Optimization of SCD and SDC Parameters for 32Gbps Differential Loopback in PCB

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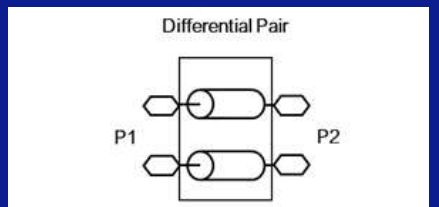
Introduction of SCD, SDC

- S parameter

$$S_{ij} = S_{out\_in} = \frac{V_{out}}{V_{in}}$$



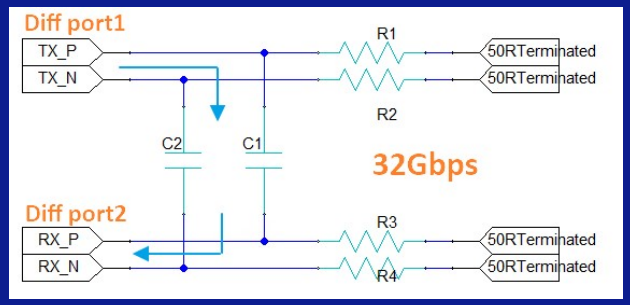
Mixed-Mode			
Differential-Differential		Common-Differential	
SDD11	SDD12	SDC11	SDC12
SDD21	SDD22	SDC21	SDC22
Differential-Common		Common-Common	
SCD11	SCD12	SCC11	SCC12
SCD21	SCD22	SCC21	SCC22

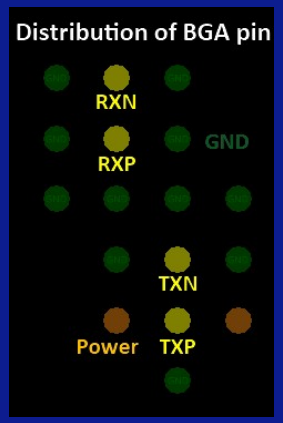
Picture Source: Reference 1.

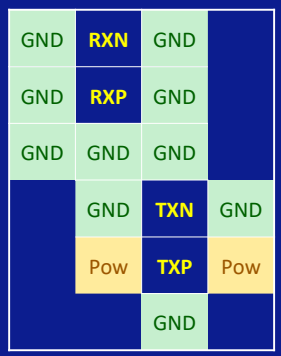
- Mixed-mode S parameter
  - SCD differential signal in → common signal out
  - SDC common signal in → differential signal out
- Asymmetry and skew between the two interconnections that make up a differential pair can cause mode transformation

Project Practice of 32Gbps Loopback

- Background







Stackup	
L40	GND
L41	Loop
L42	GND
L43	Loop
L44	GND
L45	Power
L46	GND
L47	Power
L48	GND
L49	Power
L50	GND
Bottom	DUT

Sim Target	SCD&SDC 0-32GHz <-20dB	PN Skew 1ps	SDD, SCC, TDR, Corsstalk…

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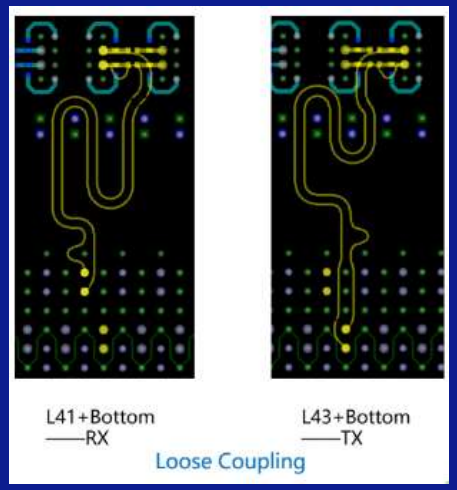
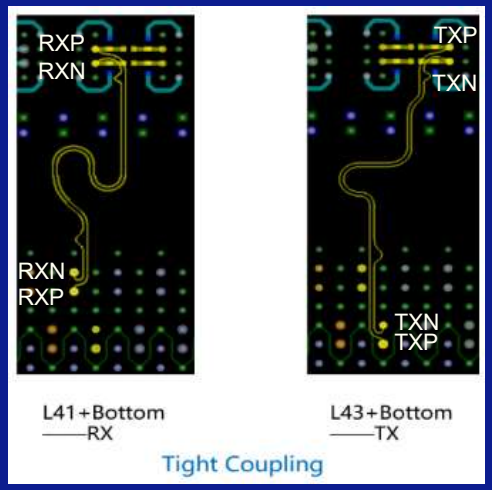
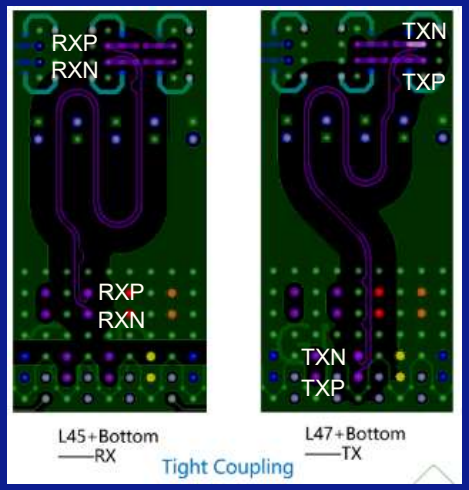
Project Practice of 32Gbps Loopback







V1 → Change coupling mode → V2 → V3

Shorten signal vias
Chang PN relative position of caps
Add GND vias around signals in BGA

	V1	V2	V3
PN Skew /ps	4.03	3.59	0.43
SCD&SDC@16GHz/ dB	-18.39	-15.81	-31.55
SCD&SDC@32GHz/ dB	-14.26	-13.55	-23.07

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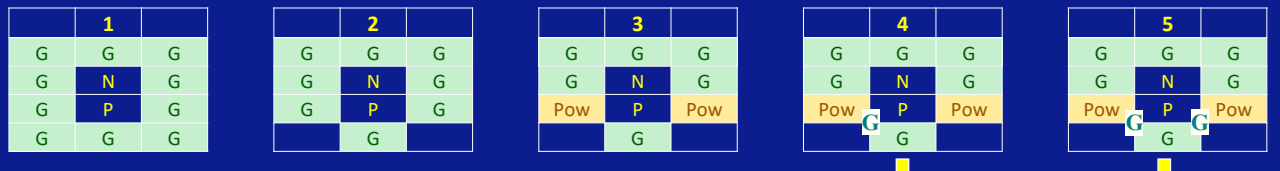
Project Practice of 32Gbps Loopback

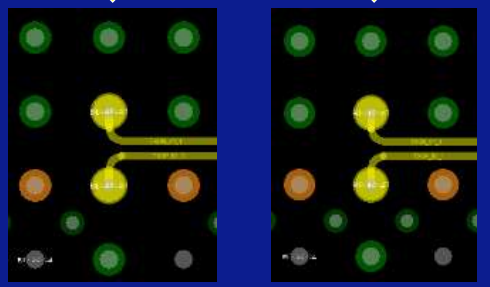
- Questions:
  - Power and GND around signal vias will affect skew and SCD/SDC. How to improve?
  - The method of length match, how and where? How to optimize routing?
  - Tight coupling can achieve better fanout in limited space. Can loose coupling get the similar SCD&SDC result?
  - How to optimize the left 0.43ps skew?

Factor Analysis

- Via



Sim result



Case	Via Length/um	Skew(P-N)/ps	SCD&SDC/dB
1	891	0.001	-70.79
2	891	0.061	-49.23
3	891	0.28	-38.00
4	891	0.117	-44.89
5	891	0.032	-40.51
6	1135	0.071	-47.11
7	647	0.036	-52.21

Conclusion:

- Compare case1, 2, 3, 4 ,5 → Power and GND around signal vias affects symmetry and skew.
- Compare case2, 6, 7 → length of asymmetric vias affects skew.
- From case5, inconsistent impedance of P&N affects SCD&SDC.

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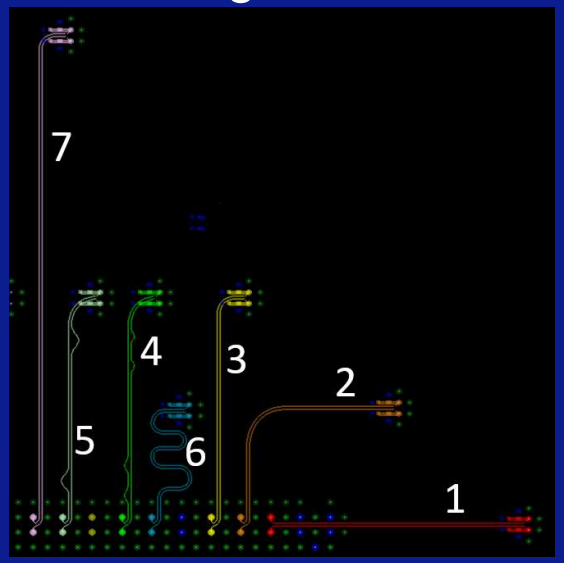
Factor Analysis

- Routing



Sim result

Case	Skew(P-N)/ps	SCD&SDC/dB	Note
1	0.001	-70.79	straight trace with no bend
2	0.306	-37.58	trace with a large bend
3	0.289	-38.00	trace with a small bend
4	0.29	-37.89	dynamc length match trace with two small tunes
5	0.288	-38.09	dynamc length match trace with a large tune
6	0.287	-37.92	serpentine line
7	0.294	-37.99	double length trace with a small bend

Conclusion:

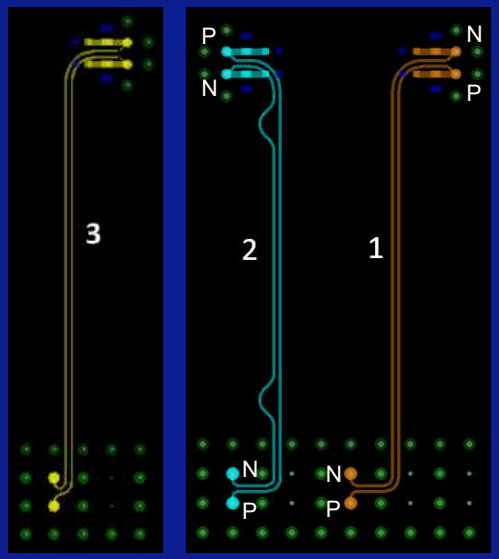
- Bending, trace length and dynamic length match will not cause asymmetry and affect SCD/SDC.

Question:

- For case2-7, what cause 0.3ps skew?

Factor Analysis

- Placement and Fanout



Sim result

Case	Skew(P-N)/ps	SCD&SDC/dB
1	0.019	-55.23
2	0.284	-38.22
3	0.289	-38.00

Conclusion:

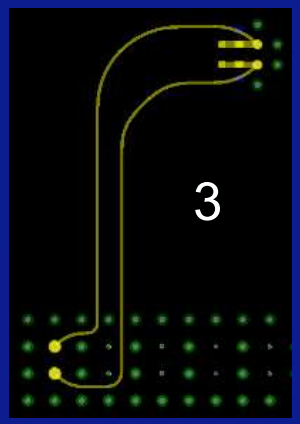
- Asymmetric fanout and length match to P&N trace will affect skew and SCD&SDC.

Layout advice:

- Keep the same fanout for P&N trace.
- Optimize placement to decrease unequal length.

Factor Analysis

- Coupling



Sim result

Case	Skew(P-N) ps	SCD&SDC @16GHz dB	Trace width um	SDD12 @16GHz dB
1	0.001	-70.79	96	-0.96
2	-0.003	-66.11	117	-0.89
3	0	-51.83	117	-0.89

Conclusion:

- Coupling mode does not affect skew and SCD&SDC

Layout advice:

- Select coupling mode according to routing space and loss

Summary

- Factors affect symmetry and skew:
  - Power and GND around signal vias,
  - asymmetric via length
  - impedance of P&N signals
  - fanout from vias
- Factors does not affect symmetry and skew:
  - Bending, trace length and dynamic length match to both P&N trace
  - Coupling mode
- Layout advice
  - Before routing, planning vias → placement → coupling mode → fanout in sequence will help to reduce time of modification and simulation.

Reference

- *1. Bert Simonovich. Single-ended to Mixed-Mode Conversions. Signal Integrity Journal Magazine, July 2020. https://blog.lamsimenterprises.com/2020/07/24/single-ended-to-mixed-mode-conversions/*

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