left) and 0.2mm (right)

The simulation of 0.85mm BGA

When the 0.85 mm pitch BGA is simulated, it uses the same advanced processing capability as 1.0 mm pitch BGA, the simulation results are shown in Figure 6.

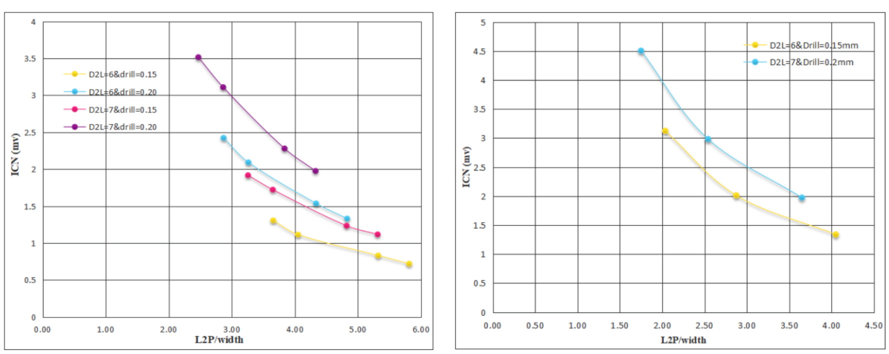


Figure 6 The variation of ICN (112G PAM4) with L2P/Width, D2L and drill when the copper is 0.5 oz. (left) and 1.0 oz. (right)

Similarly, ICN increases almost exponentially with the decrease of L2P/Width in 0.85mm BGA. Furthermore, the effect of copper thickness on crosstalk is compared in Figure 7.

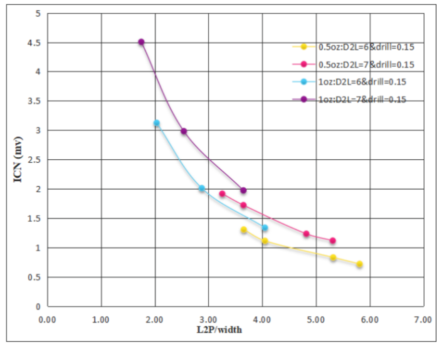


Figure 7 The comparison of crosstalk ICN (112G PAM4) between 0.5oz. copper and 1oz. copper

The crosstalk of 1oz. copper is still larger than that of 0.5oz. under the same conditions. If you want to get less L2P crosstalk, you need to use advanced processing capabilities, which means higher costs. In order to reduce the crosstalk of L2P and L2V, this paper introduces a new optimization method. The specific structure of this method is shown in the Figure 8.

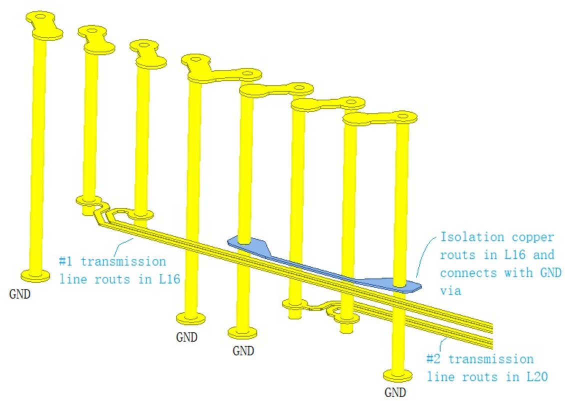


Figure 8 The structure of L2V after adding isolation copper

Figure 9 shows the contrast of electric field. When the isolation copper is added, the electric field coupled to the pad will be reduced, and most of the noise will be transmitted to the ground through the isolation copper.

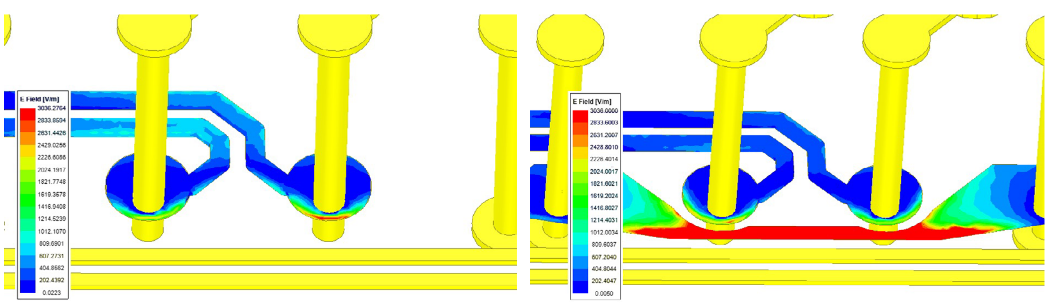


Figure 9 The comparison of electric field on copper and pad with (left) and without (right) isolation

The optimization of 0.85mm BGA 0.5oz.

Get the crosstalk data with and without isolation copper from simulation. It can be seen the improvement of ICN in Figure 10.

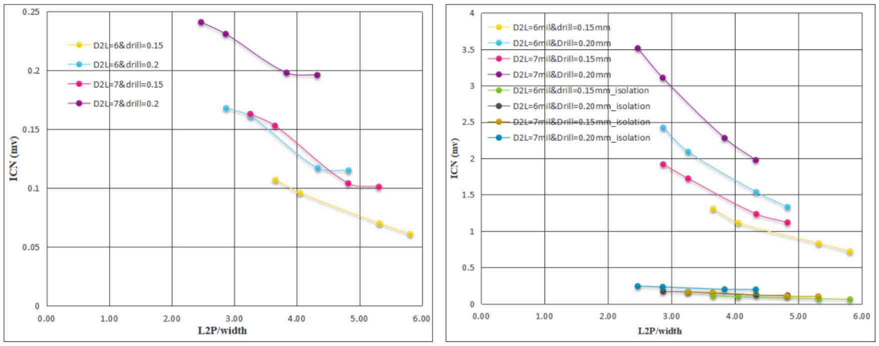


Figure 10 The change of 0.5oz. copper ICN (112G PAM4) after optimization (left)
and the comparison of ICN (112G PAM4) with and without isolation (right)

The maximum crosstalk is 3.515mV, which is reduced to 0.241mV after optimization, with 93% improvement.

The optimization of 0.85mm BGA 1.0oz.

Table 1 the crosstalk (112G PAM4) comparison of 1 oz. copper by this optimization method.

Pad (mm)	Drill (mm)	Width (mil)	Spacing (mil)	D2L (mil)	L2P/Width	Original ICN	Optimized ICN
0.35	0.15	2.5	2.5	6	4.05	1.339 mV	0.106 mV
0.35	0.15	2.5	2.5	7	3.65	1.974 mV	0.195 mV

After optimization, the value of maximum crosstalk decreases from 1.974mv to 0.195mV, which is improved by 90%.

2.2. The simulation and optimization of connector footprint

To observe the noise in footprint, we create a footprint model base on TE Connectivity's STRADA Whisper Absolute PiC connector. The total board thickness is 4mm and there are 20 layers. The port definition is shown in Figure 11. The main noise contributor between P1 and P3 is L2V coupling. The main noise contributor between P5 and P7 is L2P coupling. And the main noise contributor between P1 and P5, or P7 and P8 is V2V coupling. Except for the connector ground vias, lots of SI vias are added between columns to isolate the noise.

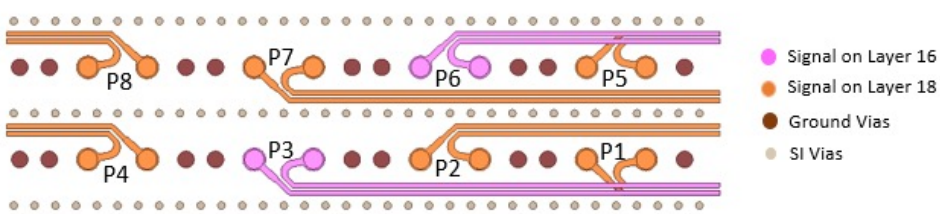


Figure 11 Footprint Port Definition

When two pairs next to each other or within one column are routed on the same layer, they will have trace to pad noise. For example, P5 and P7, the main noise contributor is the coupling between trace and pad (Figure 12).

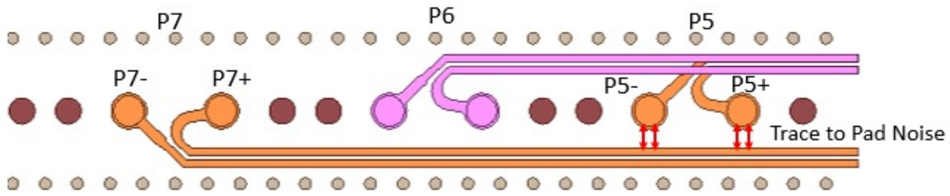


Figure 12 Trace to Pad Coupling

Due to the space limitation, the distance from trade-to-pad is not big enough. The coupling between trace and pad is tight. The coupling of P5 to P7+ is tighter than the coupling of P5 to P7-. So, the noise on P7+ is much bigger than the noise on P7- (Figure 13). After subtracting each other, there is still a big amount of noise left on P7.

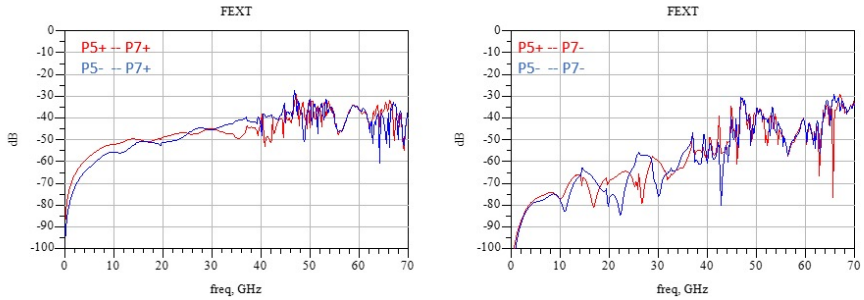


Figure 13 Trace to Pad SE Noise

We use the same routing structure as BGA to reduce the coupling between the trace and pad. It is shown in Figure 14. This new ground structure is placed between the trace and pad on the same layer. The noise can have more than 10dB improvement under 50 GHz with this ground isolation structure (Figure 15).

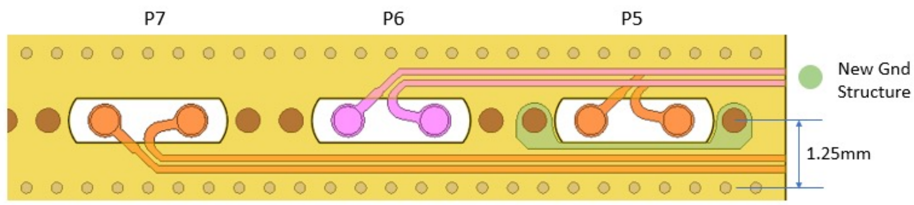


Figure 14 New Ground Isolation Structure

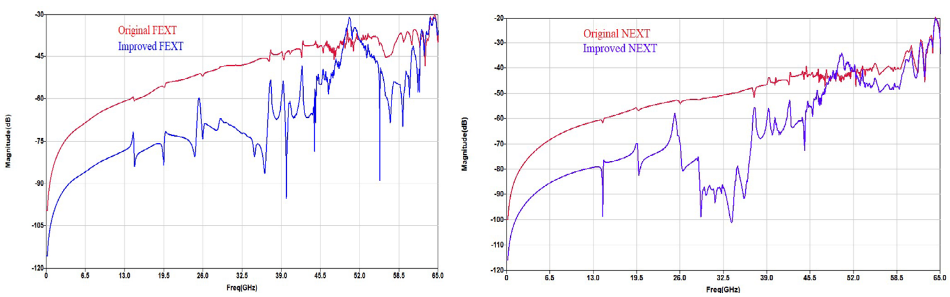


Figure 15 Improved Trace-to-Pad Noise

When two pairs are routed on the different layers, they may have trace to via noise. For example, P1 and P3, the main noise contributor is the coupling between trace and via. Since the distance from trace to via is a little bigger than distance from trace to pad, its noise is a little better. Same to L2P noise, it also can be improved by applying the ground isolation structure (Figure 16). The noise can have more than 10dB improvement under 50 GHz.

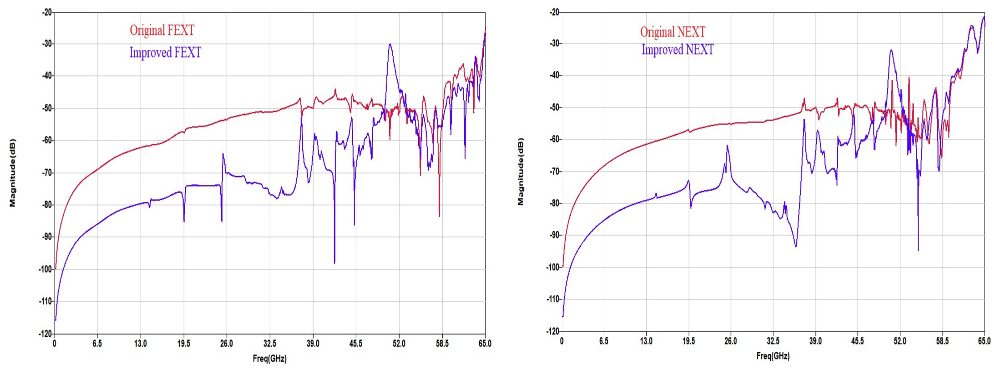


Figure 16 Improved Trace-to-Via Noise

The ground isolation trace can reduce the noise in footprint area dramatically. Looking at the 112G PAM4 ICN data, the coupling noise energy can be reduced by more than 85% (Table 2). For 224G ICN calculation[3], the setting may be not correct as the 224G is still under discussion. Therefore, the parameter configuration of 112G PAM4 is still used for all ICN calculations of 224G PAM6 in this paper, except that fb is changed from 56GHz to 86.66GHz, but we still can see the good improvement.

112G PAM4 ICN				
	NEXT ICN (mV)		FEXT ICN (mV)	
	Original	Improvement	Original	Improvement
T2P	0.733	0.114	0.797	0.11
T2V	0.574	0.084	0.573	0.086

Table 2 The data of ICN(112G PMA4)

224G PAM6 ICN				
	NEXT ICN (mV)		FEXT ICN (mV)	
	Original	Improvement	Original	Improvement
T2P	1.344	0.897	1.289	0.65
T2V	0.967	0.837	0.804	0.492

Table 3 The data of ICN (112G PMA6

2.3. Measurement

In this test, only the crosstalk of the BGA L2P is verified. The test board picture shows in Figure 17.

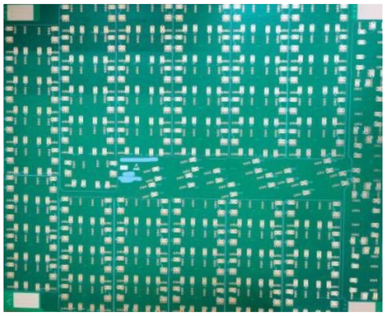


Figure 17 Test board of L2P in BGA

When the thickness of the copper is 0.5oz., the ICN results are showed in table 4.

	Width	Spacing	L2P/width	112G-PAM4 ICN (mV)	224G-PAM6 ICN (mV)
Without isolation copper	2 mil	2 mil	5.81	0.724	0.890
With isolation copper	2 mil	2 mil	5.81	0.123	0.225
Without isolation copper	2.5 mil	2.5 mil	4.05	1.029	1.178
With isolation copper	2.5 mil	2.5 mil	4.05	0.127	0.277
Without isolation copper	3.3 mil	2 mil	2.73	1.322	1.636
With isolation copper	3.3 mil	2 mil	2.73	0.177	0.225
Without isolation copper	3.8 mil	2.5 mil	1.98	2.19	2.502
With isolation copper	3.8 mil	2.5 mil	1.98	0.294	1.106

Table 4 The ICN(0.5oz.) results

When the thickness of the copper is 0.5oz., the ICN results are showed in table 4.

	Width	Spacing	L2P/width	112G-PAM4 ICN (mV)	224G-PAM6 ICN (mV)
Without isolation copper	3 mil	3 mil	2.87	2.283	2.477
With isolation copper	3 mil	3 mil	2.87	0.515	0.727

Table 5 The ICN (1.0 oz.) results

Plot the result of ICN (112G-PAM4), while the thickness of the copper is 0.5oz.

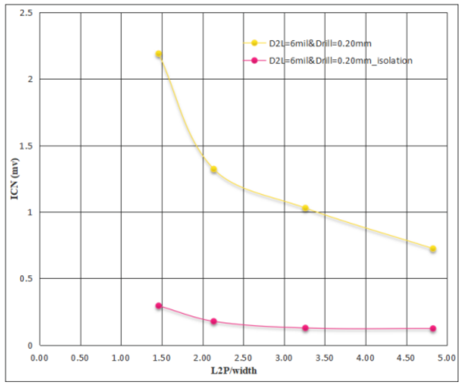


Figure 18 The comparison of ICN (0.5oz. copper) with and without isolation

The results show that when the thickness of copper is 0.5oz., the crosstalk ICN increases almost exponentially with the decrease of L2P/width, which is consistent with the simulation. The crosstalk of 112G PAM4 and 224G PAM6 is improved by more than 83% and 56% respectively after using isolation copper. Correspondingly, when the thickness of copper is 1oz., the crosstalk of 112G PAM4 and 224G PAM6 is also improved by 77% and 71% respectively by this method.

3. The simulation and measurement of V2V crosstalk

3.1. The simulation of V2V crosstalk in BGA footprint

The pitch of BGA is 0.85mm. Drill is 0.20mm. The material of PCB is R-5785(N). PCB thickness is 4 mm. The simulation cases are shown in Figure 19.

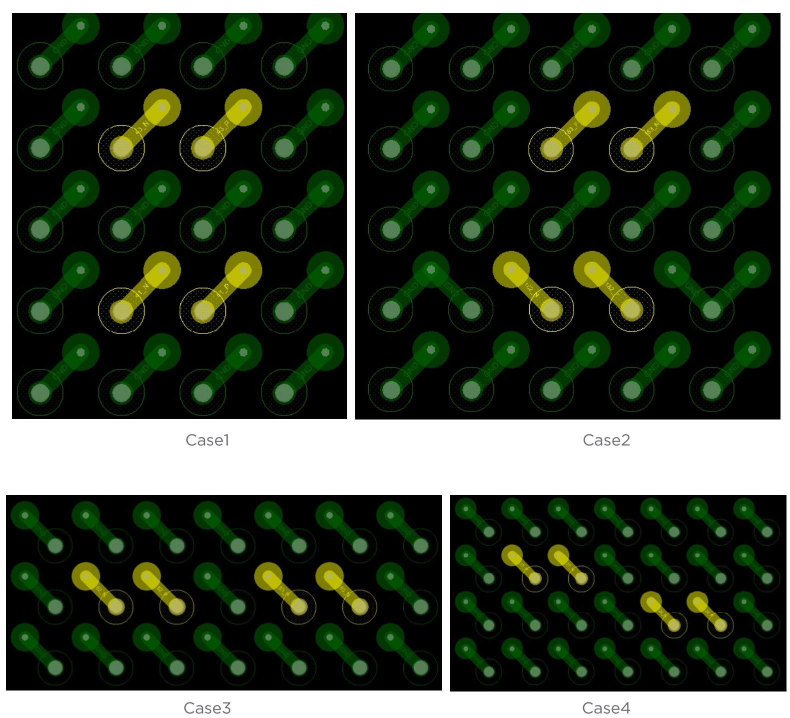


Figure 19 The structure of simulation case

The simulation of Case 1.

Create models to traverse the coupling length. The far-end crosstalk and near-end crosstalk are summarized in table 6. The row numbers in the table indicate the first pair of differential fan-out layers, and the column numbers indicate the second pair of differential fan-out layers. For example, the data in the first column of the second row is 0.296 mV, that is, the first pair of differential signals is fanned out in the L07 layer, and the second pair of differential signals is fanned out in the L05 layer. Currently, the crosstalk between the two lines is 0.296 mV.

case1	L05	L07	L09	L11	L13	L15	L17	L19	L21	L23
L05	0.29	-	-	-	-	-	-	-	-	-
L07	0.30	0.46	-	-	-	-	-	-	-	-
L09	0.26	0.45	0.59	-	-	-	-	-	-	-
L11	0.23	0.40	0.58	0.70	-	-	-	-	-	-
L13	0.23	0.37	0.53	0.70	0.79	-	-	-	-	-
L15	0.23	0.36	0.50	0.60	0.79	0.90	-	-	-	-
L17	0.25	0.40	0.49	0.59	0.77	0.91	1.01	-	-	-
L19	0.26	0.41	0.54	0.65	0.75	0.90	1.03	1.18	-	-
L21	0.25	0.41	0.53	0.63	0.79	0.88	1.06	1.25	1.34	-
L23	0.26	0.39	0.55	0.64	0.76	0.88	0.99	1.19	1.34	1.41

Table 6 case1 FEXT ICN (112G-PAM4) of traversing coupling length

case1	L05	L07	L09	L11	L13	L15	L17	L19	L21	L23
L05	0.30	-	-	-	-	-	-	-	-	-
L07	0.32	0.47	-	-	-	-	-	-	-	-
L09	0.27	0.47	0.60	-	-	-	-	-	-	-
L11	0.23	0.40	0.58	0.67	-	-	-	-	-	-
L13	0.23	0.35	0.49	0.65	0.70	-	-	-	-	-
L15	0.24	0.34	0.43	0.59	0.65	0.73	-	-	-	-
L17	0.25	0.39	0.43	0.54	0.64	0.66	0.77	-	-	-
L19	0.27	0.41	0.50	0.50	0.55	0.56	0.72	0.86	-	-
L21	0.26	0.40	0.49	0.52	0.54	0.57	0.58	0.81	0.93	-
L23	0.26	0.38	0.51	0.54	0.57	0.64	0.76	0.81	0.94	0.95

Table 7 case1 NEXT ICN (112G-PAM4) of traversing coupling length

According to the data in Table 6 and Table 7, the far-end crosstalk of the same coupling length is almost the same and increases with the increase of the coupling length. The maximum far-end crosstalk ICN is 1.413 mV, and the maximum near-end crosstalk ICN is 0.954 mV in Case 1.

The simulation of Case 2

Through the simulation of Case1, the coupling length is determined by the shortest via of the differential pair. Therefore, one of differential pair can be routed in L23 layers, and the other of differential pair is traversed to obtain crosstalk of different coupling lengths. Table 8 lists the simulation results of Case 2.

case2	L05	L07	L09	L11	L13	L15	L17	L19	L21	L21
L23	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.16	0.17

Table 9 Case 2: NEXT ICN (112G-PAM4) of traversing coupling length (Units: mV)

case2	L05	L07	L09	L11	L13	L15	L17	L19	L21	L21
L23	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.14	0.15

Comparing Case 1 with Case 2, it is found that the crosstalk of the V2V with the same BGA pin map, Case 2 is reduced by 84%.

The simulation of Case3

Table 10 and Table 11 list the far-end crosstalk and near-end crosstalk in the simulation of Case3.

case3	L05	L07	L09	L11	L13	L15	L17	L19	L21	L23
L23	0.48	0.75	1.00	1.24	1.47	1.63	1.86	2.11	2.30	2.47

Table 11 Case 3: NEXT ICN (112G-PAM4) of traversing coupling length (Units: mV)

case3	L05	L07	L09	L11	L13	L15	L17	L19	L21	L23
L23	0.41	0.62	0.78	0.85	0.87	0.80	0.76	0.86	1.09	1.28

The crosstalk ICN of Case 3 is larger than that of Case1 and Case2. Case3 is commonly used in BGA fan-out. Therefore, it is necessary to optimize the crosstalk, see Figure 20.

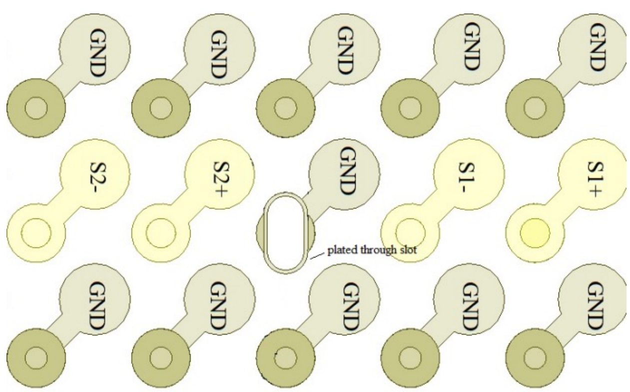


Figure 20 Design of improving case 3 crosstalk

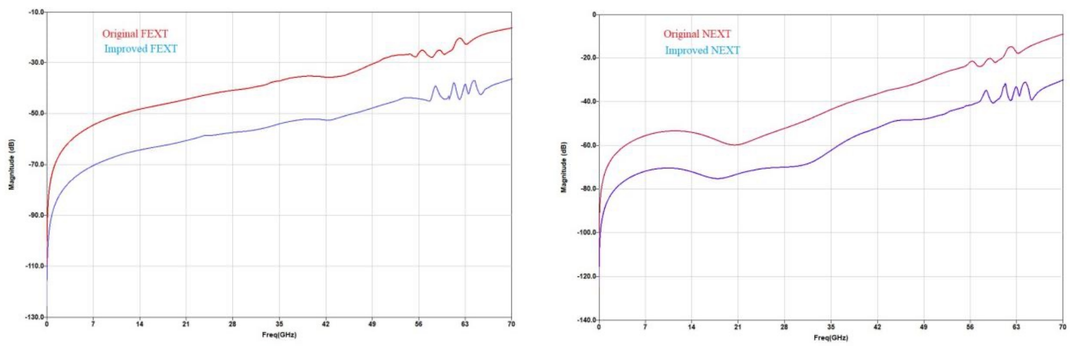


Figure 21 Comparison of FEXT (left) and NEXT (right) before and after improvement

The optimized far-end crosstalk is 0.36 mV, and the 85% is improved. The optimized near-end crosstalk is 0.15 mV, and the 88% is improved.

The simulation of Case4

The simulation results of the far-end crosstalk of Case4 are shown in Table 12, and the near-end crosstalk simulation results are shown in Table 13.

Case4DK1	L07	L11	L15	L19	L23
L23	0.393	0.642	0.871	1.091	1.345

Table 13 Case 4: NEXT ICN (112G-PAM4) of traversing coupling length

Case4DK1	L07	L11	L15	L19	L23
L23	0.395	0.540	0.538	0.538	0.723

The simulation result shows that the ICN of Case4 is better than that of Case 3.

3.2. The simulation of V2V crosstalk in connector footprint

There are different cases of V2V noise. One is the V2V noise in column, like the noise between P7 and P8 shown in figure 11. The other one is the V2V noise between columns, like the noise between P4 and P8 shown in figure 11. As the board thickness increase, the noise will be worse.

V2V Between Columns Noise Optimizations

Since the distance from P4 traces to P8 is far enough, the T2P noise can be ignored. The main noise contributor between P4 and P8 is V2V noise. Lots of SI vias are added between columns to isolate the coupling. But the crosstalk is still not low enough. It needs to enhance the isolation between columns. Maybe we can increase the density of SI vias to enhance the isolation between columns. But here we want to propose a new design. It is shown in Figure 22 and called C-slot. The C-slot of X direction at the connector ground press-fit hole location will be drilled first, then plating. After that, the resin will be filled in the slot. And then drill the hole and do the plating again. This C-slot is more like a shielding inside PCB and most of the coupling between columns are isolated. With this C-slot, the noise can be improved more than 25dB up to 65GHz (Figure 21).

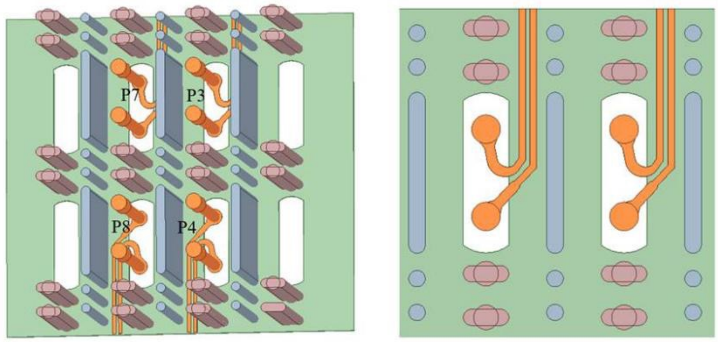


Figure 22 C-slot Between Columns

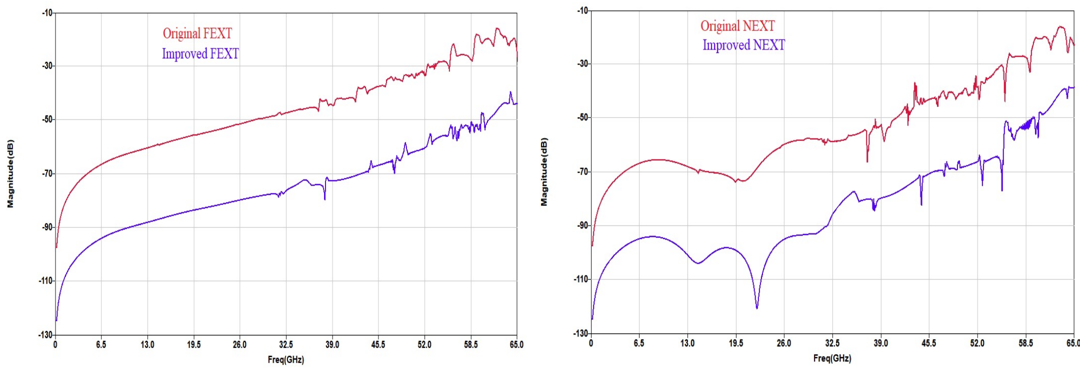


Figure 23 Improved V2V Between Columns Noise

V2V in Column Noise Optimization

The P7 traces and P8 traces are routed in the different direction, so the main noise contributor is V2V in column noise between P7 and P8. The C-slot also can be used to improve the noise between P7 and P8 (Figure 11). The crosstalk can be improved more than 15dB up to 65GHz (figure 11).

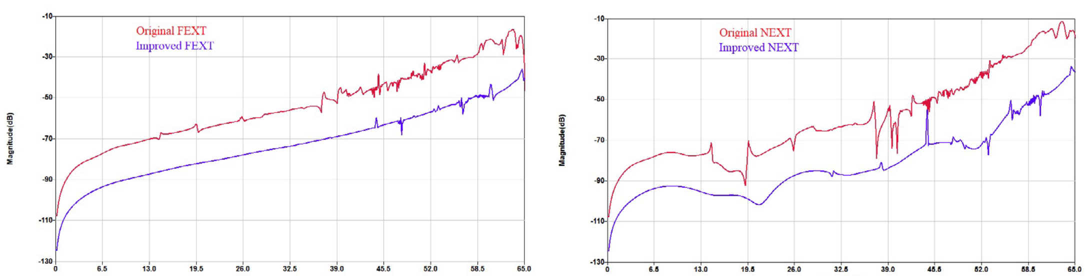


Figure 11. Improved V2V in Column Noise

The results of the connector V2V crosstalk ICN simulation are summarized in Table 14 and Table 15.

Table 14 The crosstalk ICN (112G-PAM4) of V2V

	112G PAM4 ICN			
	NEXT ICN (mV)		FEXT ICN (mV)	
	Original	Improvement	Original	Improvement
V2V in Column	0.733	0.114	0.797	0.11
V2V Bet Column	0.574	0.084	0.573	0.086

Table 15 The crosstalk ICN (112G-PAM6) of V2V

	224G PAM6 ICN			
	NEXT ICN (mV)		FEXT ICN (mV)	
V2V in Column	3.51	1.652	2.283	1.252
V2V Bet Column	4.8	0.21	3.826	0.195

3.3 Measurement

This test board only verifies the V2V crosstalk of the BGA. From the simulation data, the larger the coupling length, the larger the crosstalk. Therefore, only the sample with the longest coupling via crosstalk is designed in this test board. The coupling length is 3.8 mm.

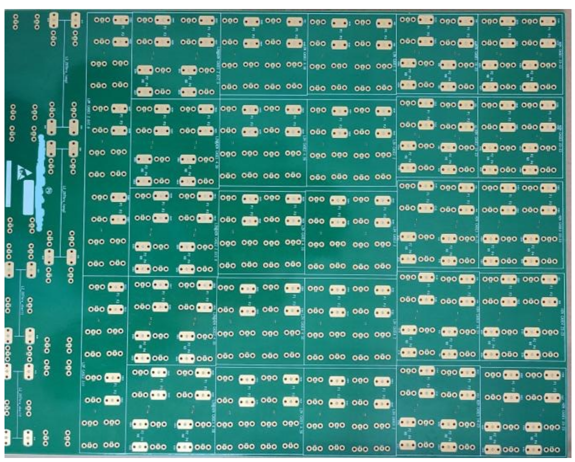


Figure 24 Test board of V2V in BGA

The test data is listed in Table 16. The optimized design of Case 3 is developed after this test board is made, so this solution is not designed in this test board.

	112G PAM4(mV)	224G PAM6 (mV)
V2V_case1	2.543	3.134
V2V_case2	0.448	0.714
V2V_case3	2.866	3.686
V2V_case4	1.573	2.049

Table 16 The FEXT ICN of V2V_case

	112G PAM4(mV)	224G PAM6 (mV)
V2V_case1	1.576	2.577
V2V_case2	0.327	0.696
V2V_case3	1.807	3.241
V2V_case5	1.031	1.839

Table 17 The NEXT ICN of V2V_case

According to the test result, the ICN trend of the V2V is consistent with the simulation result. The fan-out mode of V2V_Case2 is less crosstalk and can be used for specific purposes. The crosstalk of V2V_Case1 and V2V_Case3 is very large. Avoid it in the fan-out design.

4. System validation

Add the model before and after optimization into the system link and compare the improvement. The BGA uses the V2V crosstalk Case 3 model, the connector uses the V2V Bet Column model, and the connector body uses the same two channels. The system crosstalk S parameter is shown in Figure 17.

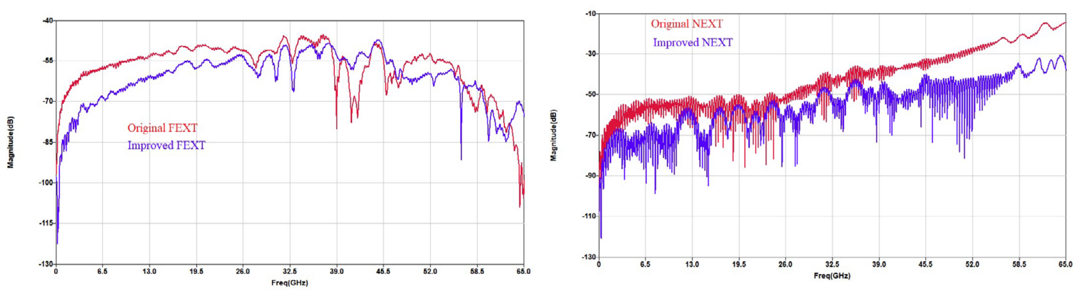


Figure 25 The comparison of crosstalk with and without optimization

Table 18 and Table 19 show the ICN comparison results. The near-end crosstalk is improved by 76% and the far-end crosstalk is improved by 44% in the situation of 224G PAM6.

112G PAM4 ICN			
NEXT ICN (mV)		FEXT ICN (mV)	
Original	Improvement	Original	Improvement
1.23	0.50	1.07	0.54

Table 18

224G PAM6 ICN			
NEXT ICN (mV)		FEXT ICN (mV)	
Original	Improvement	Original	Improvement
3.02	0.72	1.03	0.58

Table 19

5. Conclusion

This paper describes the order of magnitude of crosstalk for L2P, L2V and V2V through simulation analysis. The isolation copper solution is used to optimize L2P and L2V. The isolation slot solution and targeted fan-out solution are used to optimize the crosstalk of V2V. Further, make a test board to verify the optimization method. When the thickness of the copper is 0.5 oz., after the isolation copper is used on the test board, the crosstalk is improved by over 83% (112G PAM4) and over 56% (224G PAM6). When the thickness of the copper is 1 oz., after the isolation copper is used on the test board, the crosstalk is improved by over 77% (112G PAM4) and over 71% (224G PAM6). After the V2V crosstalk uses a specific fan-out, the 112G PAM4 crosstalk is improved by about 80%, and the 224G PAM6 crosstalk is improved by about 73%. Finally, the optimization solution is added to the system for verification. After the optimization solution is used, the crosstalk in the system is improved significantly.

6. Future work

- The connector part only performs Simulation ptimization was performed on the connector part only, and the next step is to test and verify the connector optimization solution.
- Only the L2P sample of BGA is designed in this test board, and the next step is to test and verify the L2V crosstalk of BGA. At the same time, test and verify the optimized design of Case3 at V2V

[1] “224G Analysis using Channel Operating Margin”, OIF document number: oif2021.044.00

[2] “Common Electrical I/O (CEI) - Electrical and Jitter Interoperability agreements for 6G+ bps, 11G+ bps,25G+ bps I/O and 56G+ bps”, OIF document number:oif2018.161.00

[3] F. D.Mbairi,W. P. Siebert, and H. Hesselbom, “High-frequency transmission

lines crosstalk reduction using spacing rules,” IEEE Trans. Compon.Packag. Technol., vol. 31, no. 3, pp. 601–610, Sep. 2008.

[4] “CEI-112G-LR-PAM4 Long Reach Interface”, OIF document number:oif2018.212.12

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