



Tight vs. Loose Coupling of Differential Pairs

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Outline

- Review of differential pair properties and how they differ between tightly and loosely coupled pairs.
- Description of test set-up used to look at signal integrity through several different differential pair architectures.
- Results and Conclusions.
- Q and A

Definitions

For the purposes of this talk . . .

- “Tightly Coupled” refers to differential pairs that have on the order of 2% crosstalk or more. A typical configuration could be 5 mil trace width, 5 mil edge-to-edge spacing.
- “Loosely Coupled” refers to pairs that have very little crosstalk. A typical configuration could be 5 mil trace width, 15 mil edge-to-edge spacing.

Properties of Differential Pairs When Used In Cables

- Differential pairs are used in twisted pair cable assemblies to interconnect systems whose references, typically ground, are not the same.
- Signal swing within each half of the pair at the receiver can be quite small.
- The 2 halves of a twisted pair mutually couple so that outside interference appears equally on both halves of the pair and will be rejected at the receiver.
- EMI generation is greatly reduced.
- It is relatively easy to manufacture twisted pair to make within pair skew small and impedance constant.

Properties of Differential Pairs When Used on PCBs

- Effects of voltage noise and ground bounce between driver and receiver can be mitigated. This becomes more important as edge rates increase and higher frequencies appear on the power distribution system.
- Signal swing within each half of the pair at the receiver can be quite small. This can be important because glass-epoxy board material can be quite lossy at high frequencies.
- Cross-coupling between two halves of a pair is typically quite small, even for 5 mil edge-to-edge spacing. Also, many current high speed board designs place copper plane layers next to signal layers which further isolates the two halves of a pair from each other.

Properties of Differential Pairs When Used on PCBs (cont.)

- Tight coupling reduces the voltage swing of the individual signals within a pair.
- EMI generation is greatly reduced by coupling to an adjacent plane.
- Matching trace lengths can be layout intensive.

Comparison of Tight vs. Loose Pairs

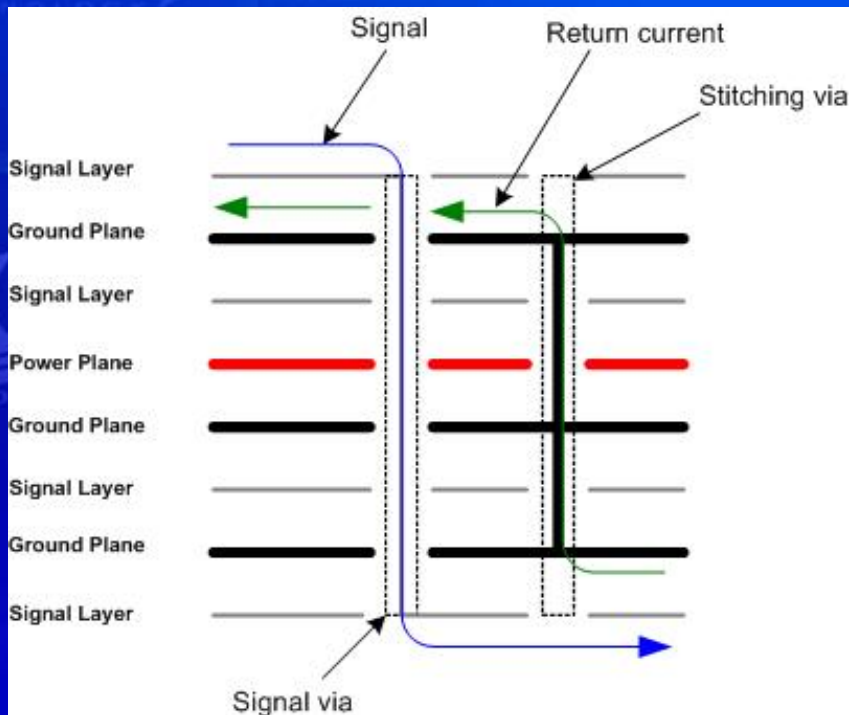
Tightly Coupled

- Each segment of a pair must have very little skew, and the total flight time must have very little skew.
- If via'ing to other planes, both halves of the pair must transition at the same place.
- Often must use serpentine traces near the driver to reduce skew.
- Differential impedance can change when routing to connectors/components.

Loosely Coupled

- Each half of the pair must have the same total flight time to reduce skew.
- Each half of the pair can be designed as a 50 ohm transmission line. This can be maintained when routing to connectors/components.
- Board layout/fabrication must provide consistent impedance and propagation delay across the area of the board.

Image Current in the Adjacent Plane Provides the Return Current

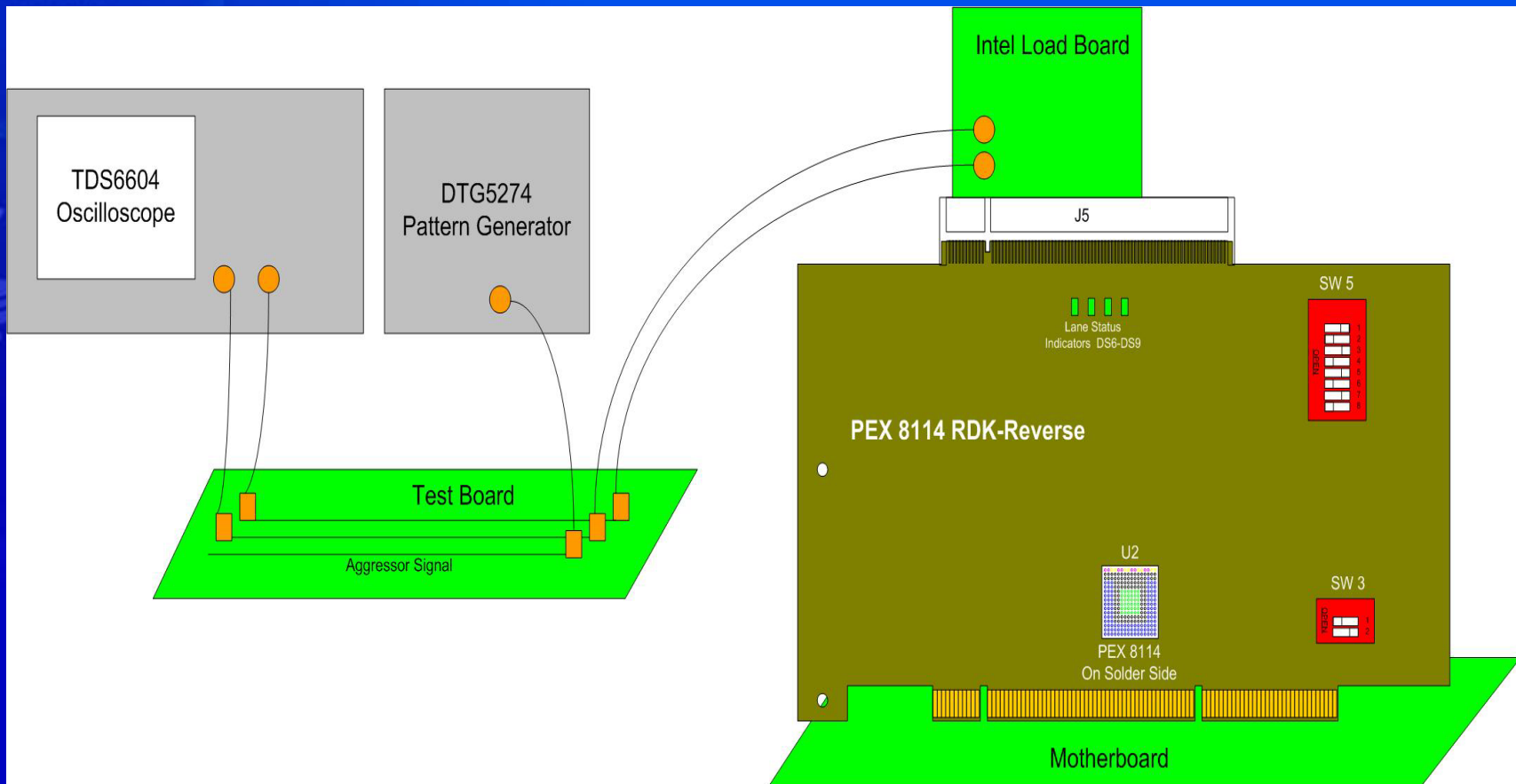


- Assume a plane separated from a signal layer by 3.5 mil.
- Return current will want to flow along the same X-Y path as the signal.
- If it is prevented from doing so, it may be difficult to determine the route it does take.
- This will cause impedance discontinuities and differential mode noise.



Trying to See the Difference Between Tight and Loose Differential Pairs

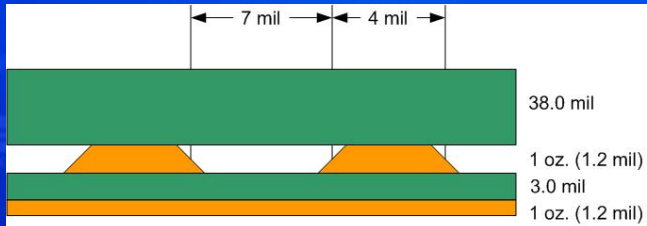
Test Set-Up



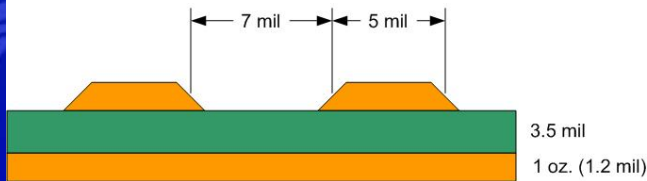
Test Board Differential Pairs

- Loose Coupling – 100 mil edge-edge separation.
- Tight Coupling – 7 mil edge-edge separation.
- Broadside Differential Pair.
- Via mismatch pairs. 1 inch separation.
- Aggressor traces – 7 mil edge-edge separation from one half of a pair.
- All traces are 12 inch total length.

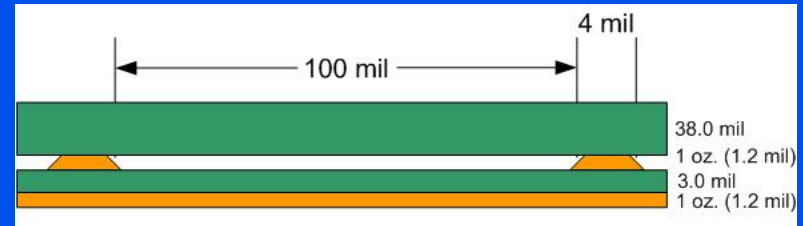
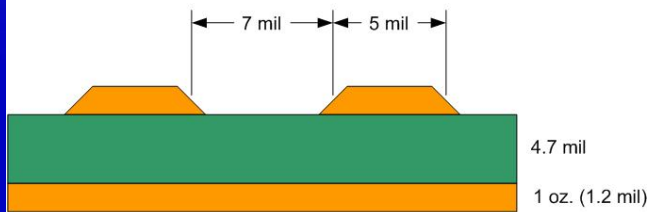
Tight and Loose Coupling Pairs



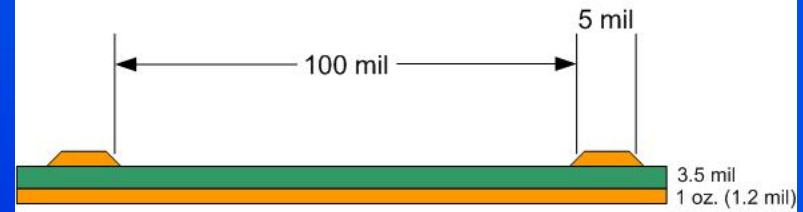
Stripline



Microstripline



Stripline



Microstripline

Test Board Stackup

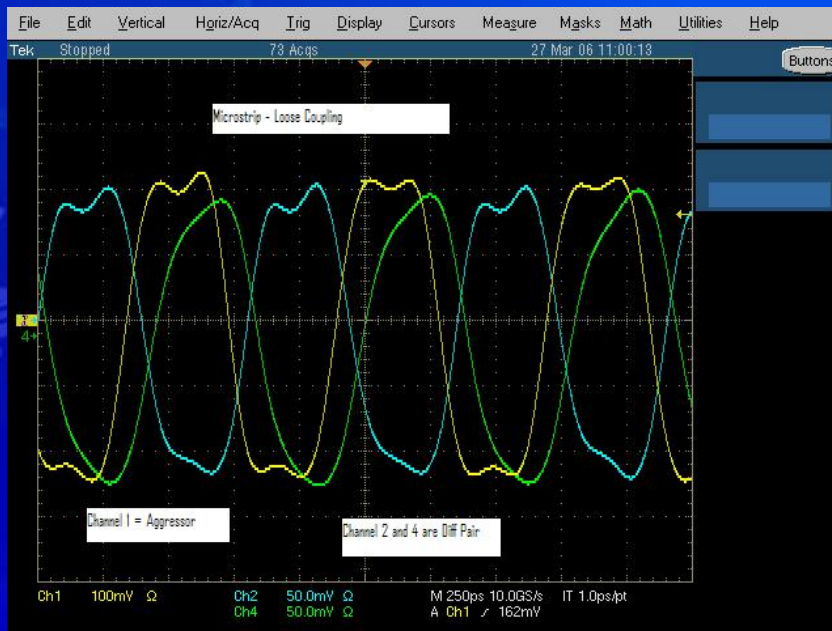
1.4 mil		Cu Plating	
0.6 mil		Signal	0.5 oz
3.5 mil		B-Stage	FR 406
1.2 mil		Plane	1.0 oz
3.0 mil		Core	FR 406
1.2 mil		Signal	1.0 oz
38.0 mil		B-Stage	FR 406
1.2 mil		Mixed	1.0 oz
3.0 mil		Core	FR 406
1.2 mil		Plane	1.0 oz
4.7 mil		B-Stage	FR 406
0.6 mil		Signal	0.5 oz
1.4 mil		Cu Plating	

- Outer Trace Width 5.25 mil
- Inner Trace Width 4.00 mil
- Differential Spacing 6.75 mil

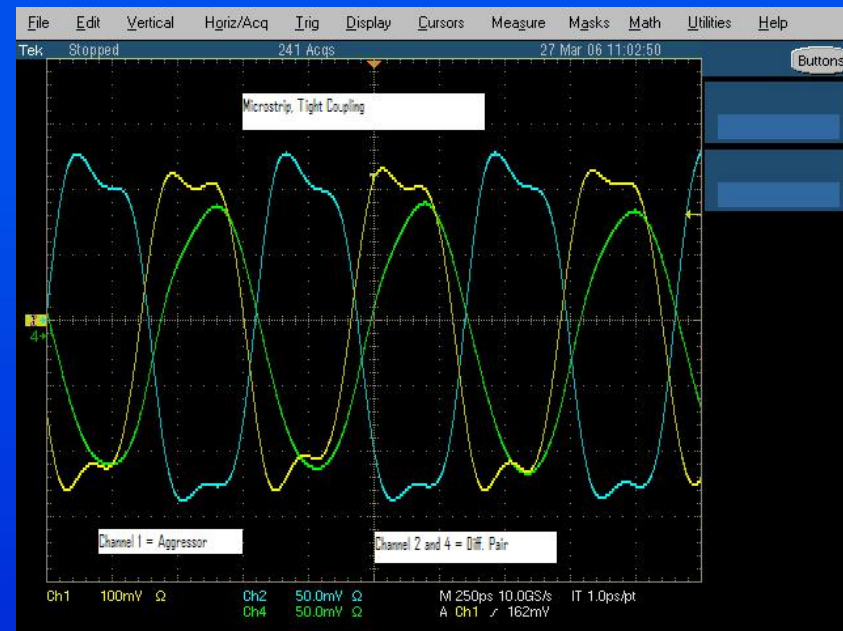
- 50 ohm single-ended
- 100 ohm differential

Noise Pickup from Aggressor

Loose Coupling

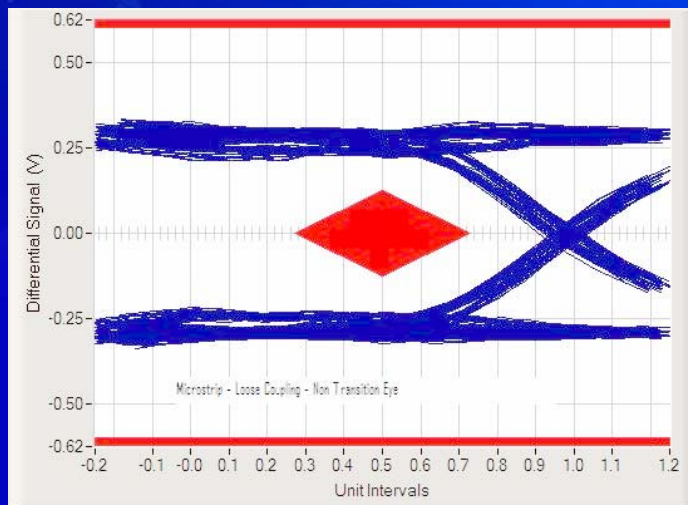
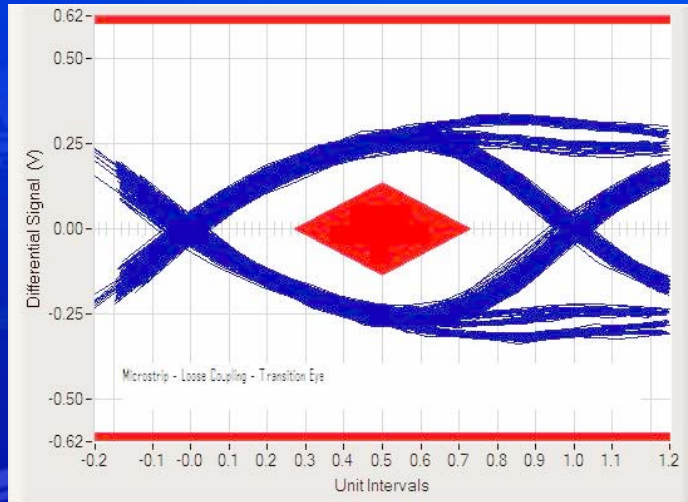


Tight Coupling

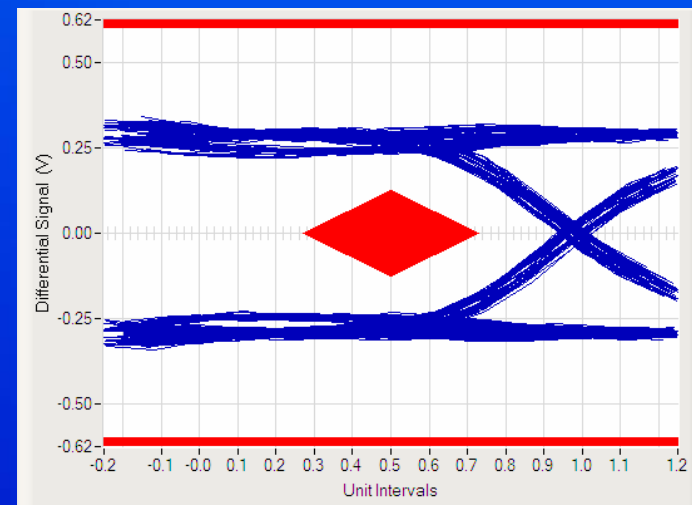
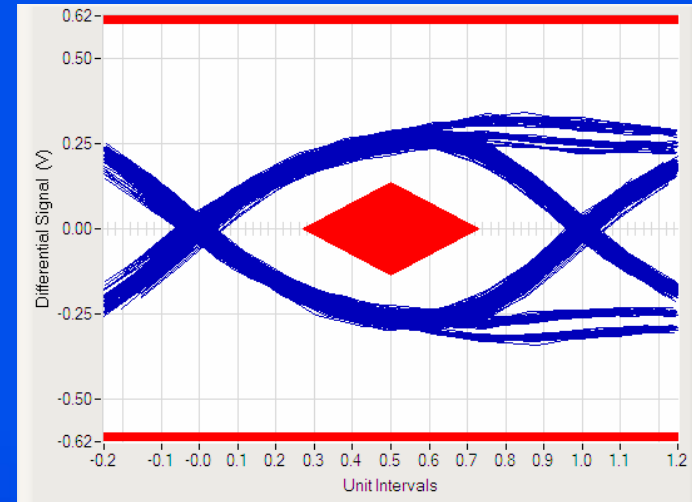


Microstrip Pair - Eye Diagram

Loose Coupling

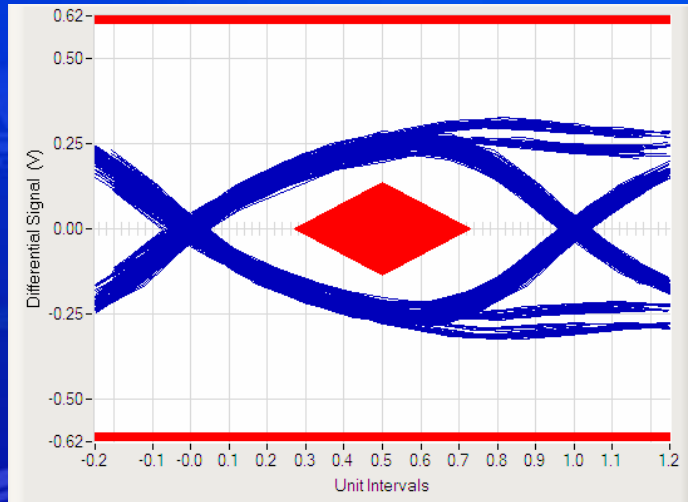


Tight Coupling

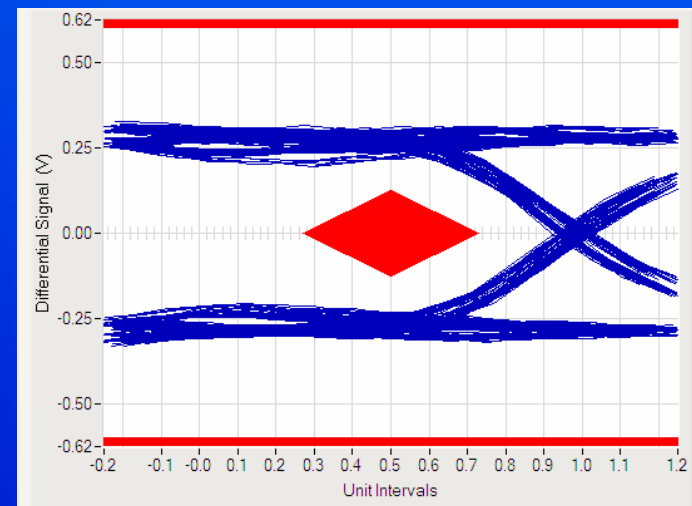
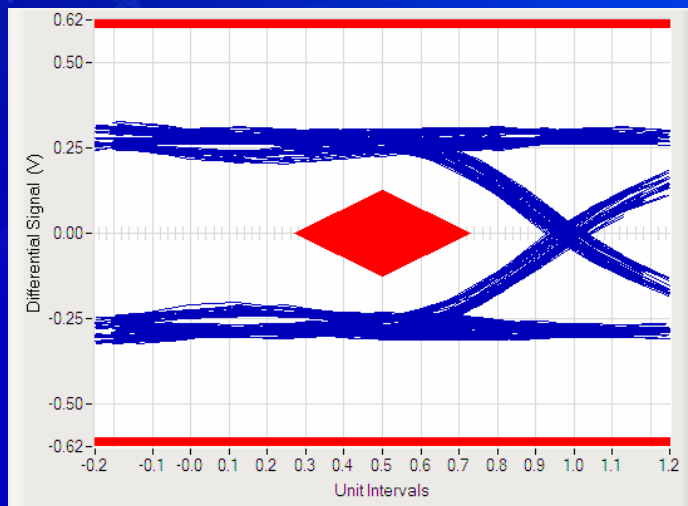
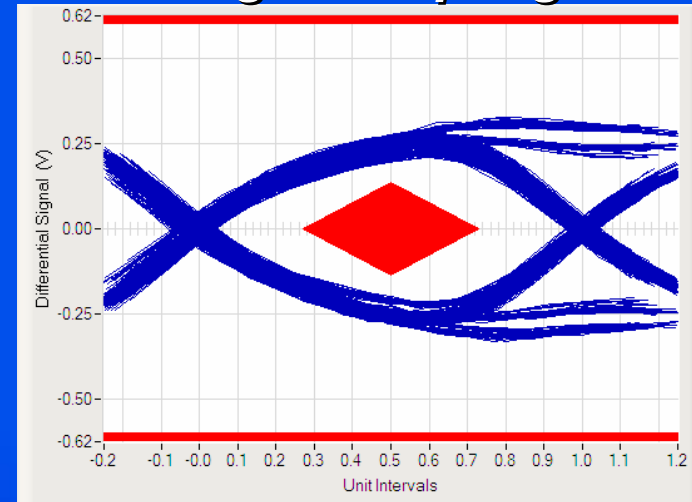


Stripline Pair – Eye Diagram

Loose Coupling

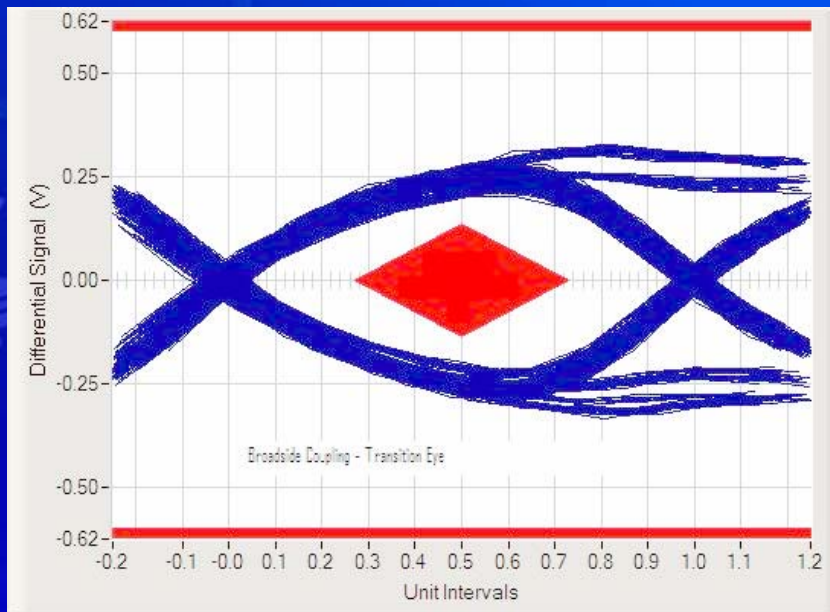


Tight Coupling

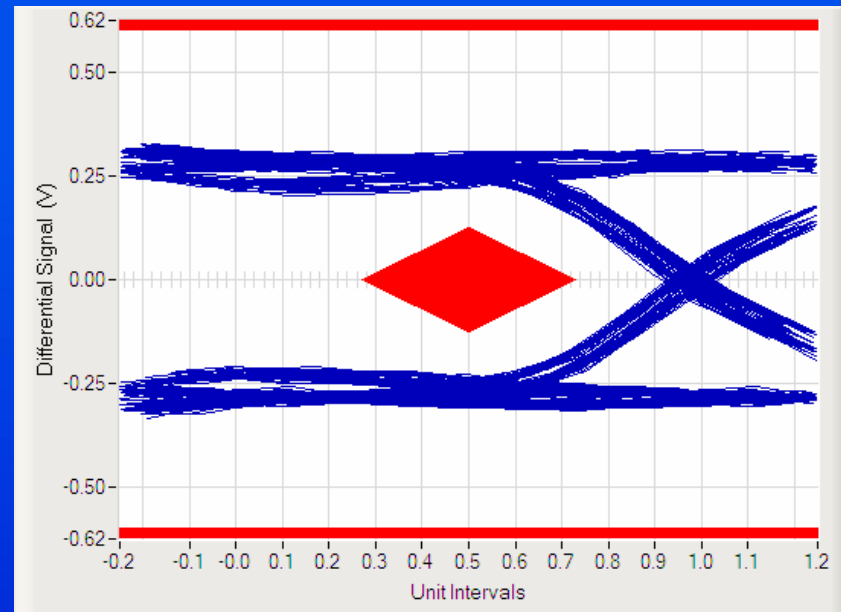


Broadside Coupling – Eye Diagram

Transition Eye

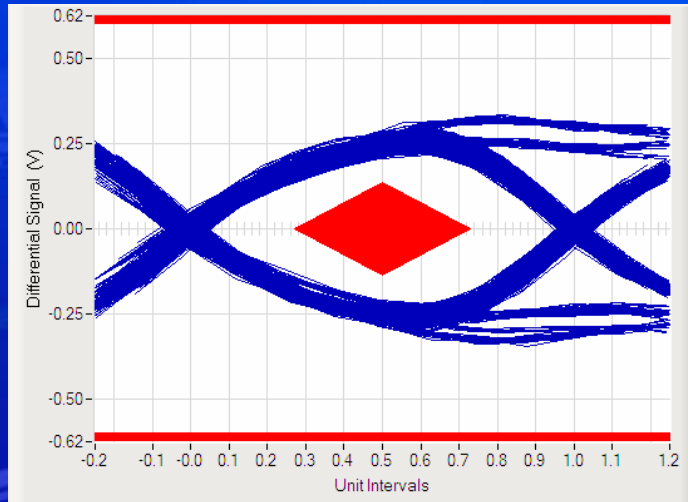


Non-Transition Eye

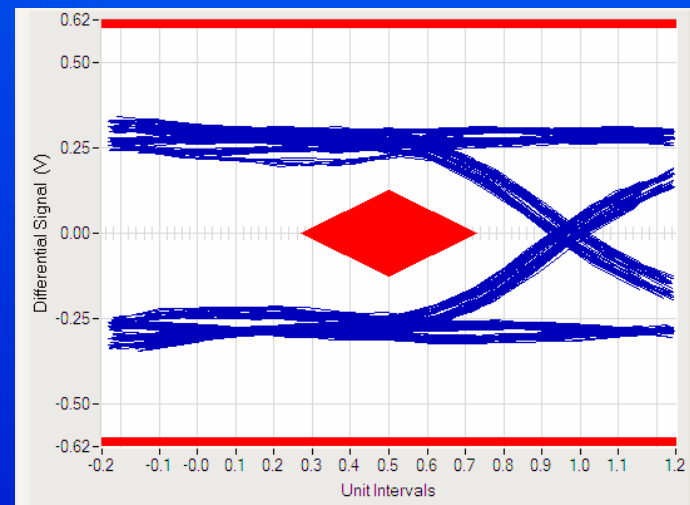
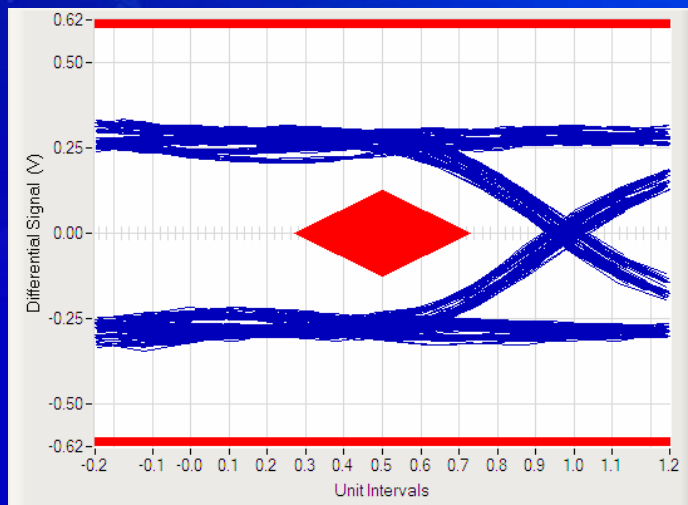
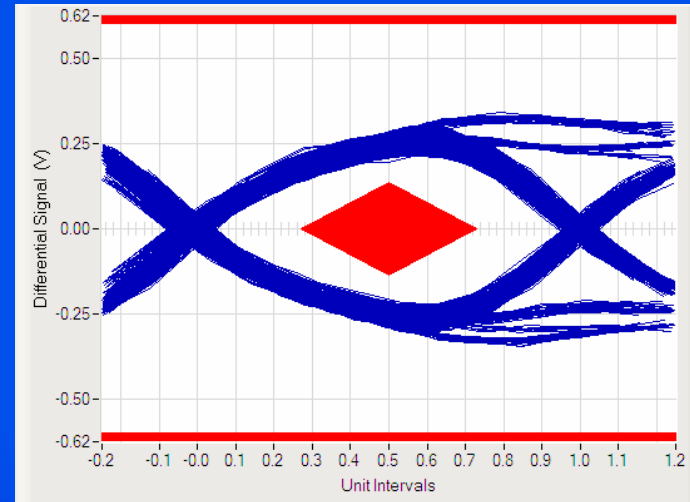


Vias Separated by 1 Inch

Loose Coupling



Tight Coupling



Conclusions

- Observed that noise injected into one half of a pair did not significantly couple over to the other half.
- Saw no significant difference in eye pattern among the differential pair structures tested.
- These results were obtained using a passive board. Results could be different for a board with active circuitry.

References

- Johnson, Howard & Graham, Martin, “High-Speed Digital Design, A Handbook of Black Magic.” Prentice-Hall, New Jersey, 1993.
- Ritchey, Lee & Zasio, John, “Right the First Time.” Speeding Edge, 2003.
- PLX Technology, “PEX 8532 Quick Start Design Guide, v1.1.” 2005.