SW Test Workshop
Semiconductor Wafer Test Workshop
2-0-1-7

Probe Pattern Design for Low-Cost and High-Speed Loopback Test

Norman
Chunghwa Precision Test Tech

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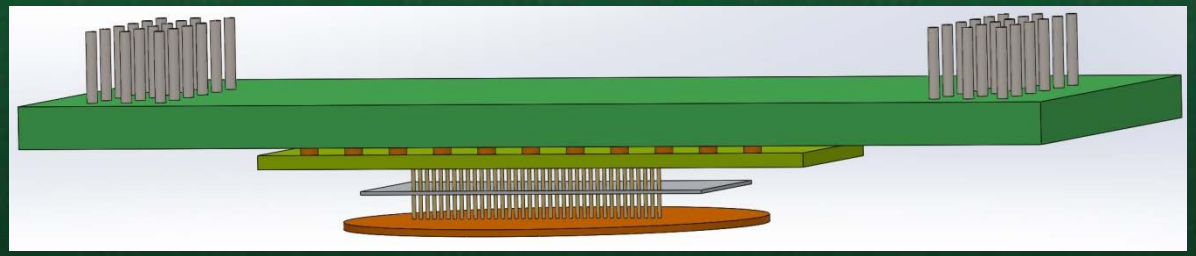
Overview

- VPC Test Structure
- The Importance of Impedance Continuity
- Impedance Control on Probe Pattern
- The Best Transmission Structure
- Examples of How to Find the Most Appropriate Solution
- Conclusion

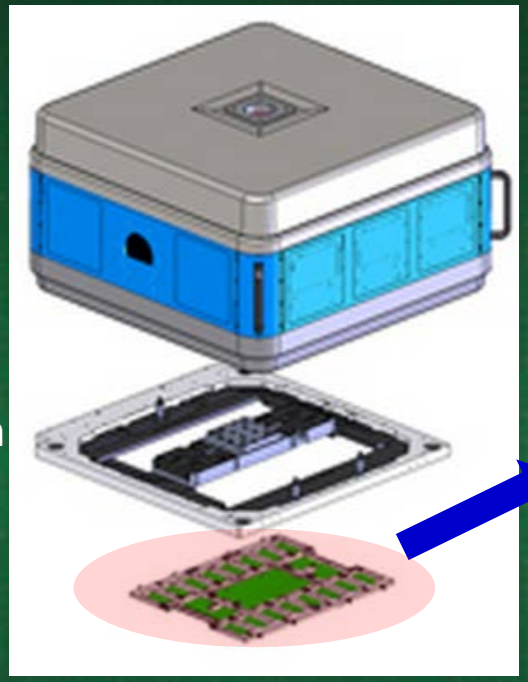


VPC Test Structure

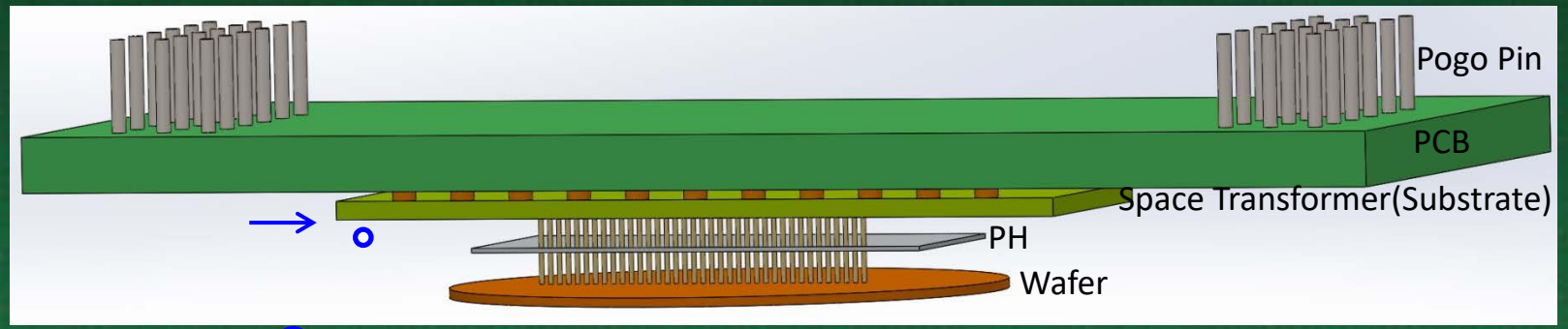
ATE

Bridge Beam

Probe Card



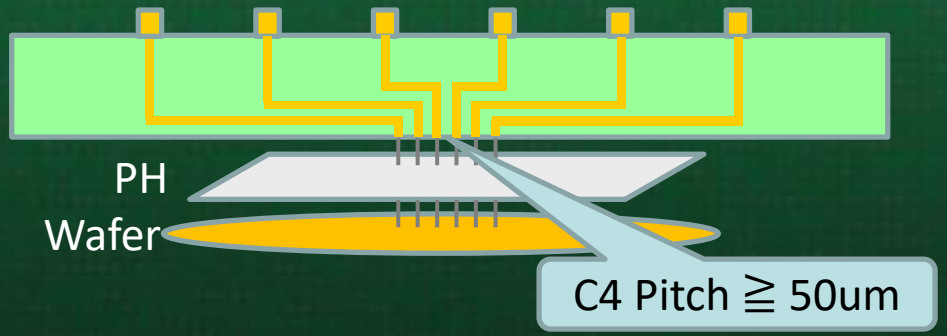
For VPC test



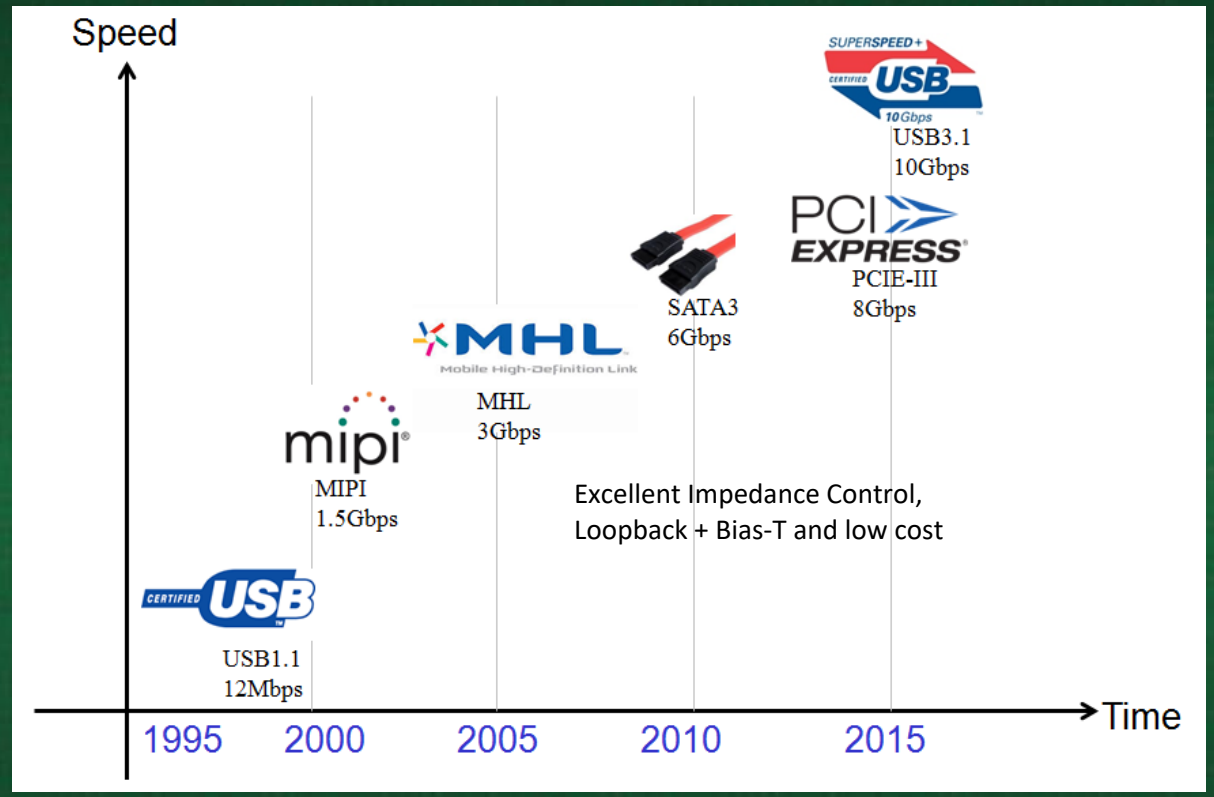
Why using Substrate?

Substrate

For fine-pitch fan out routing

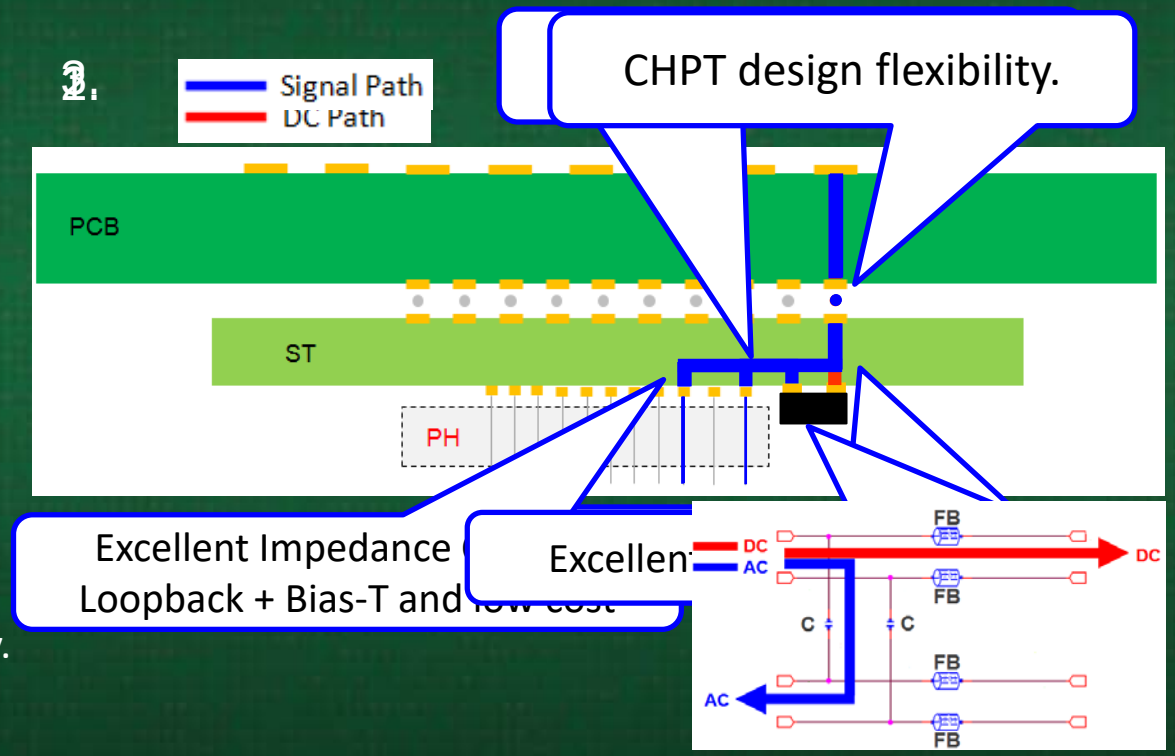


VPC Test Structure



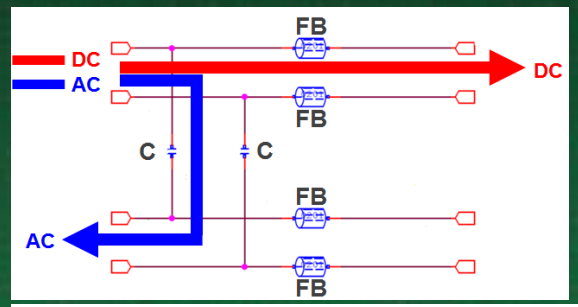
•The speed of signal is getting faster with the evolution of the technology.

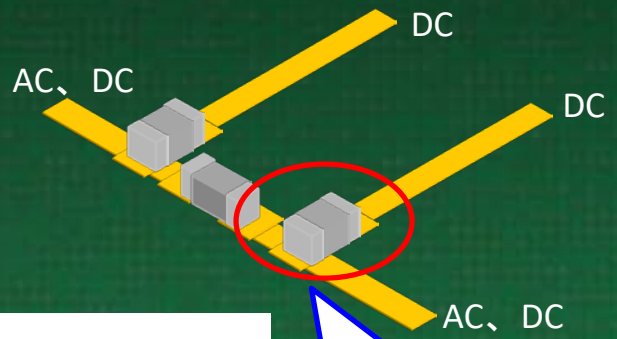
What are CHPT's solutions for high speed signal on probe card?

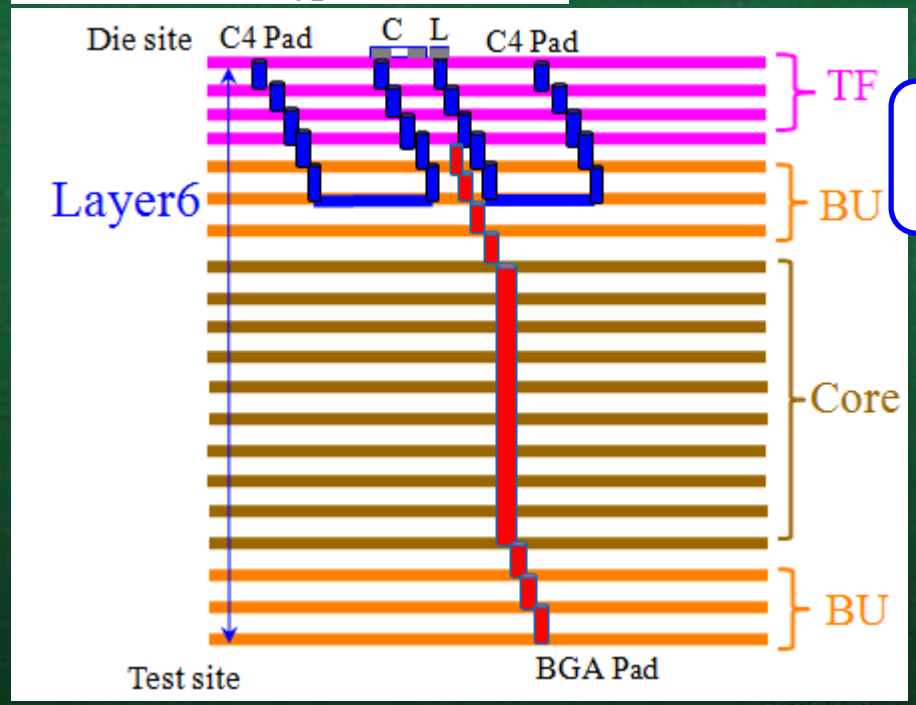


VPC Test Structure

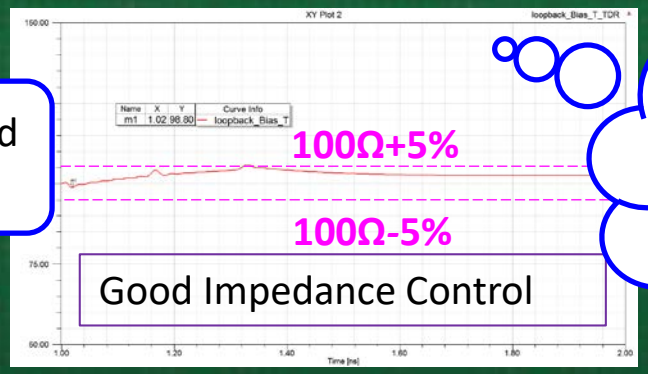
ST Loopback +Bias-T Design

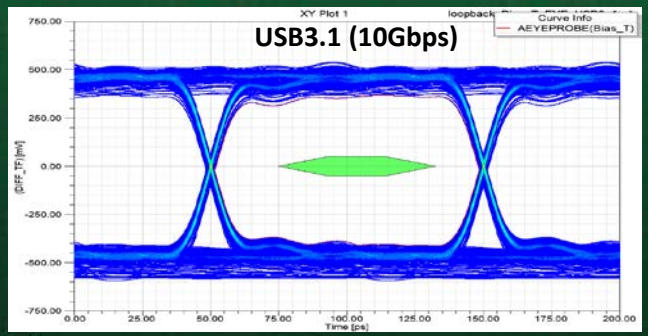






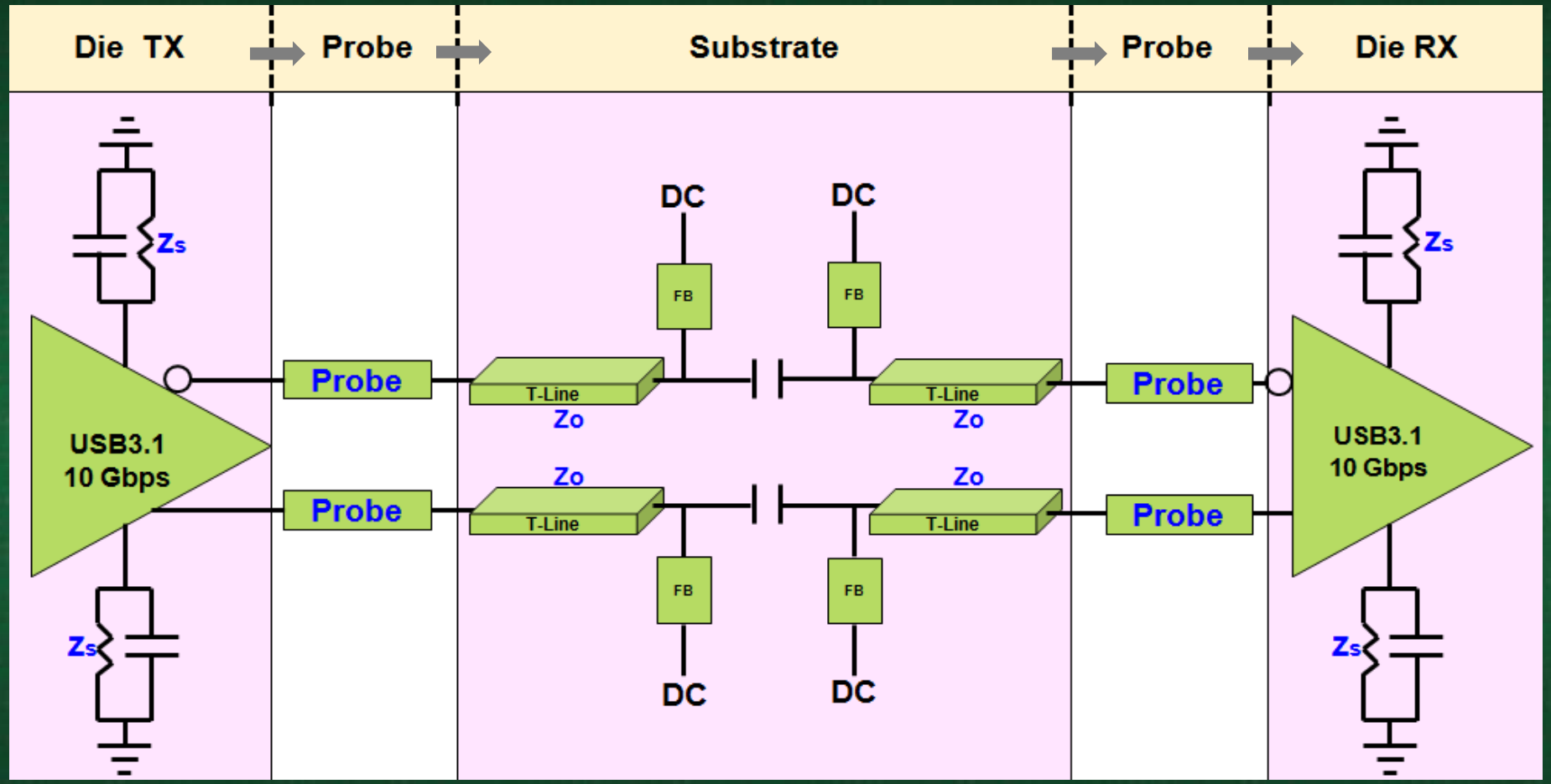
FB right on high speed trace to avoid stub.





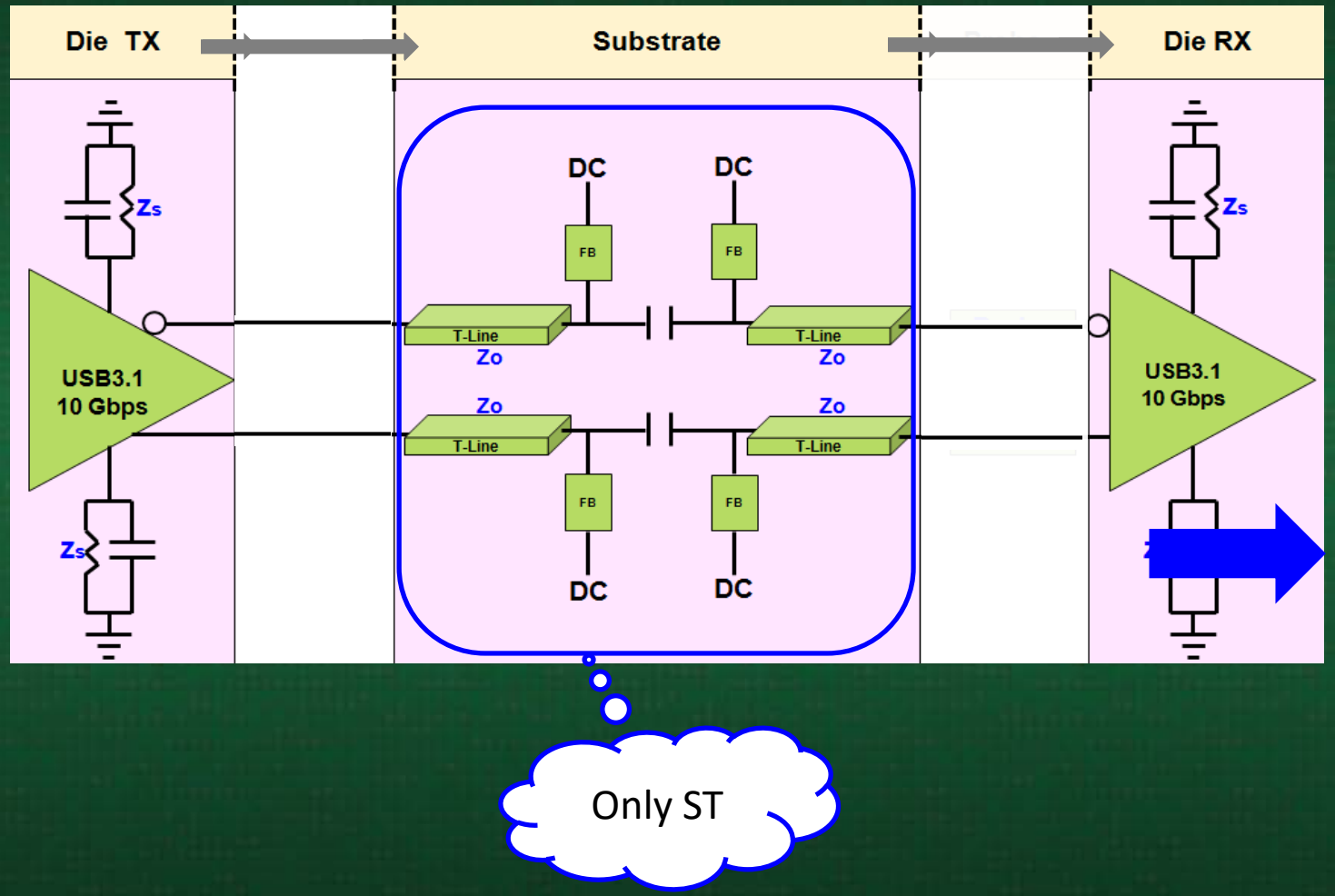
CHPT is specialized at PCB/PC design for good SI.

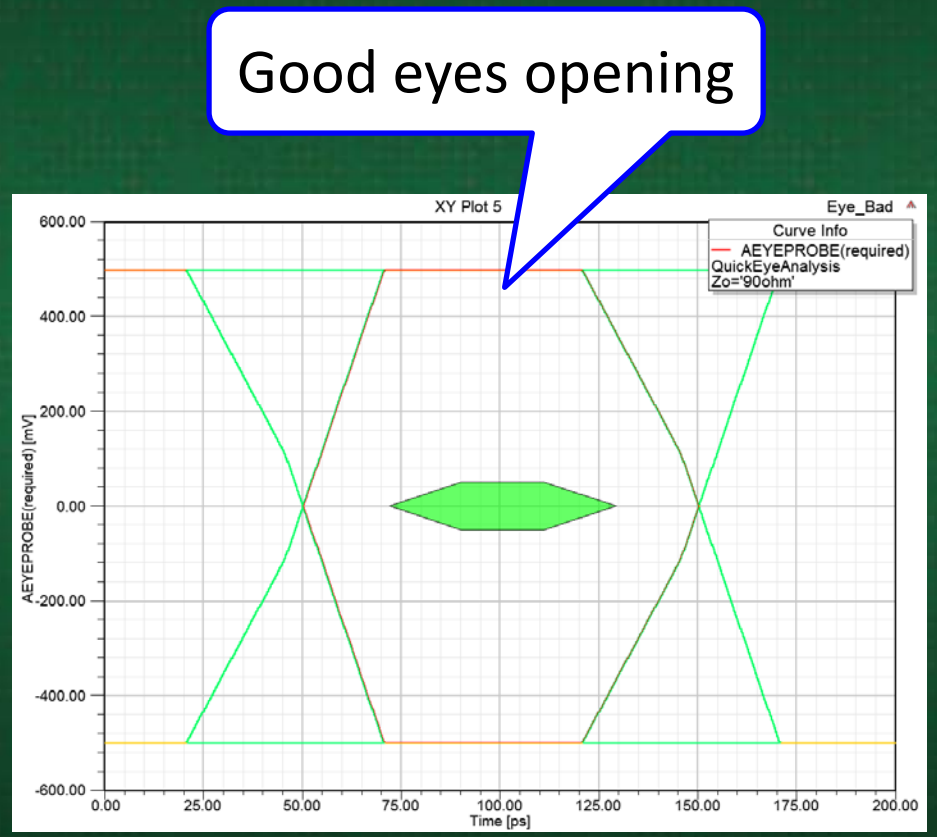
The Importance of Impedance Continuity



Blue ➔ Key Factor

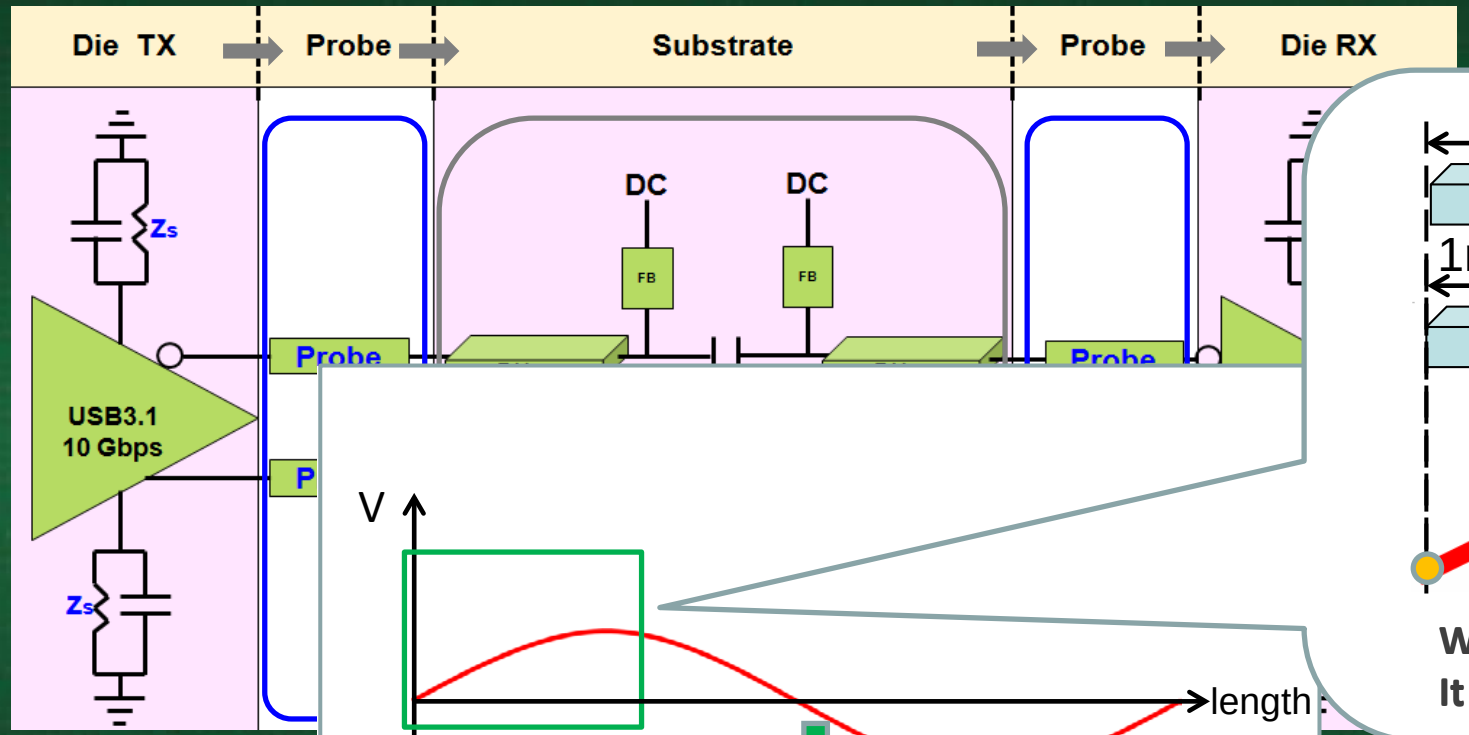
The Importance of Impedance Continuity

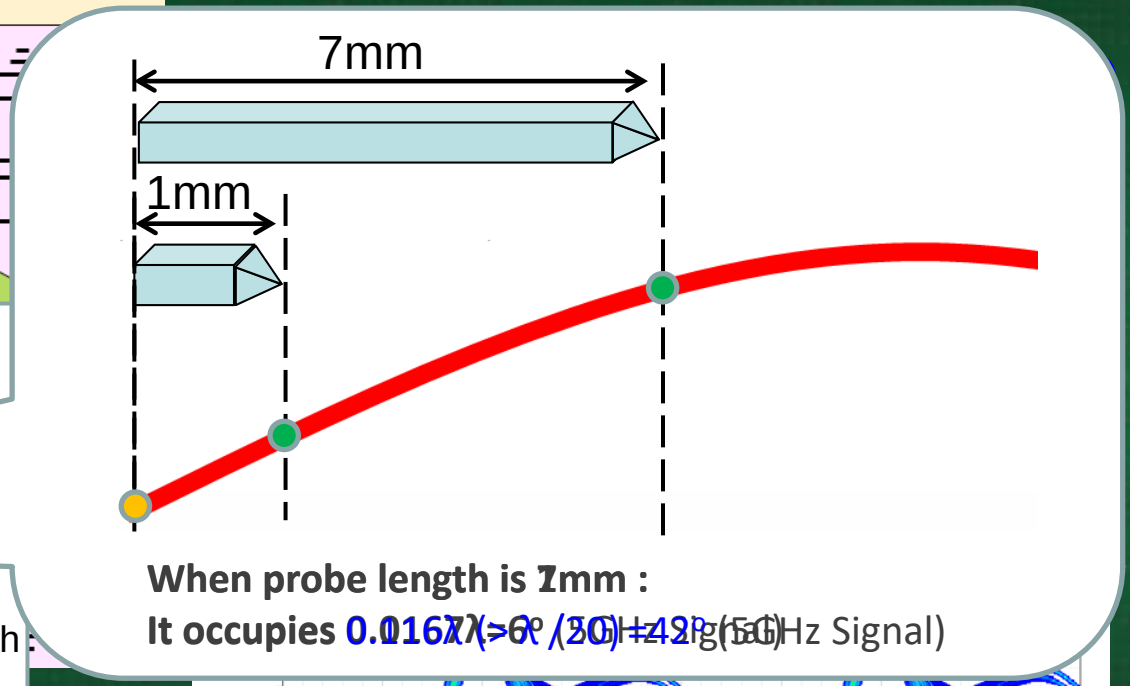


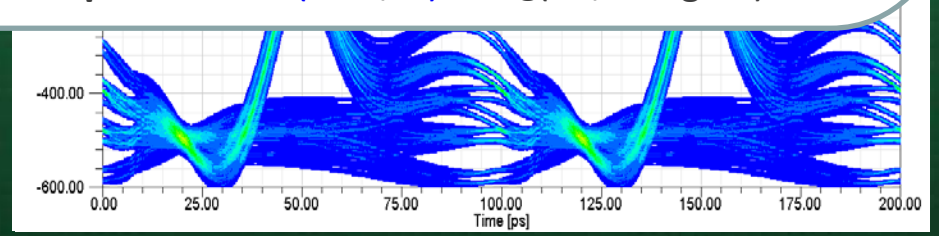


10Gbps (USB 3.1 Gen2)

The Importance of Impedance Continuity

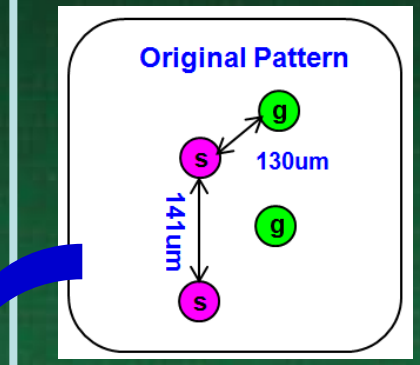


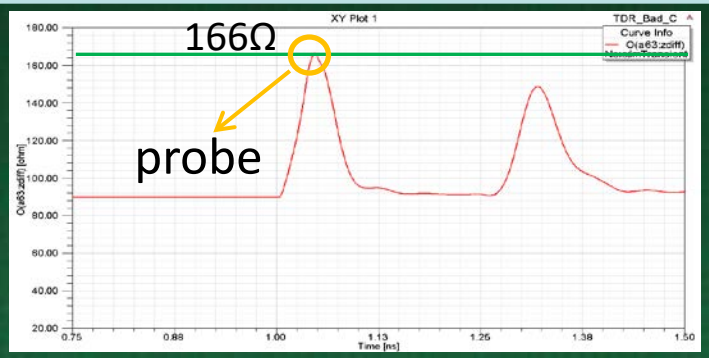


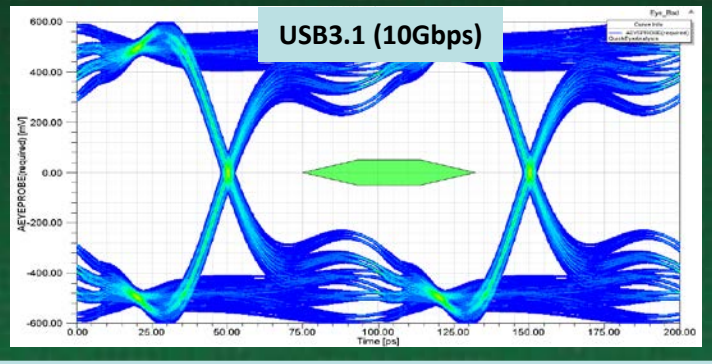


10Gbps (USB 3.1 Gen2)

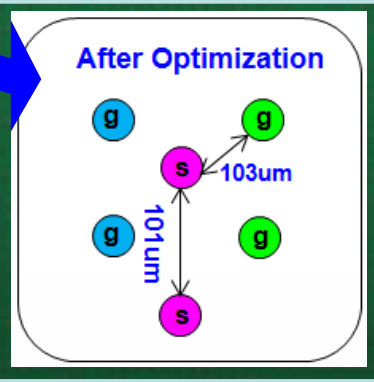
The Importance of Impedance Continuity

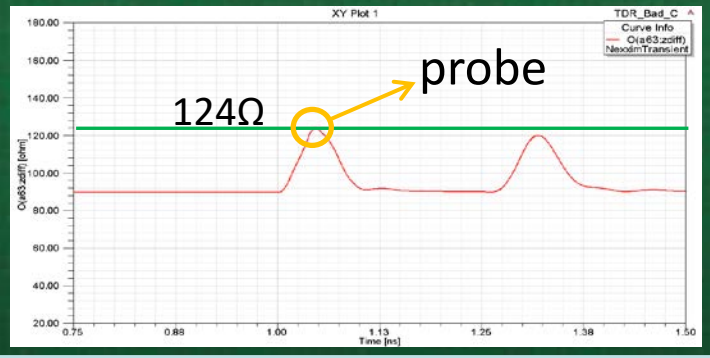


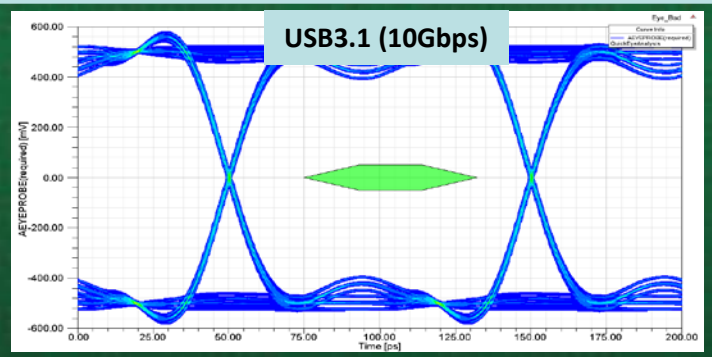




To adjust pattern

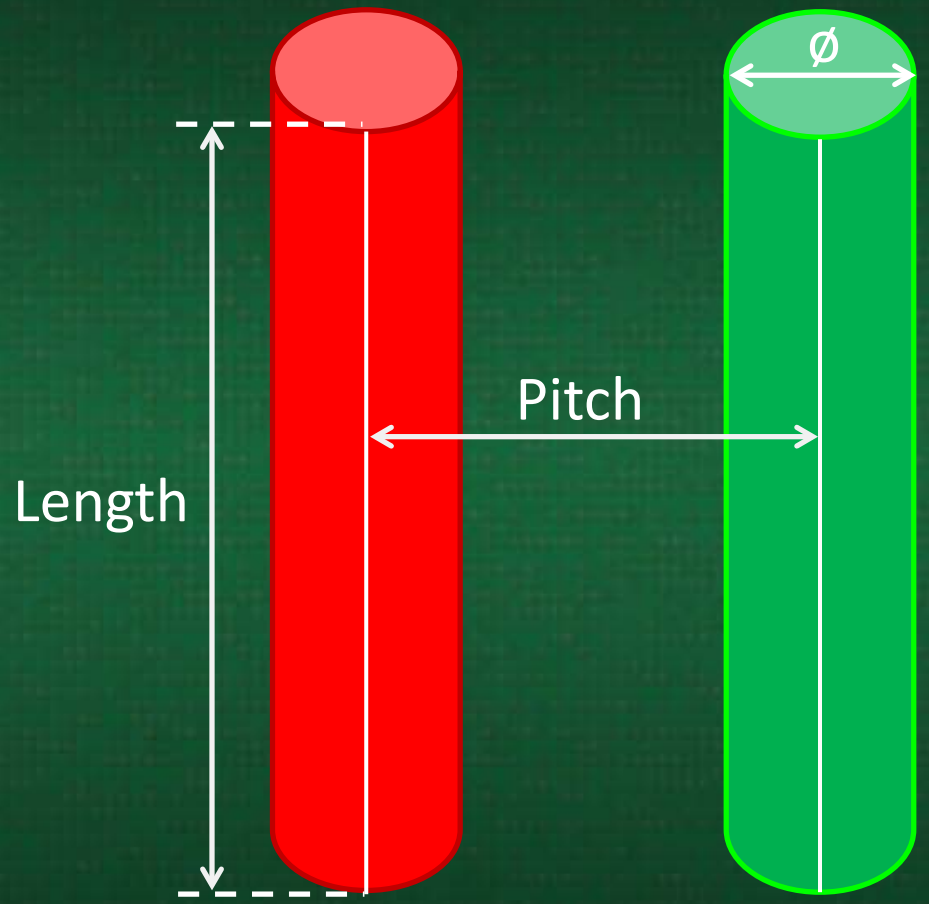


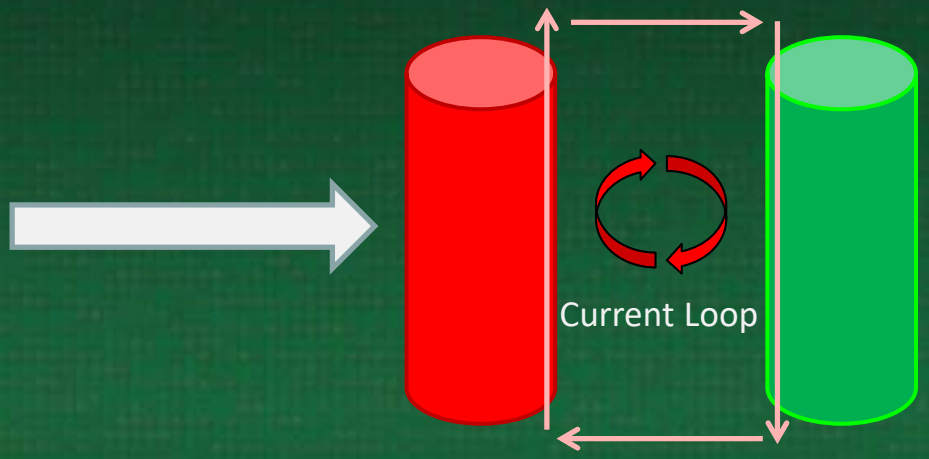




Eye Opening could be improved by optimizing probe pattern(Signal and GND) for better impedance continuity .

The Importance of Impedance Continuity





Wire Pitch↑➔Loop Inductance↑➔Z_o↑
Wire Length↑➔Loop Inductance↑➔Z_o↑
ø↑➔ Loop Inductance ↓➔ Z_o↓

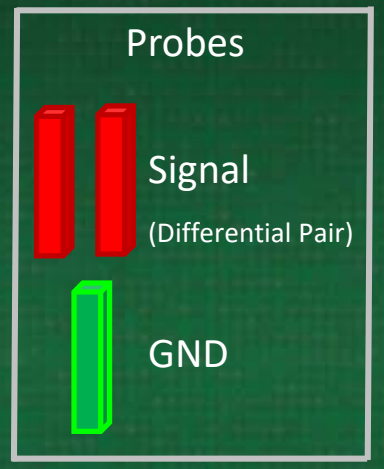
$(Z_o=\sqrt{\frac{L}{C}})$

Key factors of impedance control on open-wire T-Line :

1. Pitch (Signal to GND)
2. Length
3. Diameter

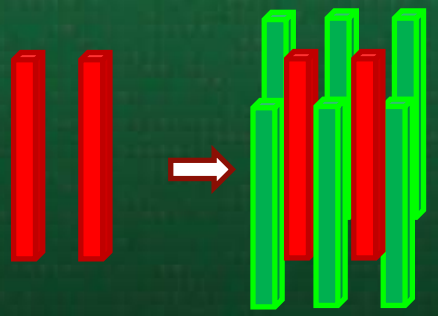
Impedance Control on Probe Pattern

The key factors of impedance control for probe pattern :



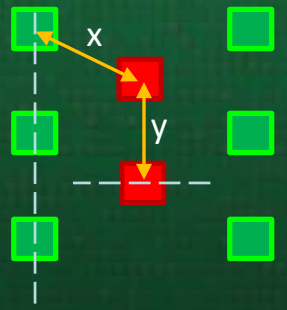
Change Probe Pattern		W/O Change Probe Pattern
Increase Impedance	Decrease Impedance	Decrease Reflection
①②④	①②④	③

① GND Probe Quantities



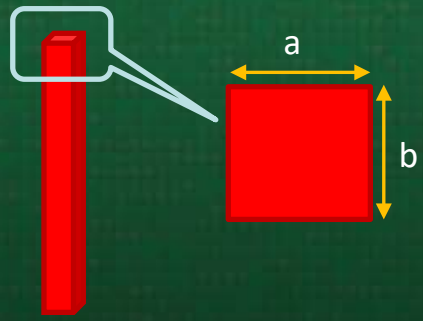
No GND probe　　6 GND probe

② Probe Pitch



③ Probe Length

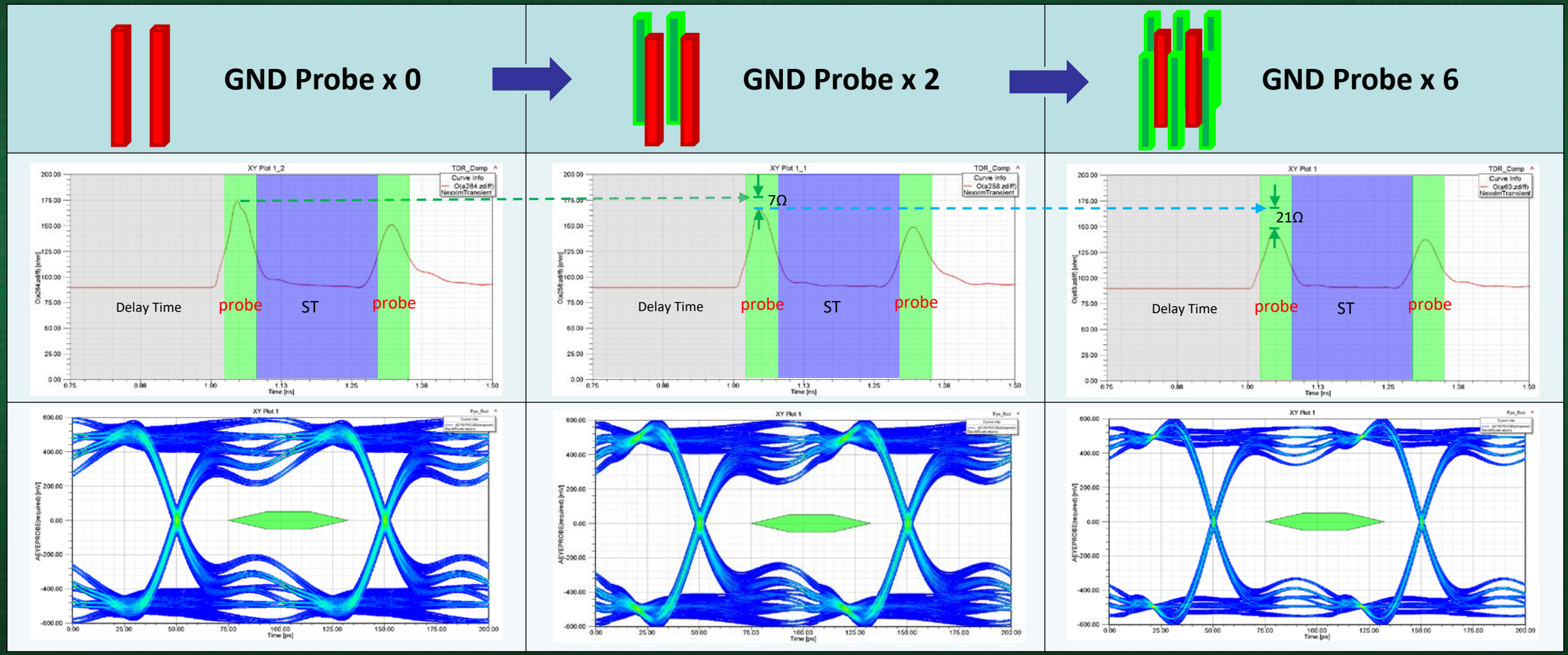
④ Probe Cross-Section



Impedance Control on Probe Pattern

① GND Probe Quantities(fixed pitch, length and cross-section)

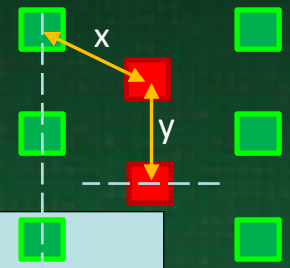
Speed : USB 3.1 Gen2, 10Gbps



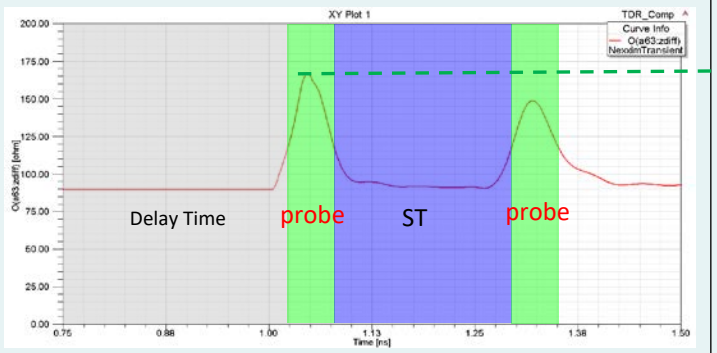
Impedance Control on Probe Pattern

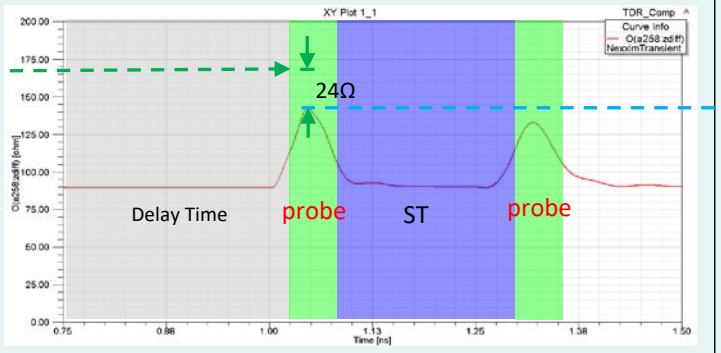
② Probe Pitch(fixed probe quantities, length and cross-section)

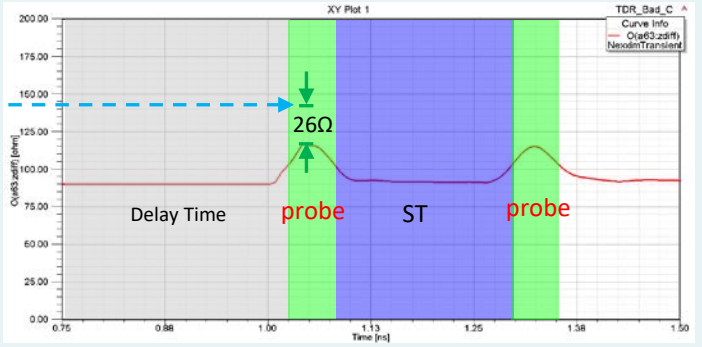
Speed : USB 3.1 Gen2, 10Gbps

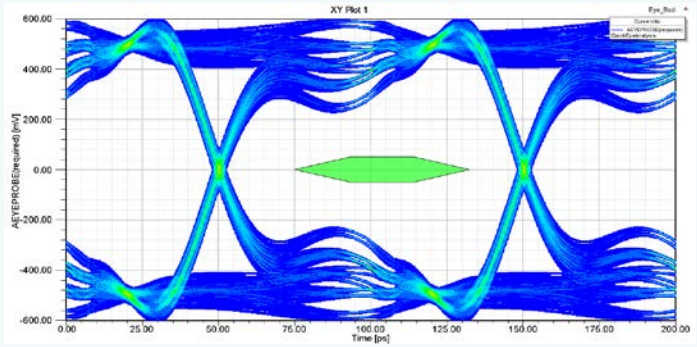


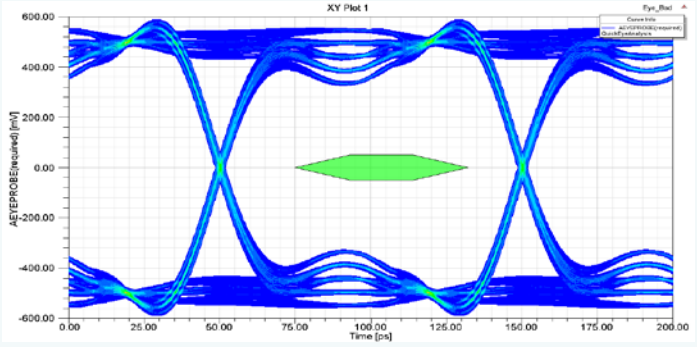
x = 130um , y =141um	x↓y↓	x = 108um , y =121um	x↓y↓	x = 93um , y =101um

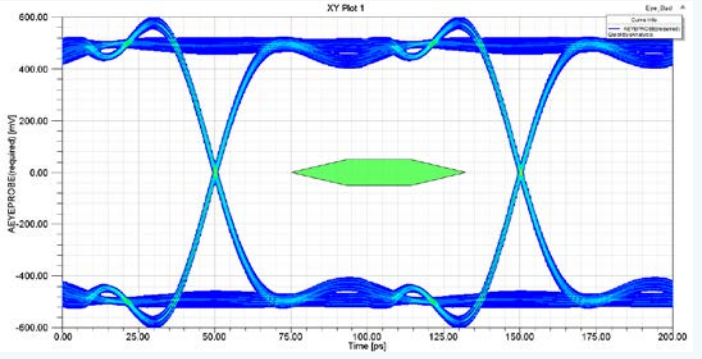








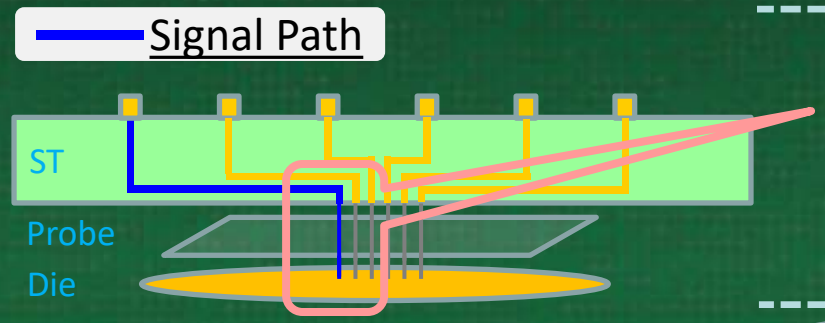


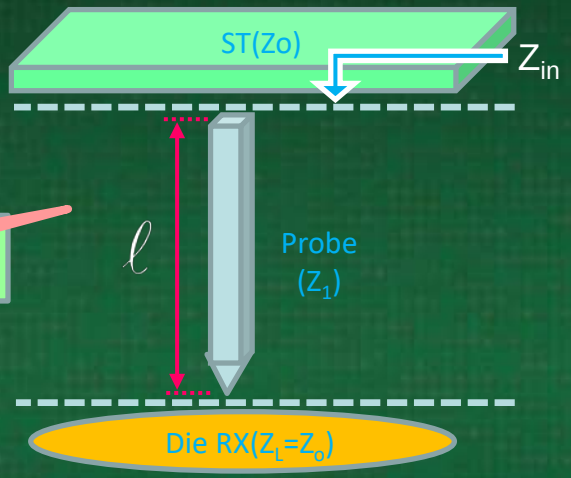


Impedance Control on Probe Pattern

③ Probe Length(fixed probe quantities, pitch and cross-section)

Speed : USB 3.1 Gen2, 10Gbps





$$Z_{in} = Z_1 \times \frac{Z_L + jZ_1 \tan \beta\ell}{Z_1 + jZ_L \tan \beta\ell}$$

$$\text{if } \ell \to 0$$

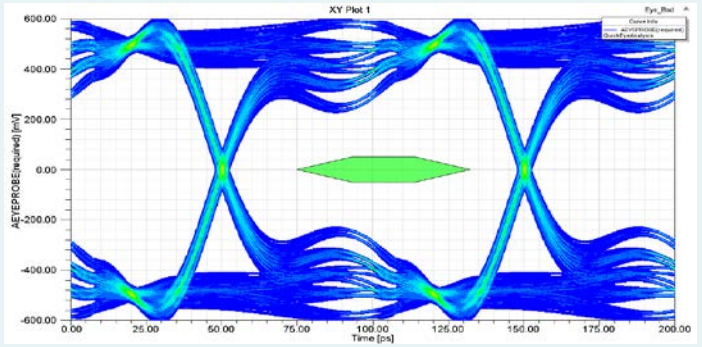
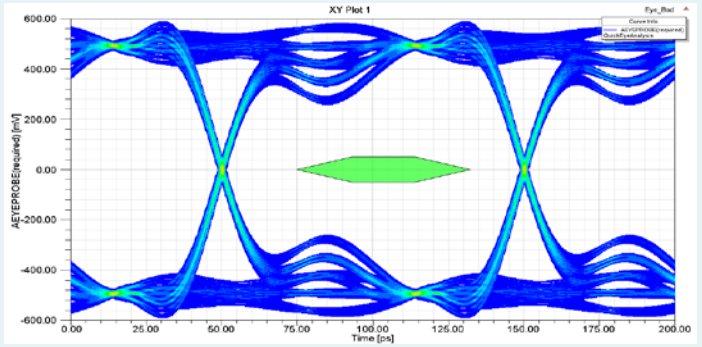
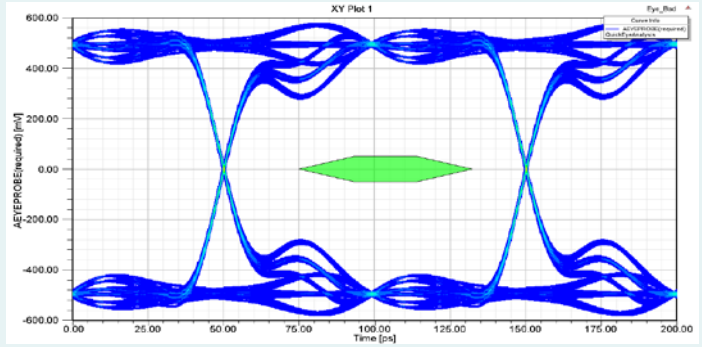
$$Z_{in} = \lim_{\ell \to 0} Z_1 \times \frac{Z_L + jZ_1 \tan \beta\ell}{Z_1 + jZ_L \tan \beta\ell}$$

$$= Z_1 \times \frac{Z_L + jZ_1 \times 0}{Z_1 + jZ_L \times 0}$$

$$\Rightarrow Z_{in} = Z_L$$

When Z_1 (probe) length is shorter, Z_{in} would be close to Z_L. When Z_L=Z_o, there is no reflection on this structure.

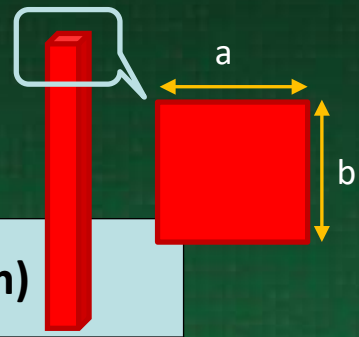
MEMS

Length = 7000um	Length = 6000um	Length = 4000um
		

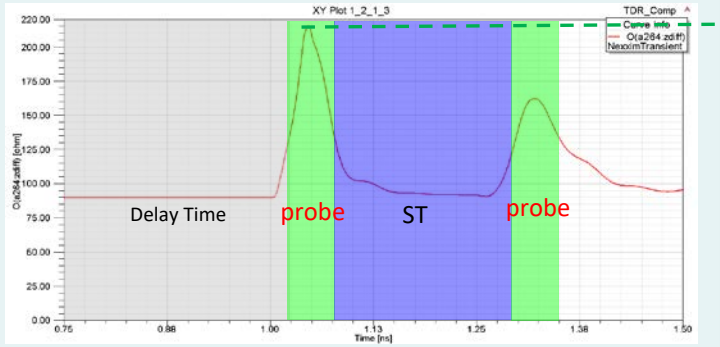
Impedance Control on Probe Pattern

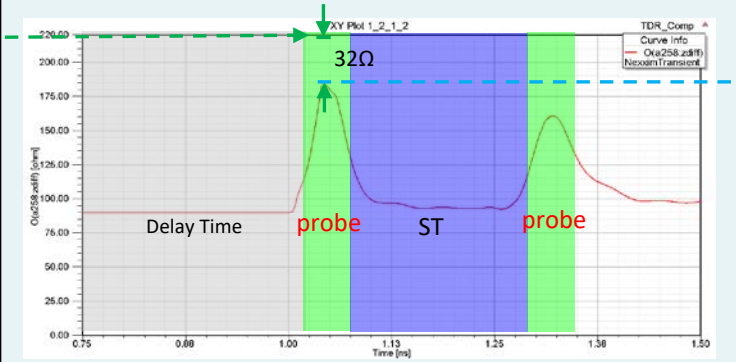
④ Probe Cross-Section(fixed probe quantities, pitch and length)

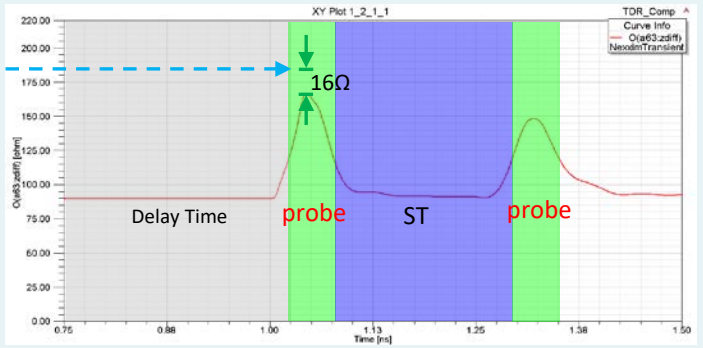
Speed : USB 3.1 Gen2, 10Gbps

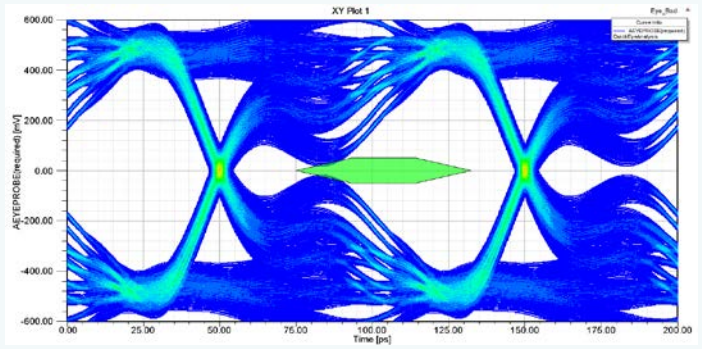


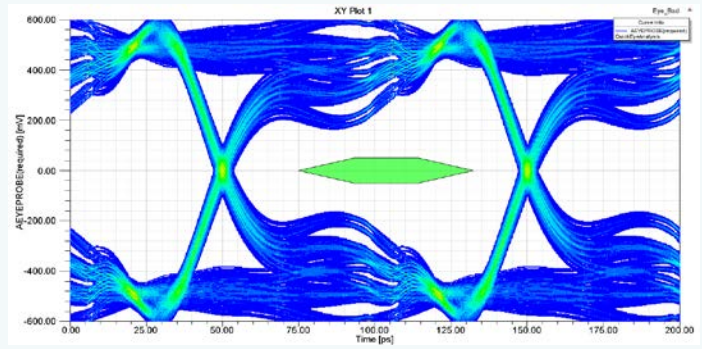
Type A(30um x 35um)	a ↑ b ↑	Type B(41um x 42um)	a ↑ b ↑	Type C(43um x 55um)

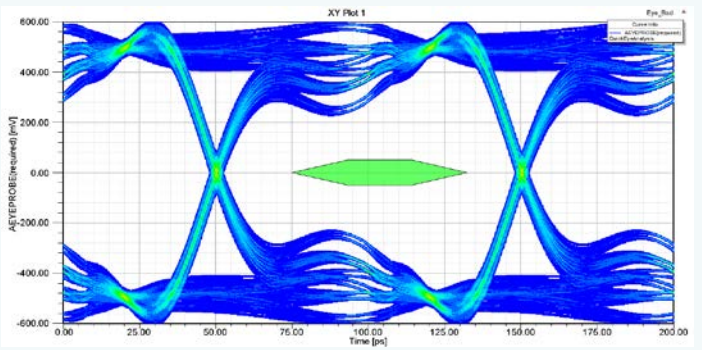




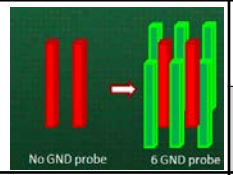
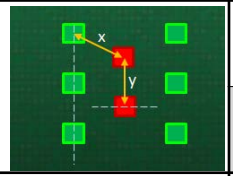
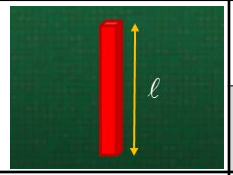
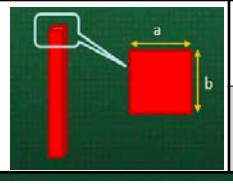








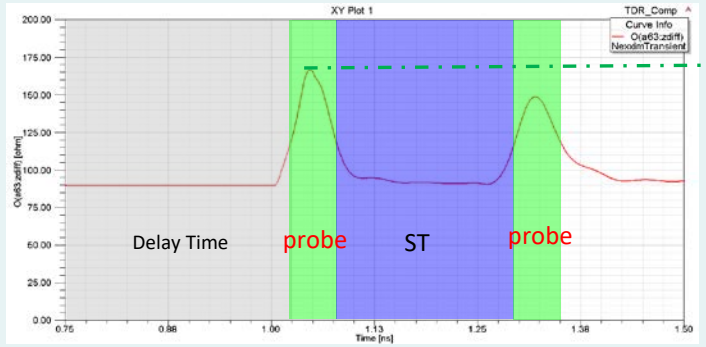
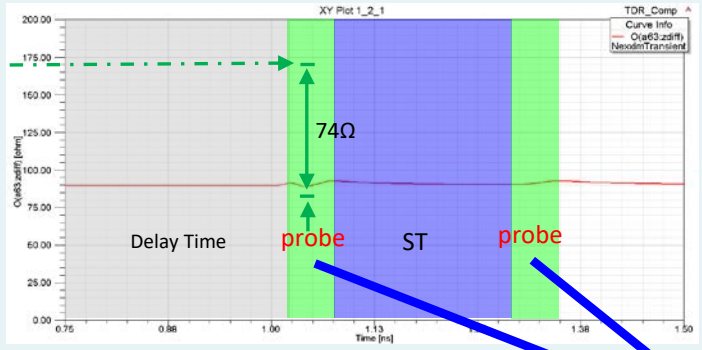
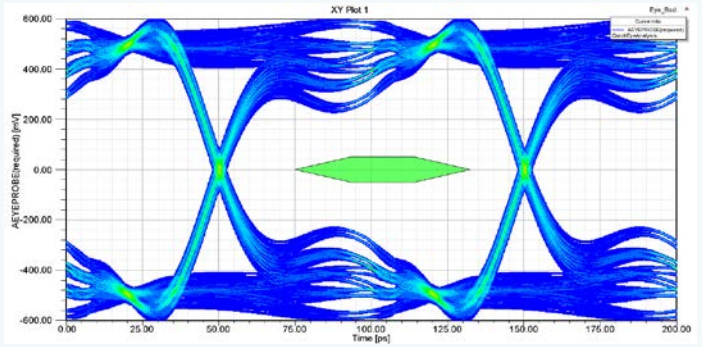
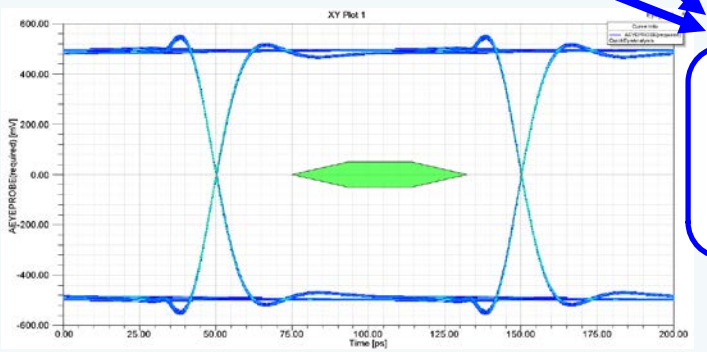
Impedance Control on Probe Pattern

Key Factors of Impedance Control	Variables of Probe Pattern		
	Eye Opening Performance		
①GND Probe Quantities 	No GND Probe	2 GND Probe	6 GND Probe
	★	★★	★★★
②Probe Pitch 	X = 130um , y =141um	X = 108um , y =121um	X = 93um , y =101um
	★	★★	★★★
③Probe Length 	Length = 7000um	Length = 6000um	Length = 4000um
	★	★★	★★★
④Probe Cross-Section 	Type A(30um x 35um)	Type B(41um x 42um)	Type C(43um x 55um)
	★	★★	★★★

Eye opening performance: ★ Bad ★★ Medium ★★★ Good

The Best Transmission Structure

- According to the previous experiment results, we could reach to the best probe pattern for good eye opening and impedance continuity.

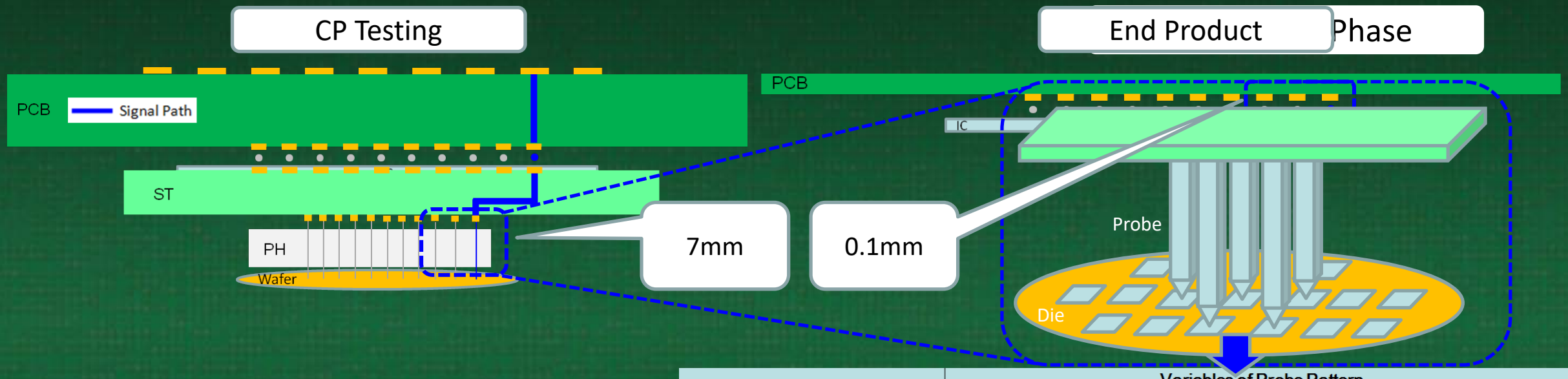
DUT + Probe(before optimization) + ST	DUT + Probe(after optimization) + ST
	
	

6 GND Probe
★★★
X = 93um , y =101um
★★★
Length = 4000um
★★★
Type C(43um x 55um)
★★★

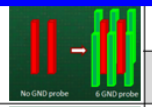
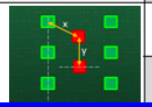
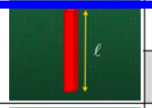
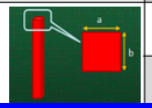
Probe pattern can be optimized to improve impedance discontinuity.

Speed : USB 3.1 Gen2, 10Gbps

Design For Testing(DFT)

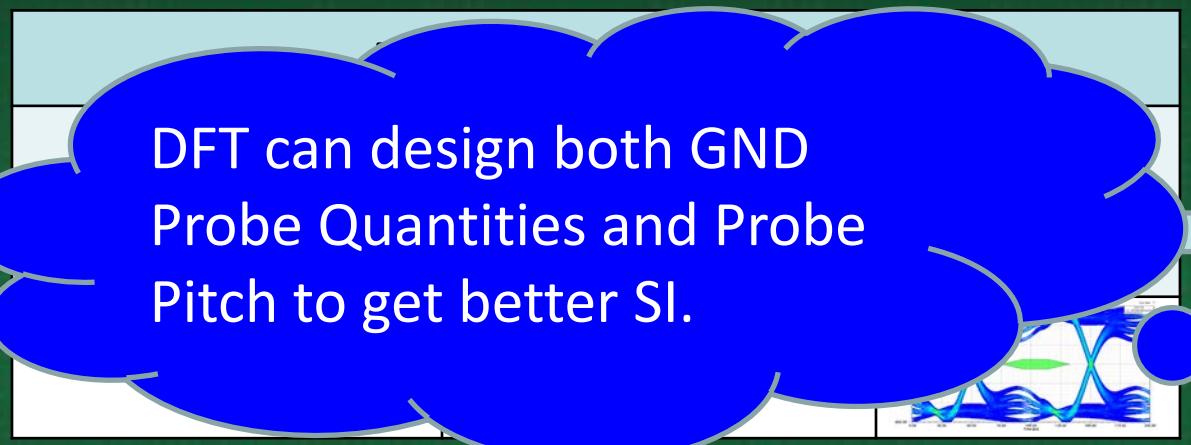


DFT should take impedance continuity of probe pattern into consideration.

Key Factors of Impedance Control		Variables of Probe Pattern		
		Eye Opening Performance		
①GND Probe Quantities		No GND Probe	2 GND Probe	6 GND Probe
		★	★★	★★★
②Probe Pitch		X = 130um , y =141um	X = 108um , y =121um	X = 93um , y =101um
		★	★★	★★★
③Probe Length		Length = 7000um	Length = 6000um	Length = 4000um
		★	★★	★★★
④Probe Cross-Section		Type A(30um x 35um)	Type B(41um x 42um)	Type C(43um x 55um)
		★	★★	★★★

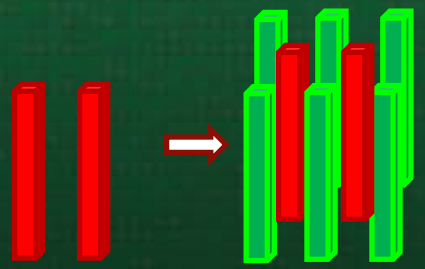
Example1 with DFT Consideration

For a chosen/fixed probe with 43um x 55um cross-section, five combinations of probe pitch and GND quantities can achieve better SI.



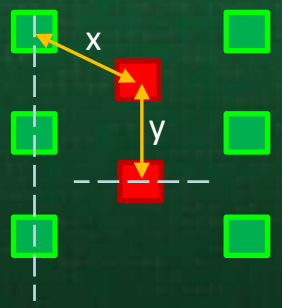
Speed : USB 3.1 Gen2, 10Gbps

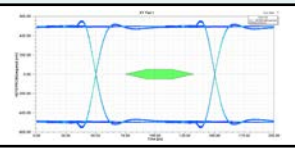
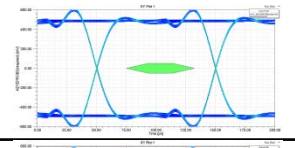
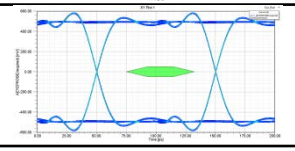
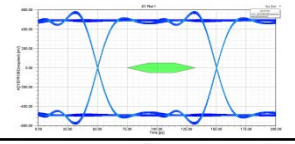
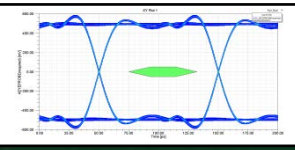
GND Probe Quantities



No GND probe 6 GND probe

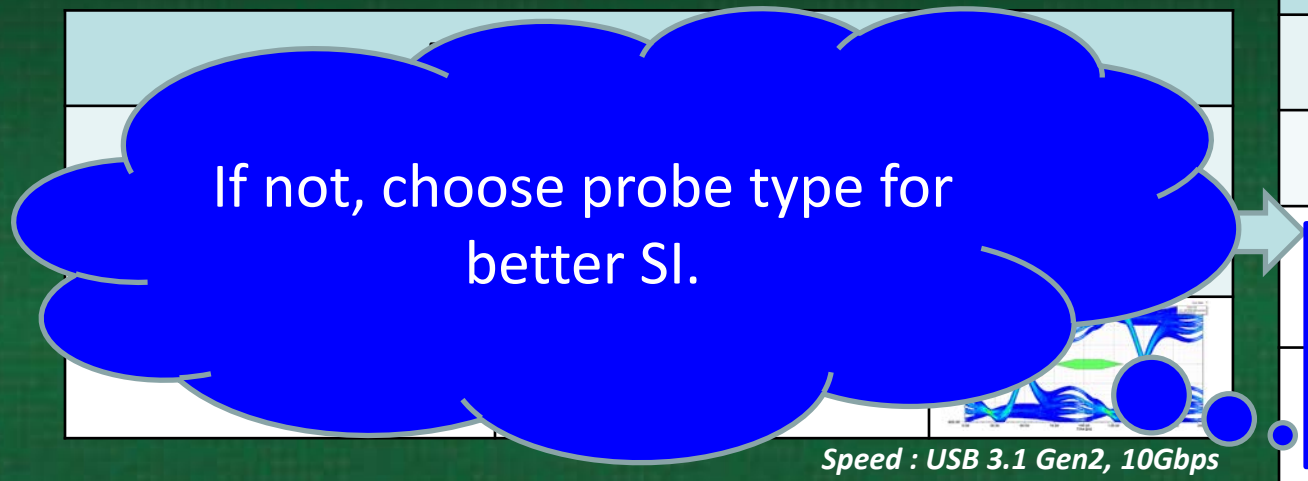
Probe Pitch



After Optimization		
Key Factors of Impedance Control		Eye Opening
GND Probe Quantities	Probe Pitch	
6GND	X = 93um , y =101um	
6 GND	X = 89um , y =111um	
4GND	X = 98um , y =81um	
4GND	X = 82um , y =101um	
2GND	X = 89um , y =81um	

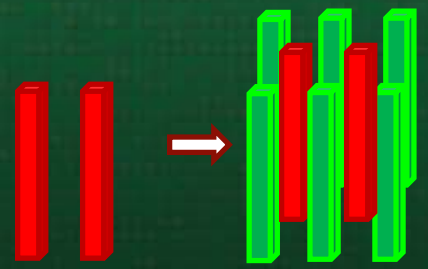
Example2 w/o DFT Consideration

For chosen/fixed probe pitch and GND Probe Quantities of 141um S to S and 130um S to G design, five combinations of probe cross-section and GND quantities can achieve better SI.

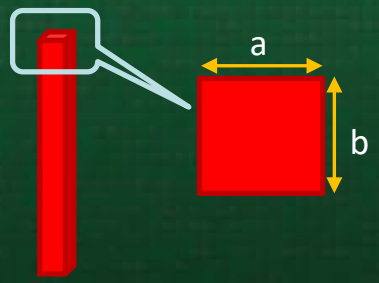


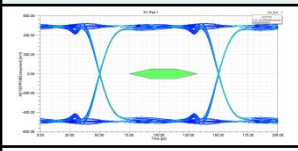
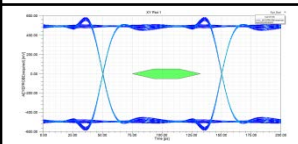
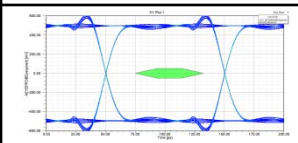
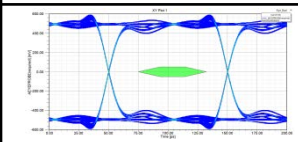
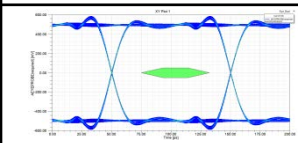
Speed : USB 3.1 Gen2, 10Gbps

GND Probe Quantities



Probe Cross-Section

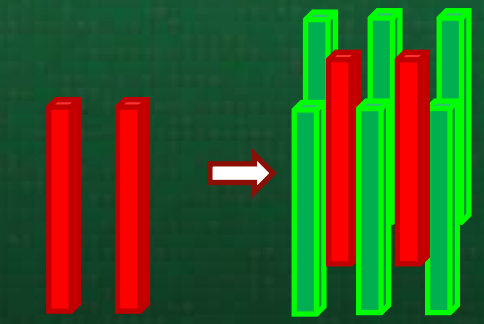


After Optimization		
Key Factors of Impedance Control		Eye Opening
GND Probe Quantities	Probe Cross-Section (Cobra Probe)	
6 GND	ϕ= 101.6um(4mil) Length=5175um	
6GND	ϕ= 76.2um(3mil) Length=4851um	
4GND	ϕ= 101.6um(4mil) Length=5175um	
4GND	ϕ= 76.2um(3mil) Length=4851um	
2GND	ϕ= 101.6um(4mil) Length=5175um	

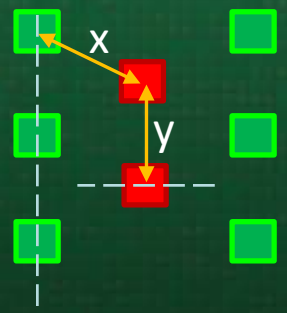
Conclusion

- The best transmission structure should consider impedance continuity between probe and space transformer.
- Probe pattern is also a key factor for high speed SI performance, therefore, it is necessary to be aware how to optimize probe pattern for impedance continuity.
- Four key factors of probe pattern should be optimized as below:

① GND Probe Quantities



② Probe Pitch



③ Probe Length

④ Probe Cross-Section