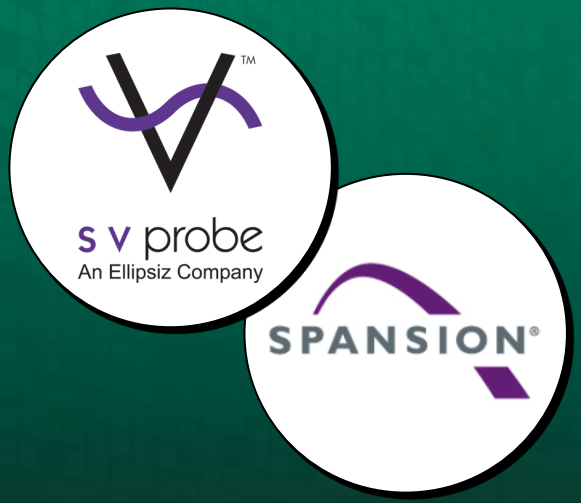
IEEE SW Test Workshop
Semiconductor Wafer Test Workshop
June 9 - 12, 2013 | San Diego, California

Probe Card Improvements to Resolve Customer-Specific Issues



Mohamed Eldessouki, PhD
Rehan Kazmi, PhD
SV Probe, Inc.
Mark Ojeda
Spansion, Inc.

Presentation Overview

- Motivation
- Objective
- Noise Sources & Bandwidth
- Modular Space Transformer (MST) Solution
- Probe Head (PH)
- Customer Measurement
- Summary & Conclusion

Motivation

- **Customer Feedback WST-based Probe Cards**
  - Customer Noticed High Noise on Both Signal & Supply Measurements
  - Average Percent of Wafer Test Yield Loss with Standard WST Technology was 3.83%
  - Customer Noticed PWR Pin Deformation Due to High Currents

Wired Space Transformer (WST) Probe Card

The Goal

- **To Keep WST Advantages:**
  - Quick Turn Around Time
  - Easy
  - Economical
- **To Address WST Shortcomings:**
  - High Noise Coupling between Signal Channels
  - Power Plane Noise Coupling
  - Low Bandwidth

Specific Objectives

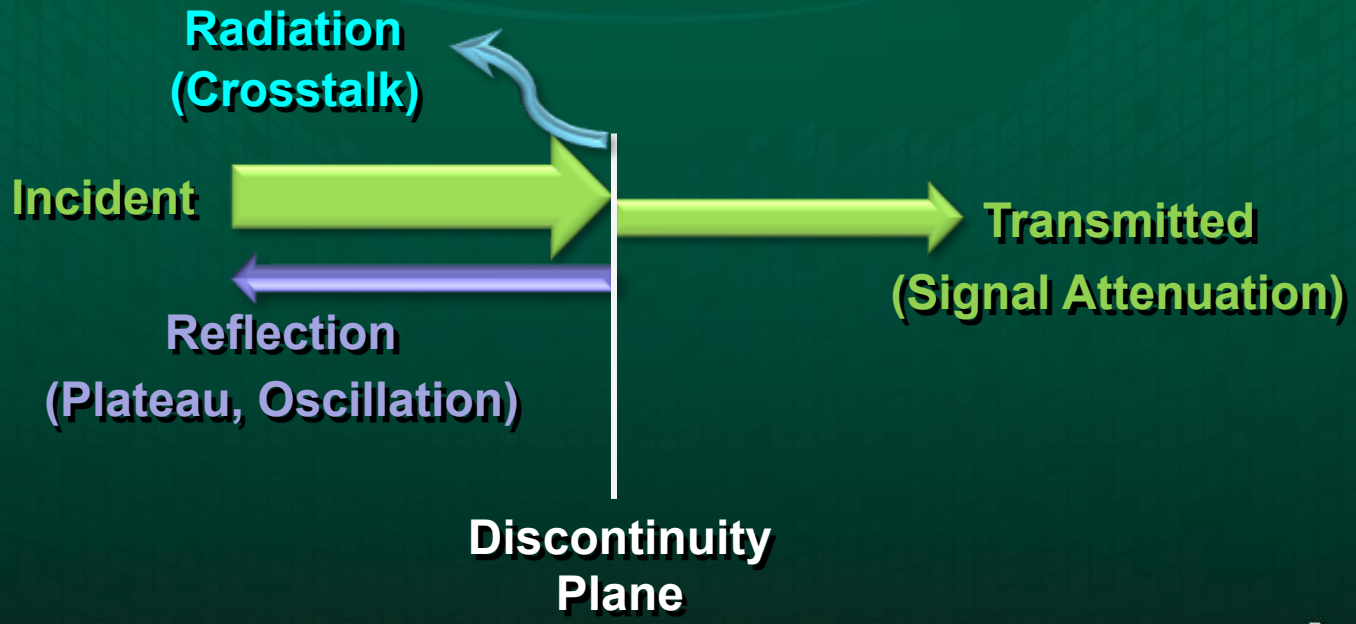
- **Signal Integrity (SI) Related**
  - Increase ST Bandwidth
  - Reduce Signal to Signal Crosstalk
  - Reduce Signal Loss
  - Better Noise Decoupling from Supply Line
  - Reduce PWR/GND Impedance
- **Power Integrity (PI) & Power Capability Related**
  - Increase Current Carrying Capacity
  - Introduce Low Stable Contact Resistance
- **Productivity Related**
  - Keep Turn Time Short by Introducing Modular Solution

Noise Sources & Bandwidth

- **Noise Sources:**
  - Reflection Noise
  - Crosstalk Noise
    - Radiation
    - Coupling
  - Power/GND Noise
- **Bandwidth:**
  - Transmission Line (TL) Type with a Low Pass Filter (LPF) Characteristic
    - Parallel Wire TL
    - Strip Line, Micro-strip

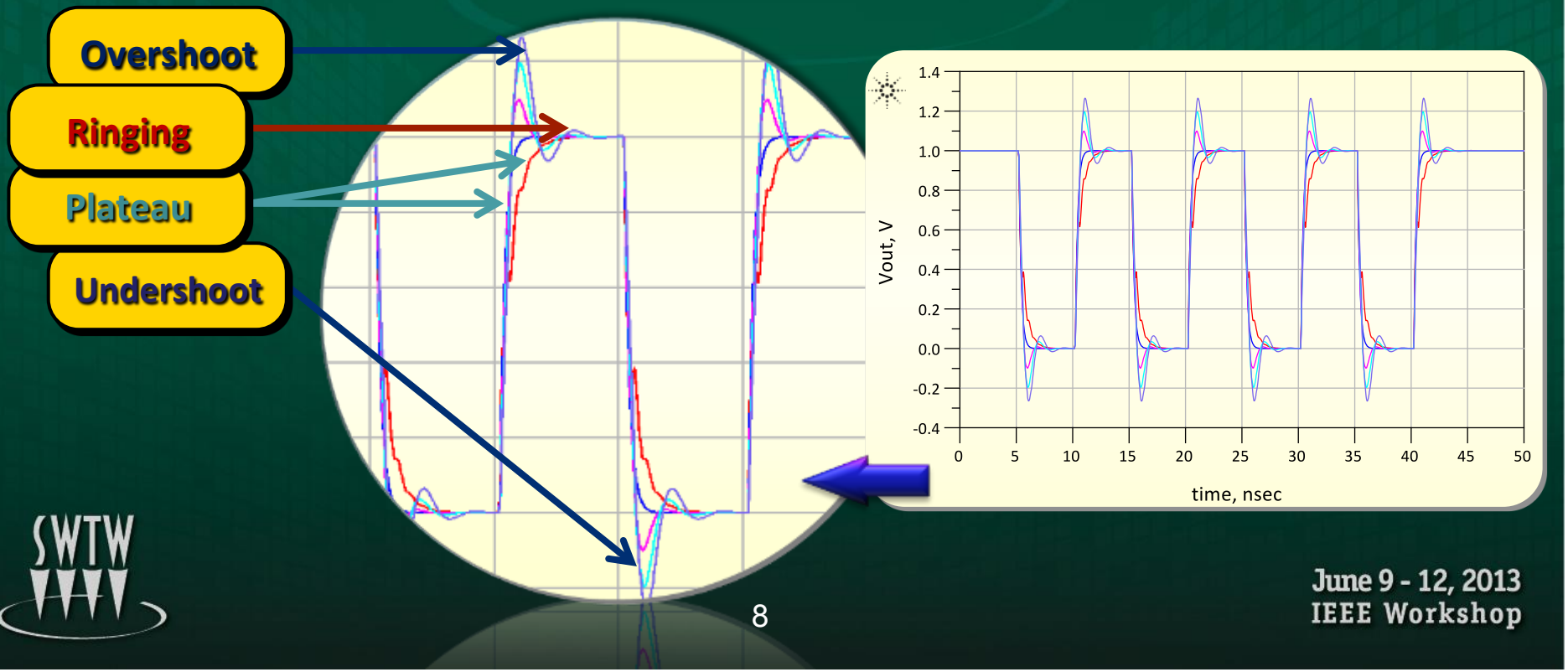
Noise Sources & Bandwidth

- **Reflection & Multiple Reflection Noise**
  - Impedance Mismatch Discontinuity & TL Delay
  - Return Path Discontinuity
  - Transition (Wire to Pin Connection, Connectors, etc)



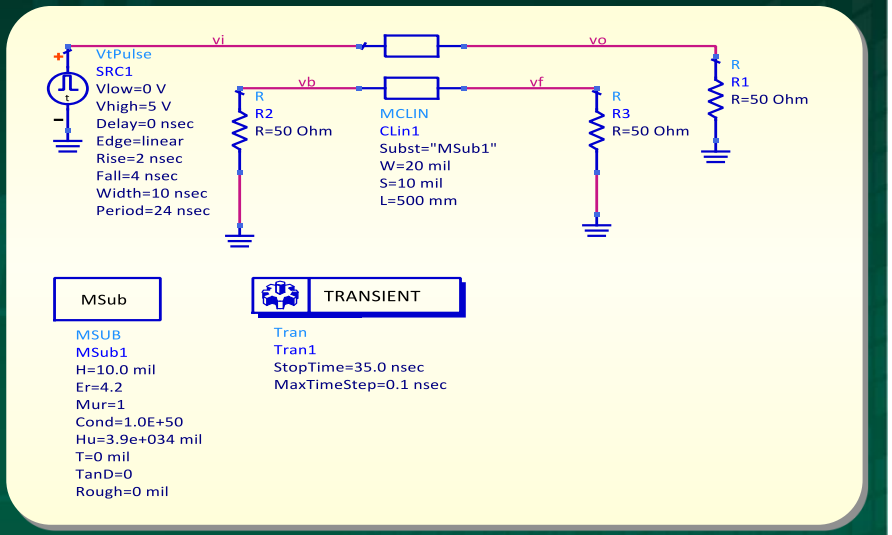
Noise Sources & Bandwidth

- **Reflection & Multiple Reflection Noise**
  - Impedance Mismatch Discontinuity & TL Delay
  - Return Path Discontinuity
  - Transition (Wire to Pin Connection, Connectors, etc)

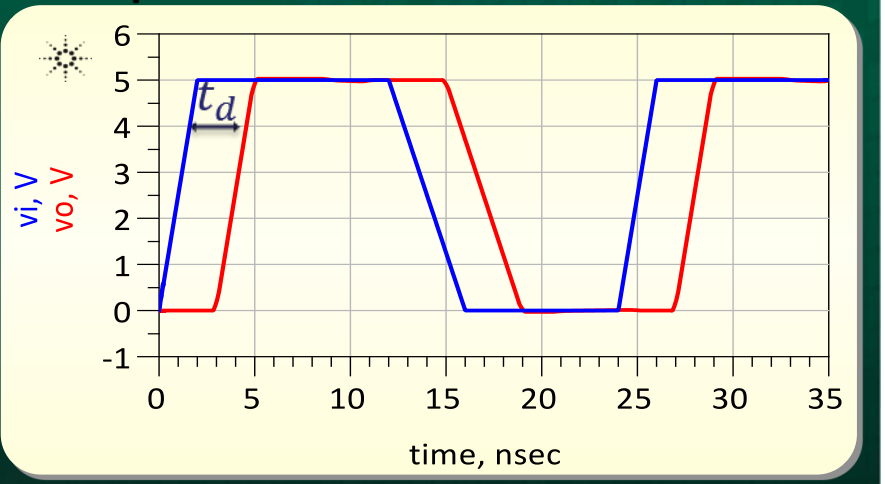


Noise Sources & Bandwidth

- **Crosstalk:**
  - Source of Crosstalk:
    - Capacitive Coupling
    - Inductive Coupling
    - Radiation
  - Crosstalk Types
    - NEXT (TL Delay Time Related)
    - FEXT (t_r and t_f Related)



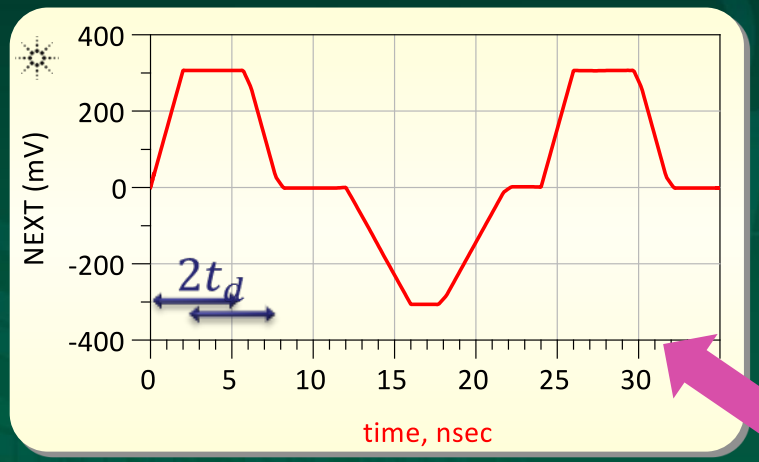
Coupled Lines

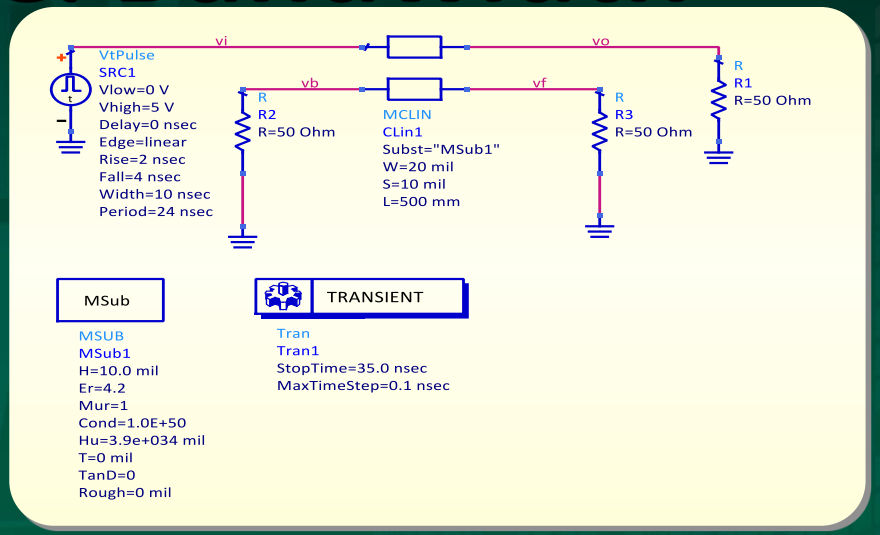


Input & Output Signals

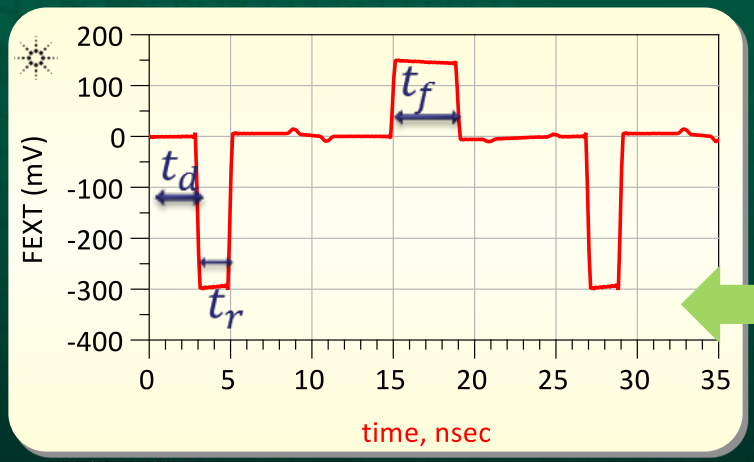
Noise Sources & Bandwidth

- **Crosstalk:**



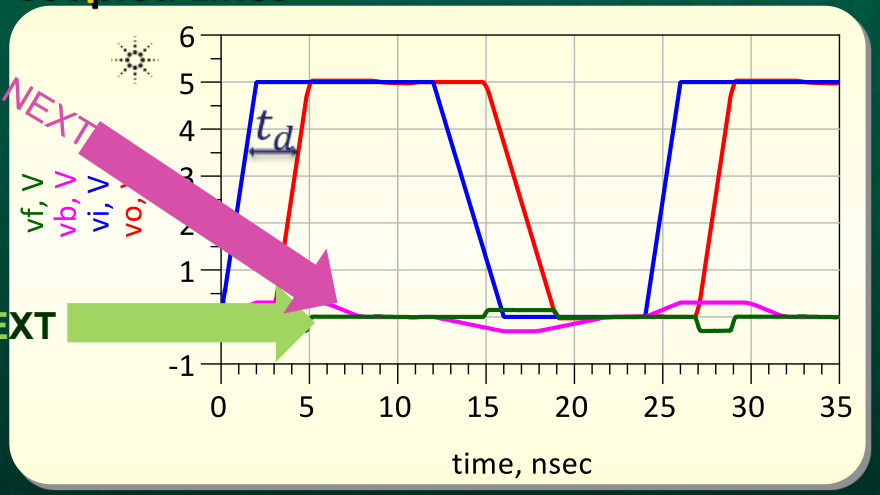


Coupled Lines



NEXT

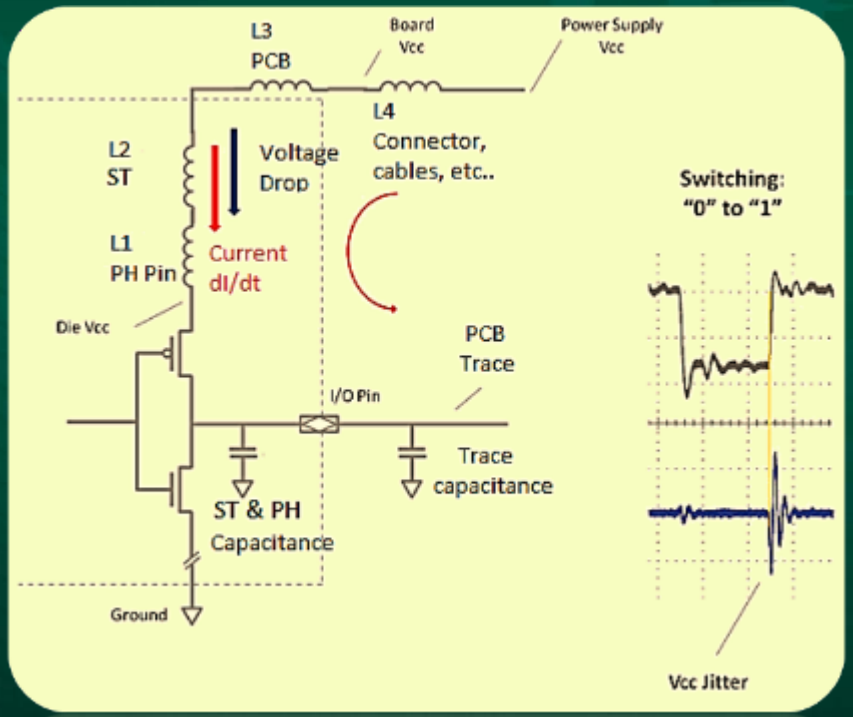
FEXT



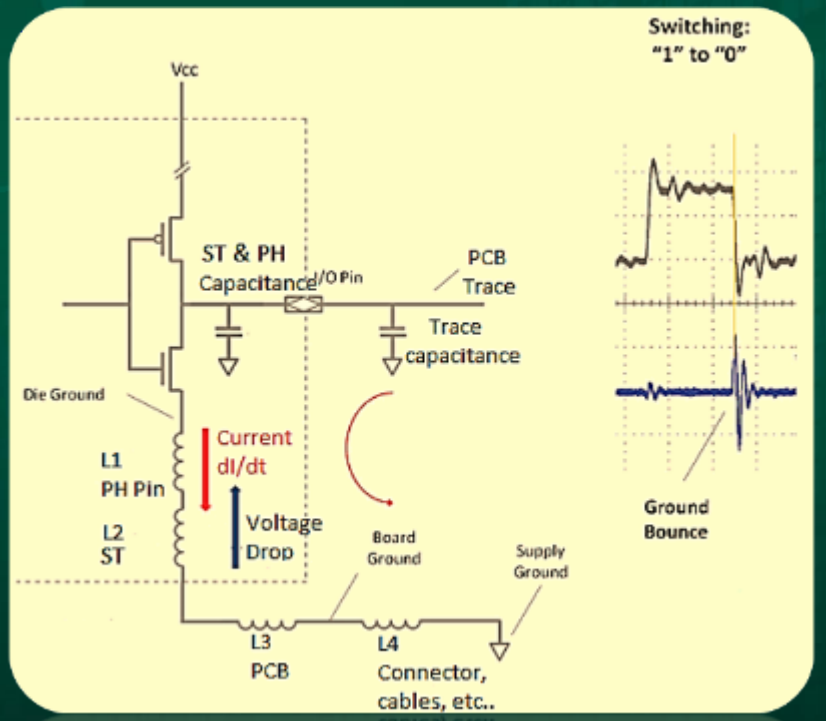
Input, Output NEXT & FEXT Signals

Noise Sources & Bandwidth

- **Power/GND Noise:**
  - Higher Impedance of the Power/GND Plane at Higher Frequencies



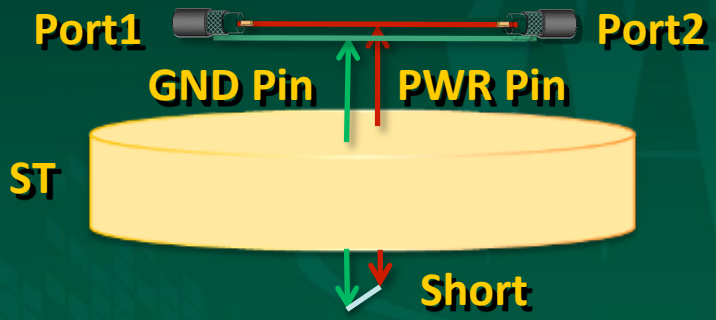
VCC Drop Jitter

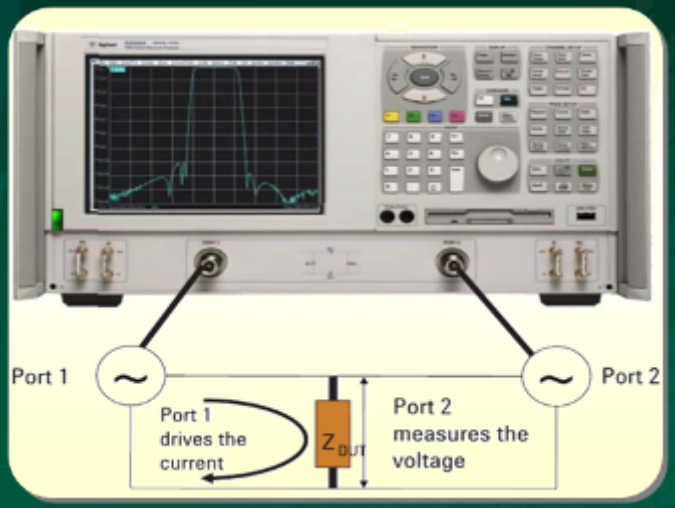


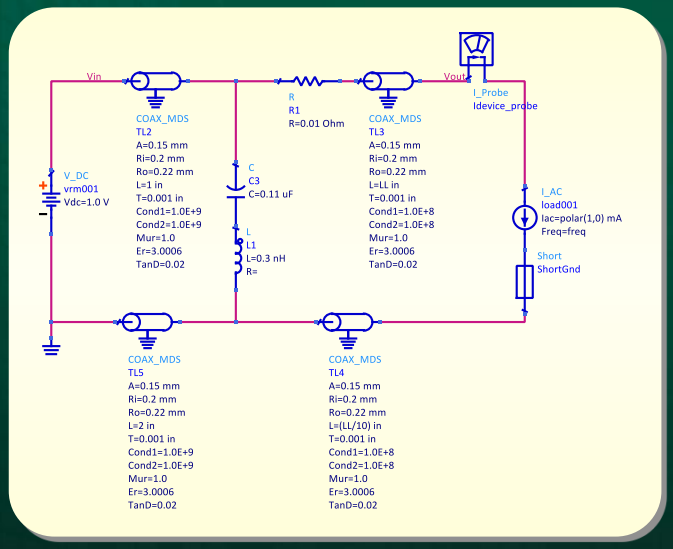
Ground Bounce

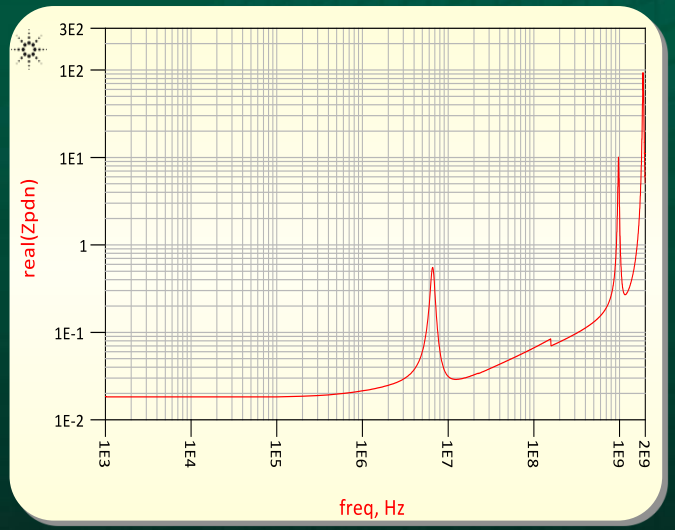
Noise Sources & Bandwidth

- **Power/GND Noise:**



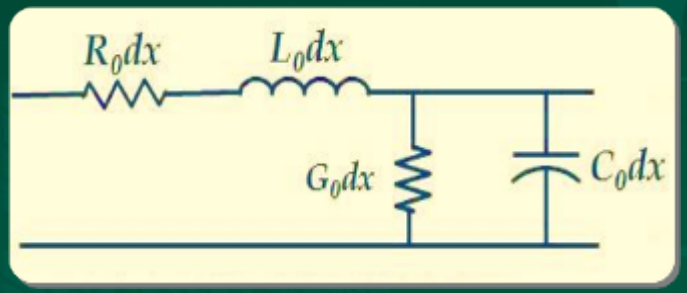






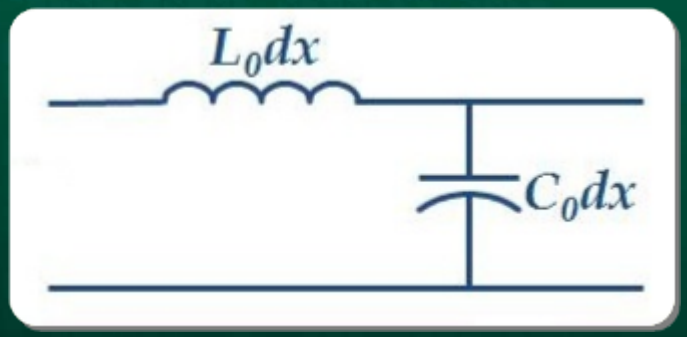
Noise Sources & Bandwidth

- **Bandwidth:**
  - TL Type with a LPF Characteristic

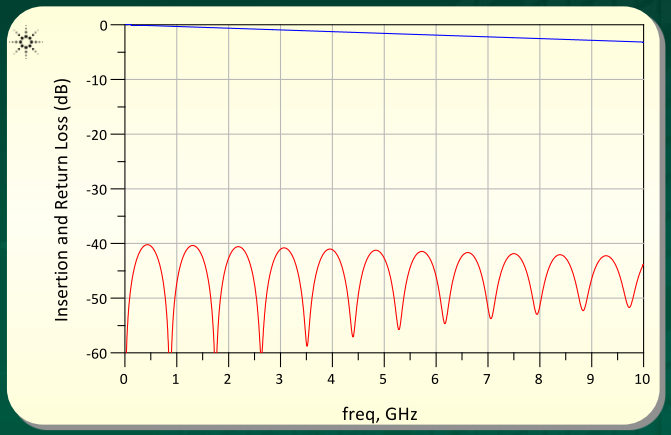


TL Equivalent Circuit Model

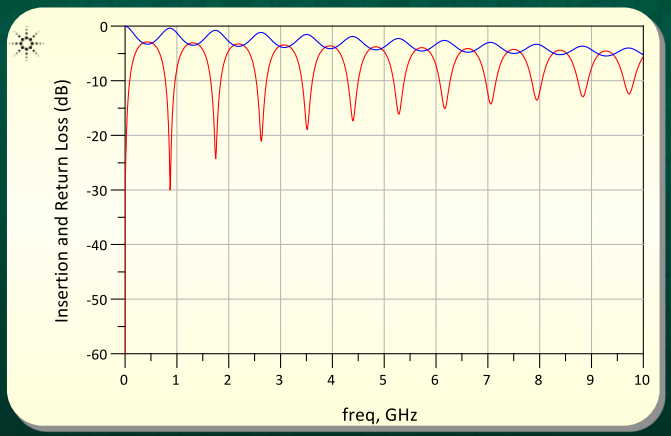
$$f_c = \frac{1}{2\pi\sqrt{LC}}$$



Loss-less TL Equivalent Circuit Model



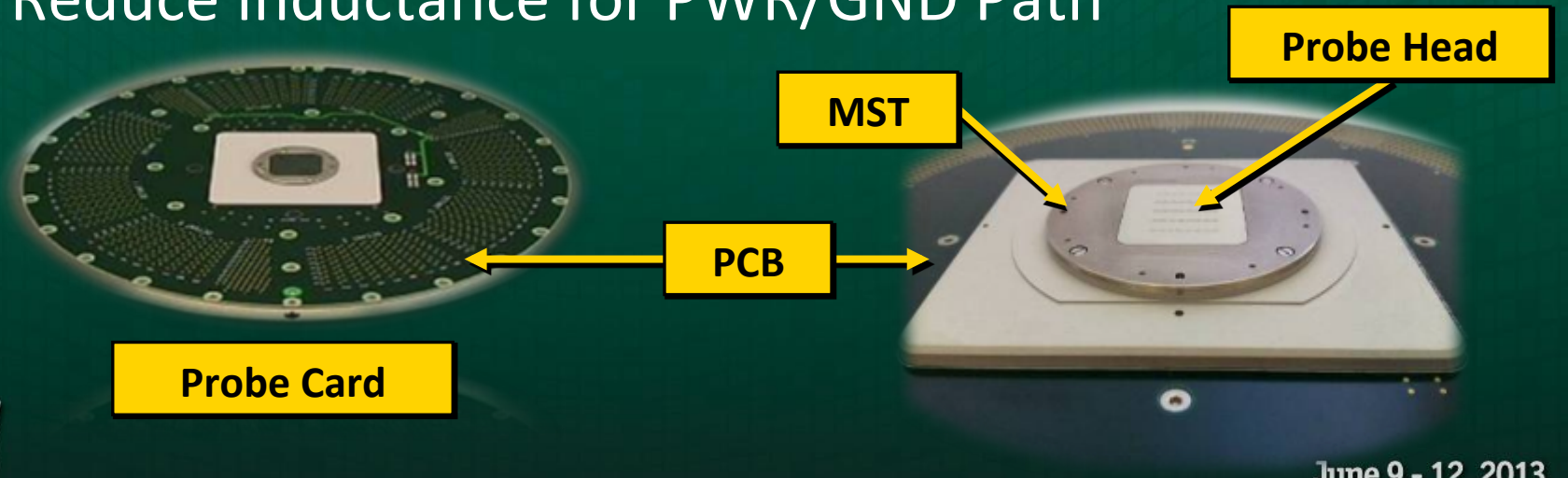
Matched TL



Mismatched TL

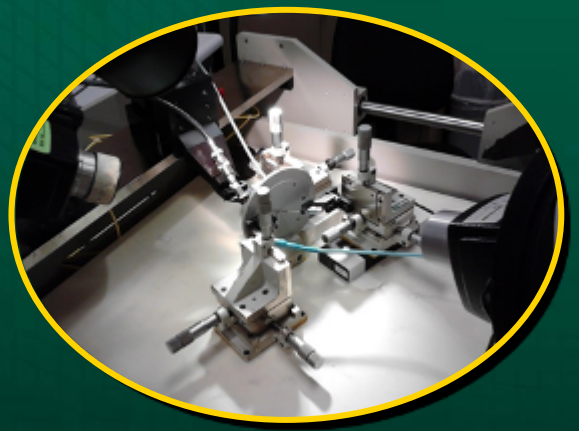
MST is the Solution

- **Action Items:**
  - Minimize Discontinuity for Signal Path
  - Provide Continuous Return Path
  - Bring Decoupling Capacitors as Close as Possible to the DUT PWR Pad
  - Reduce Inductance for PWR/GND Path



MST is the Solution

- **Experimental Methodology**
  - Bandwidth Measurement
  - PWR/GND Path Resistance Measurement
  - TD Analysis

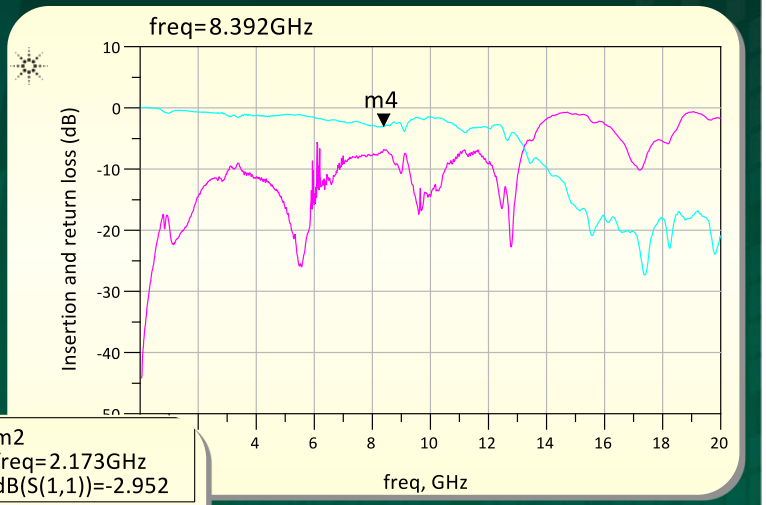


Measurement Setup

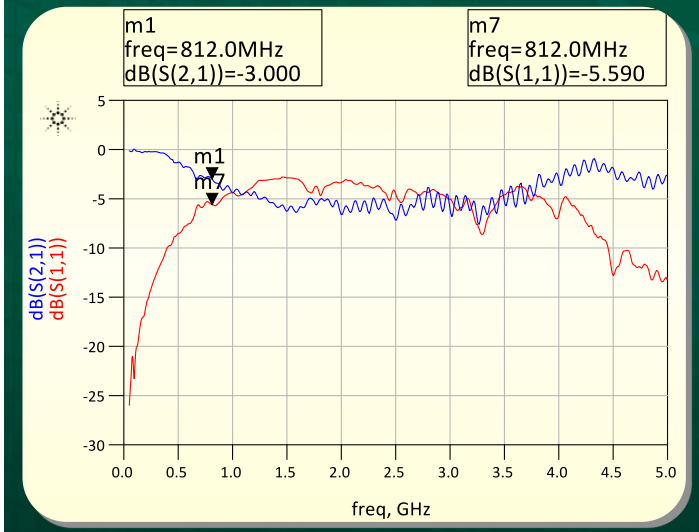
Probe Card using MST

MST is the Solution

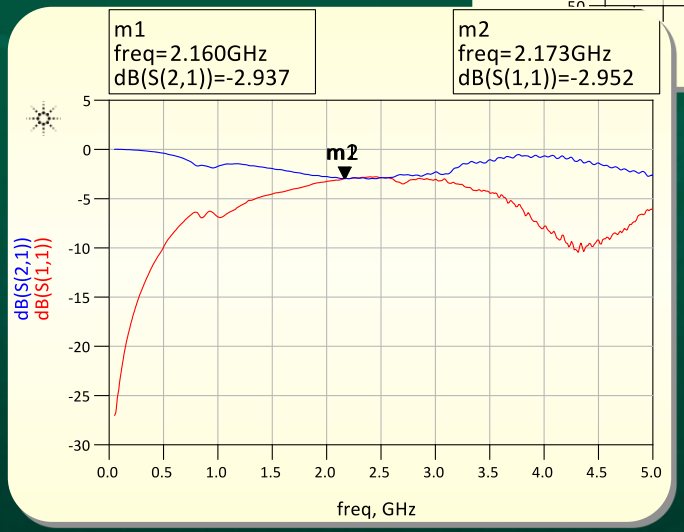
- **FD Measurements:**
  - 50 Ω Single Ended & 100Ω Differential Channel Measurement



50 Ω Single Ended
MST Rev02



MST Rev01

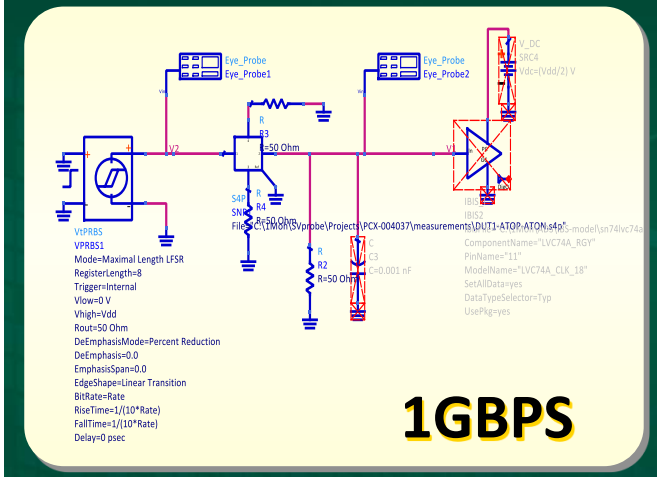


MST Rev02

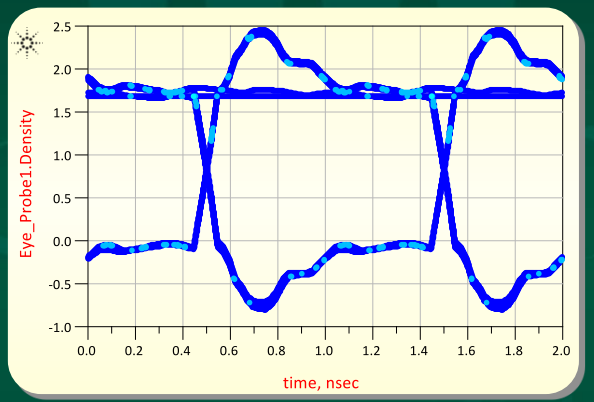
100Ω Differential

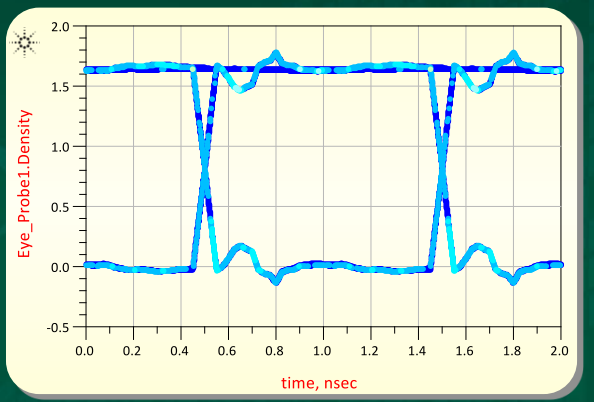
MST is the Solution

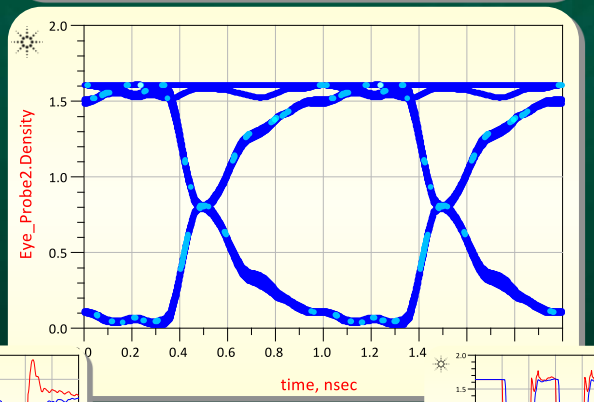
- **Measurements:**
  - TD Analysis (Eye Diagram)

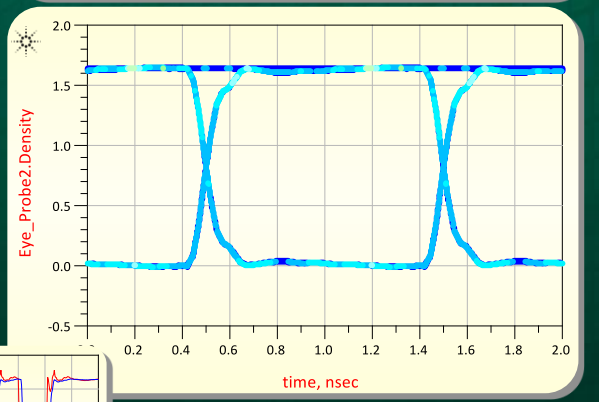


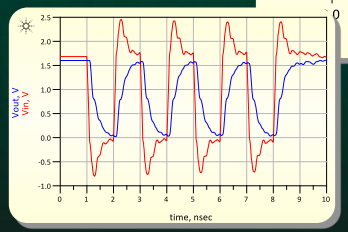
1GBPS



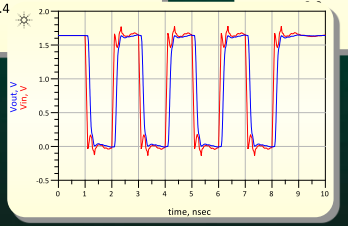








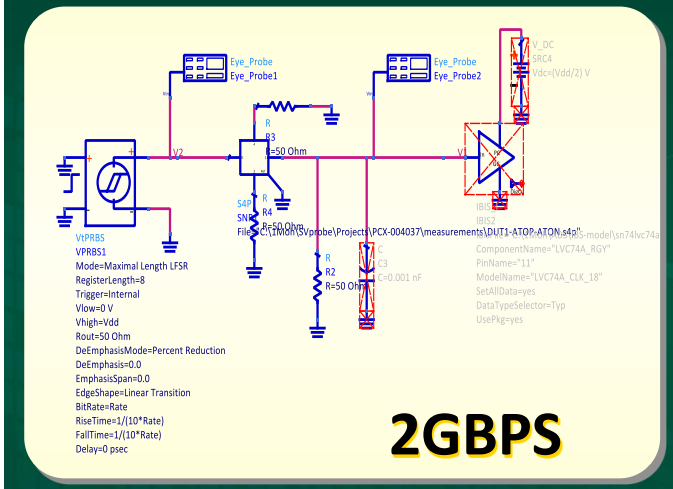
MST Rev01



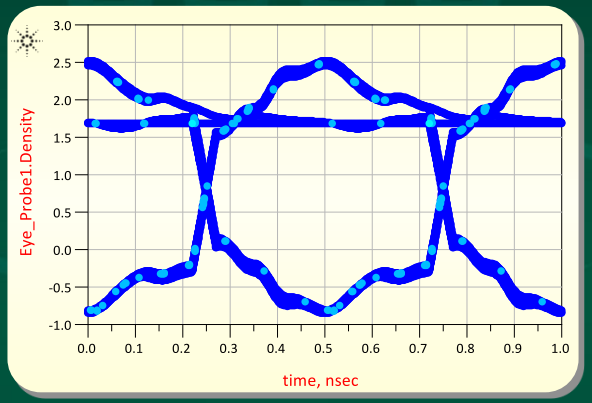
MST Rev02

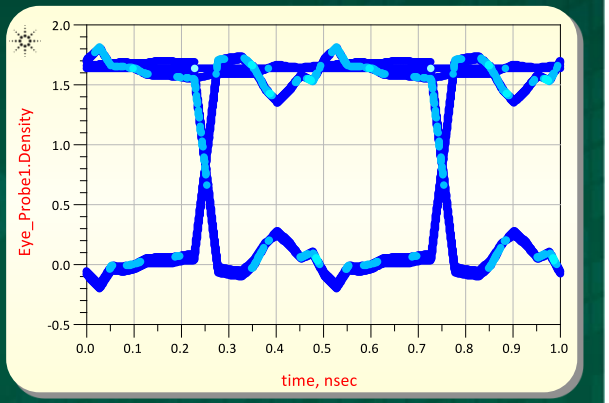
MST is the Solution

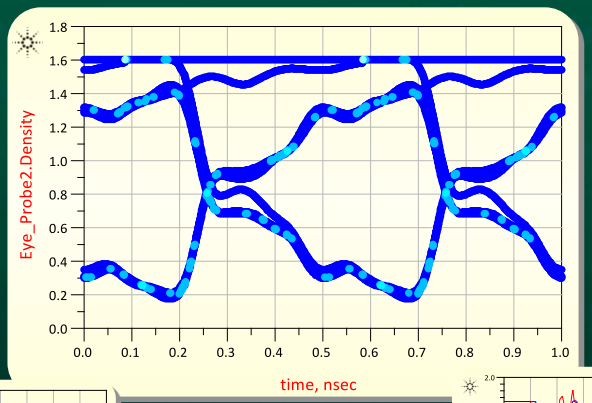
- **Measurements:**
  - TD Analysis (Eye Diagram)

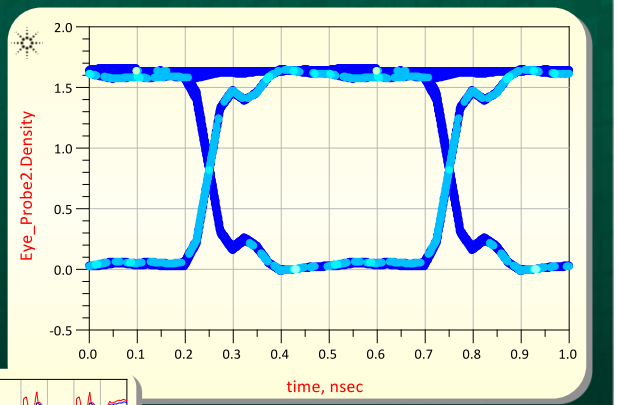


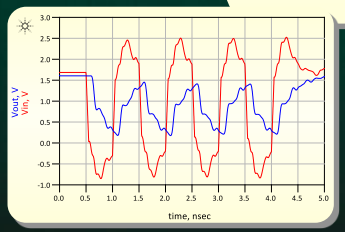
2GBPS



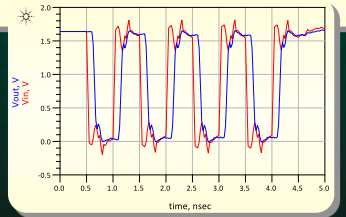








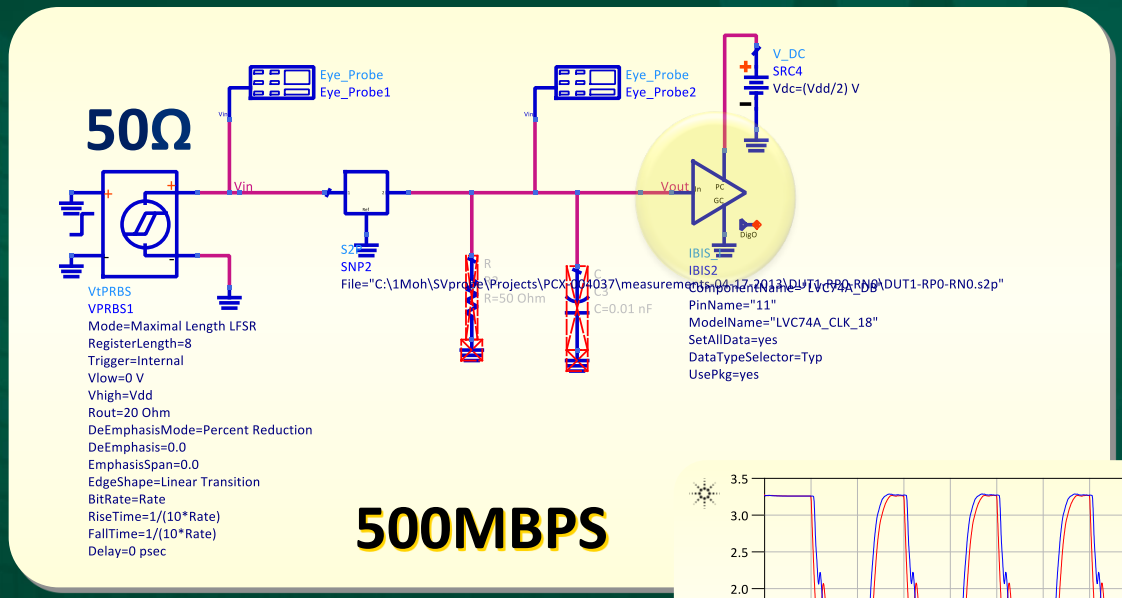
MST Rev01



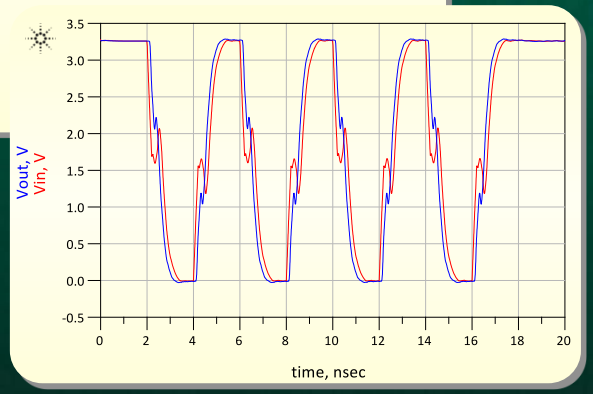
MST Rev00

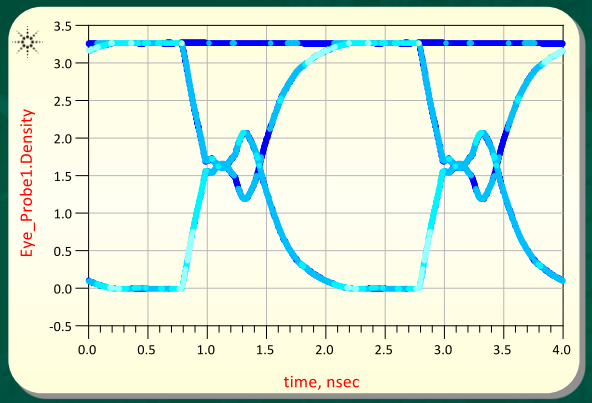
MST is the Solution

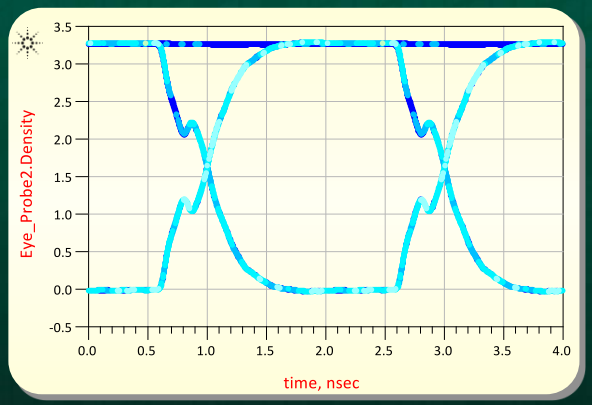
- **Measurements:**
  - TD Analysis (Eye Diagram)



MST Rev02

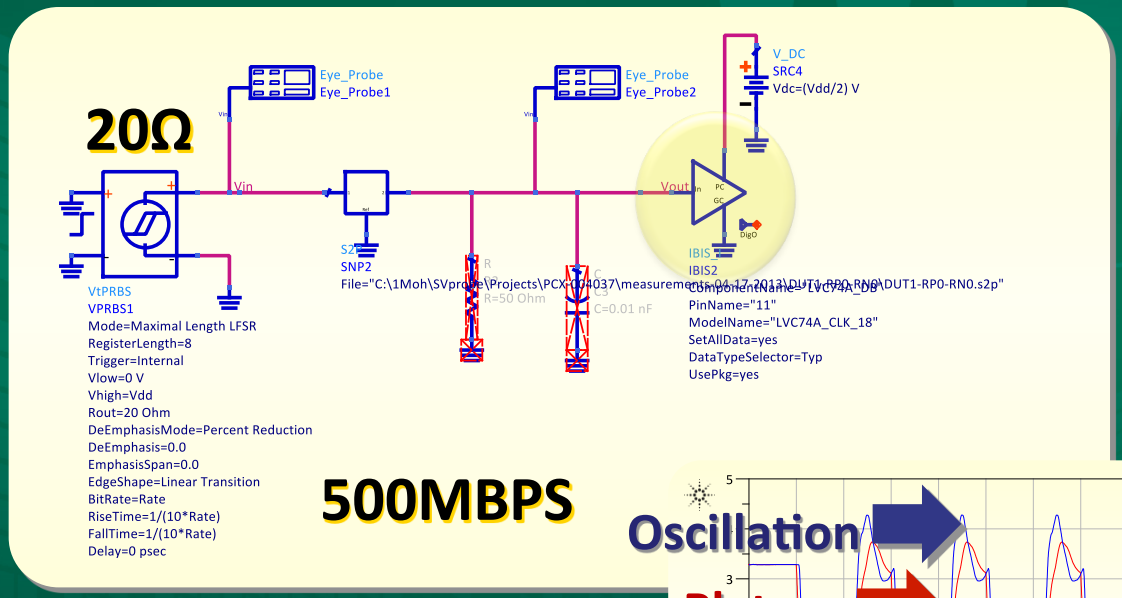


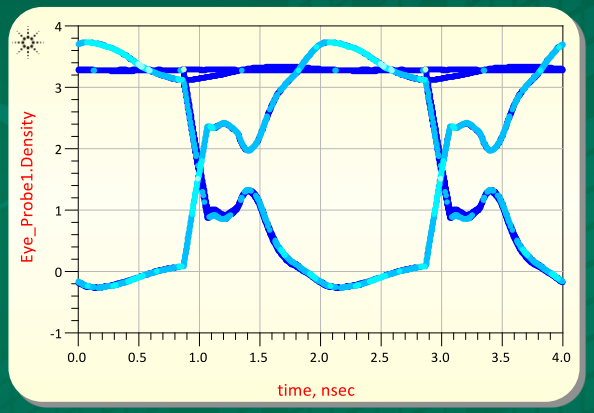


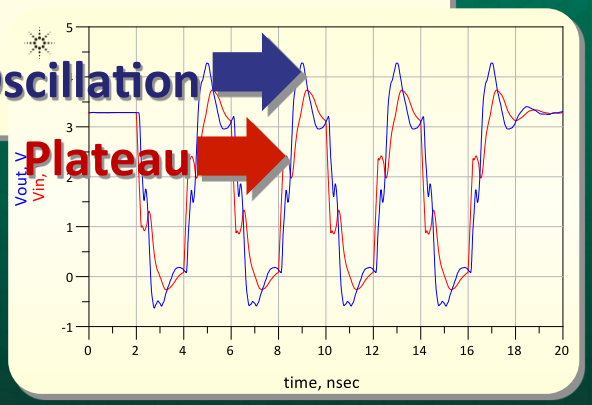


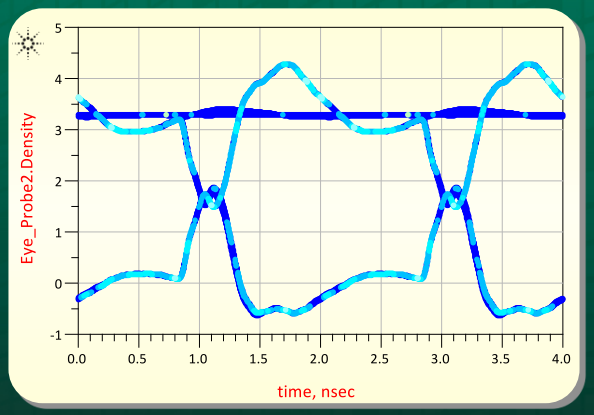
MST is the Solution

- **Measurements:**
  - TD Analysis (Eye Diagram)





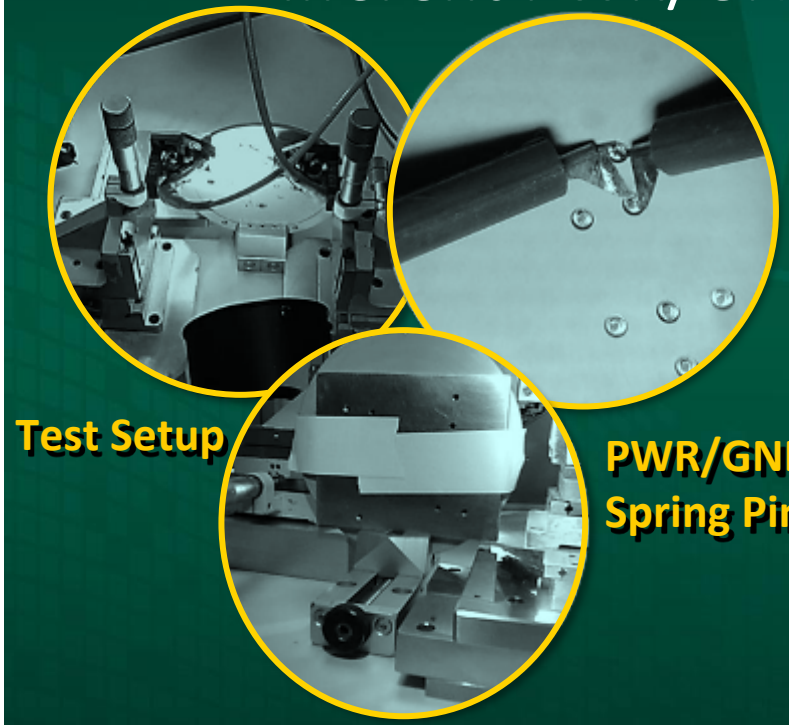


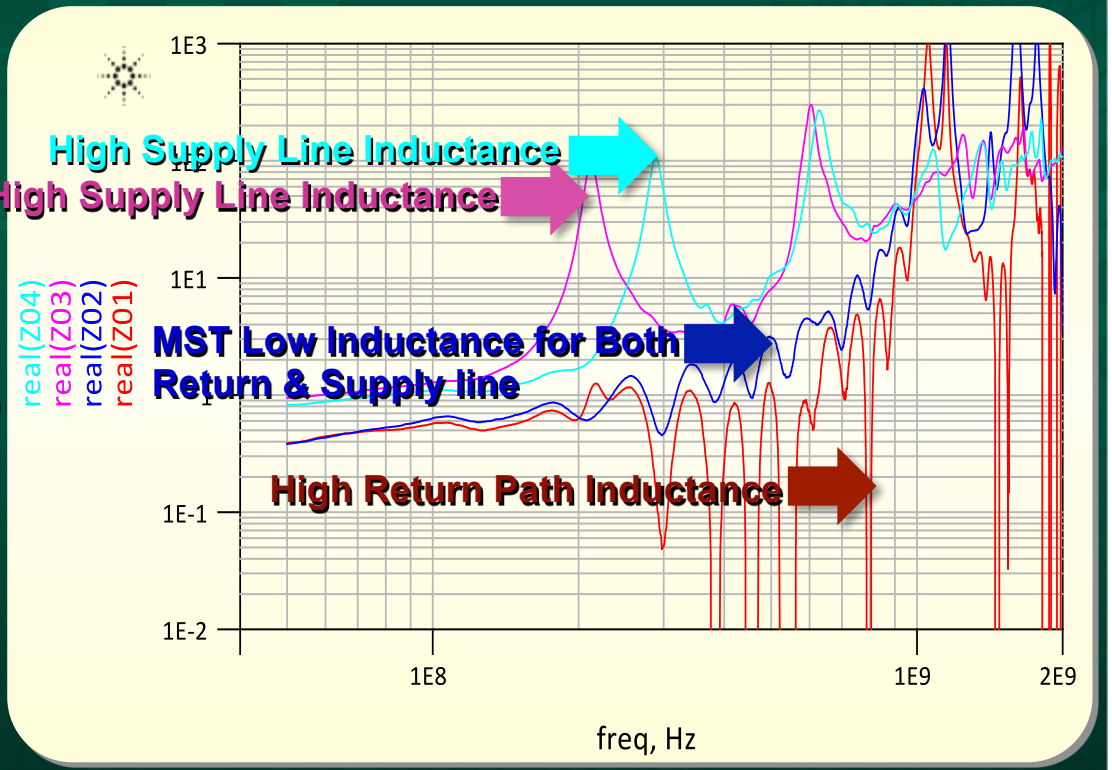


MST Rev02

MST is the Solution

- **Power/GND Measurements:**
  - Different PWR/GND Plane Measurements





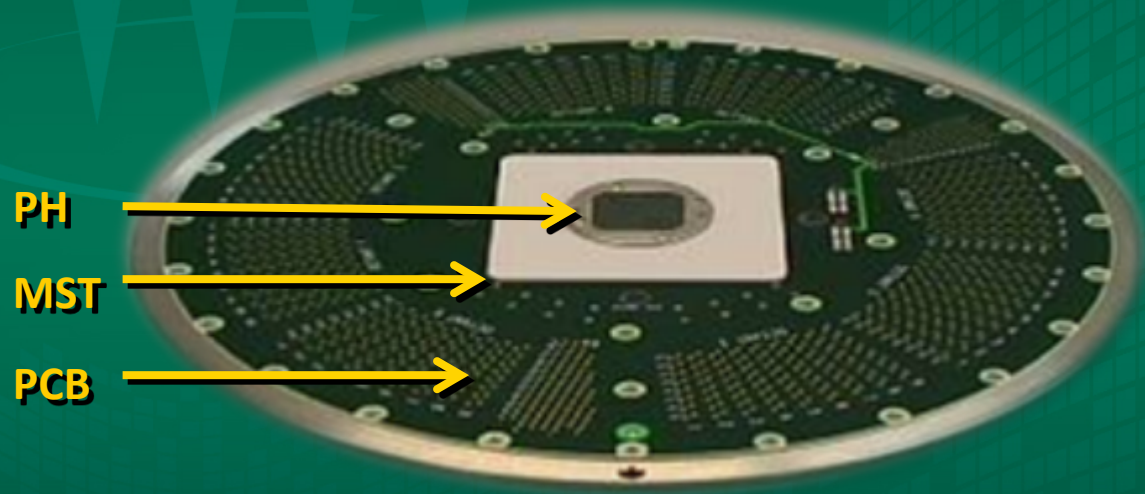
MST is the Solution

- **Validated Advantages:**
  - Higher Bandwidth
  - Low Noise Coupling
  - Higher Bit Rate Capability
  - Low Path Resistance for Both PWR & GND

Power Capability

- Reduce Path Resistance & Increase CCC

Bottleneck for CCC



Probe Card

Probe Pin

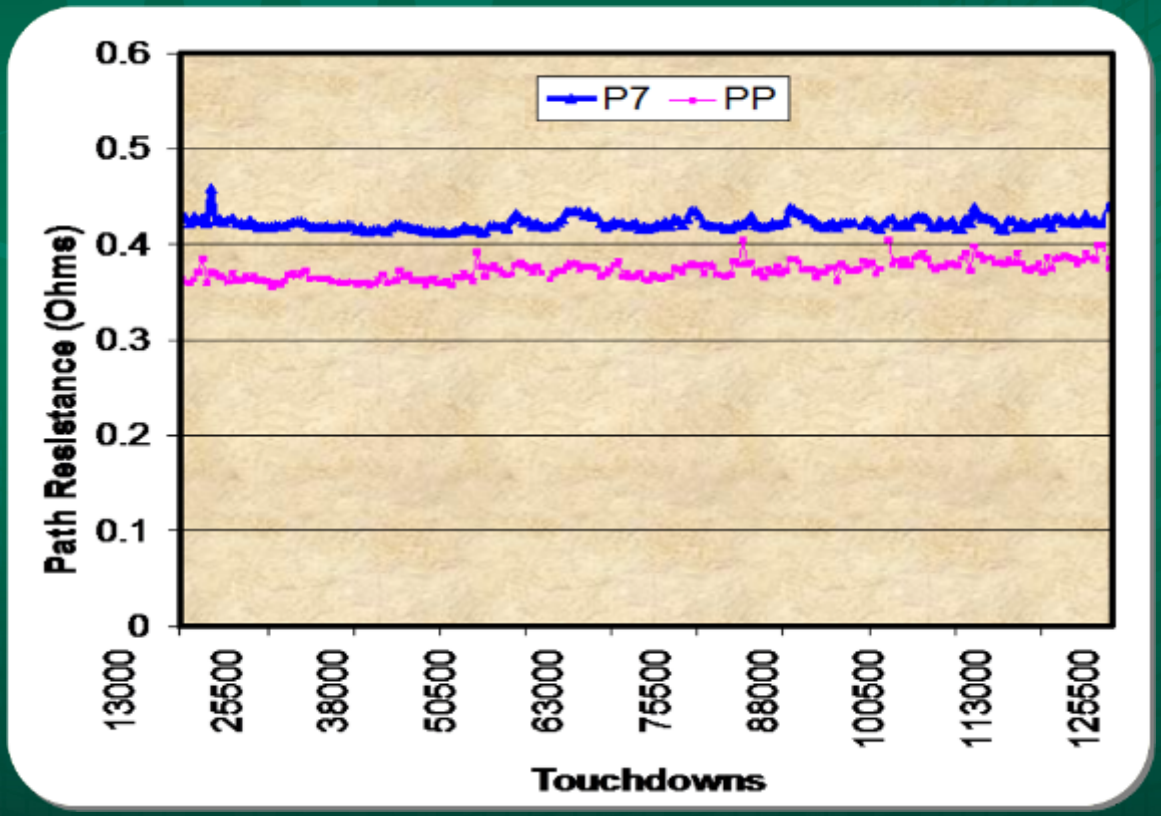
- **P7 & PowerPlus™(PP) Properties Comparison:**

	Paliney 7	PowerPlus™
Resistivity	32 μΩ-cm	12 μΩ-cm
Oxidation at 25°C	Low	Low
Oxidation at 150°C	Low	Low
Melting Temp	1015°C	960°C

Probe Pin

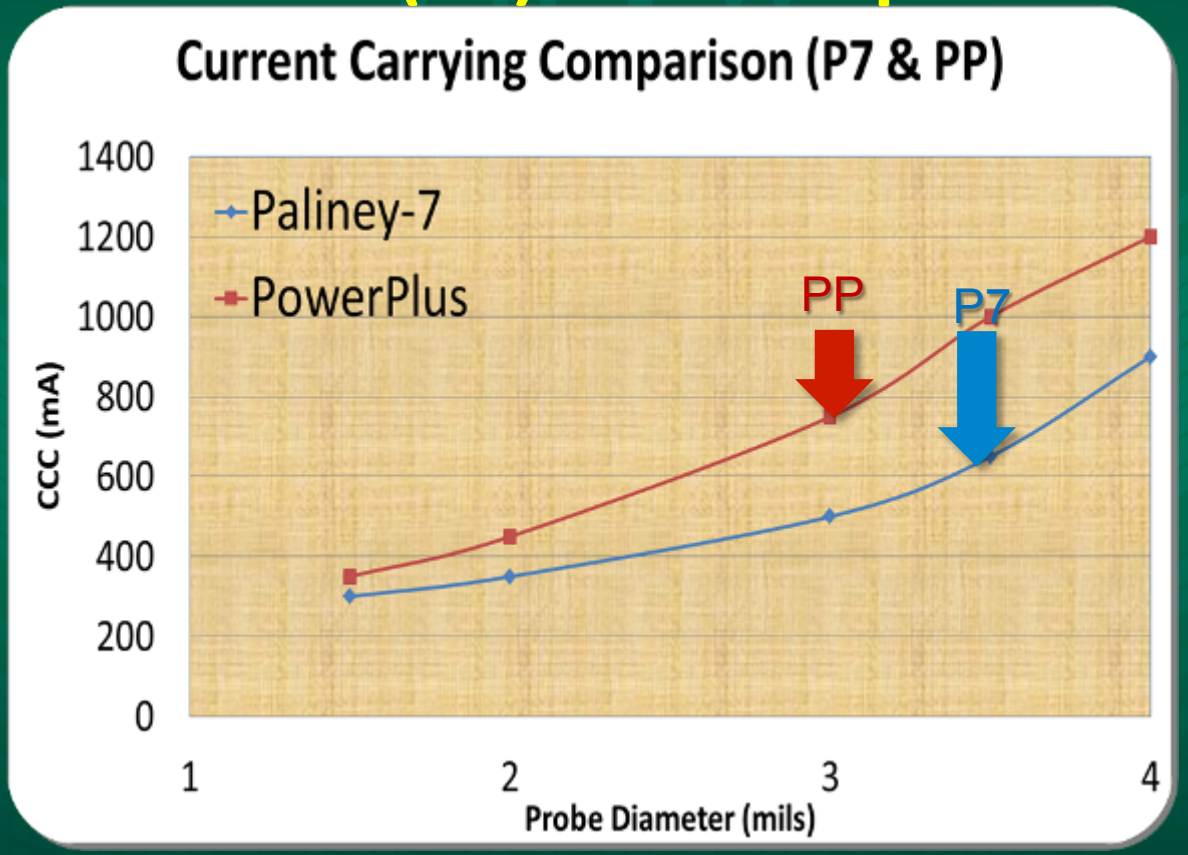
- P7 & PowerPlus™(PP) Performance Comparison:

Path Resistance Measurement



Probe Pin

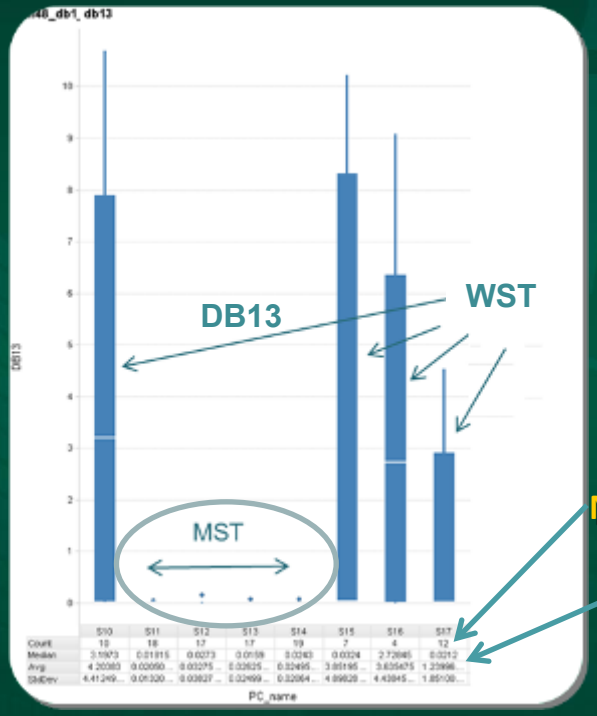
- **P7 & PowerPlus™(PP) CCC Comparison:**



10% Force Drop Methodology

Customer Results

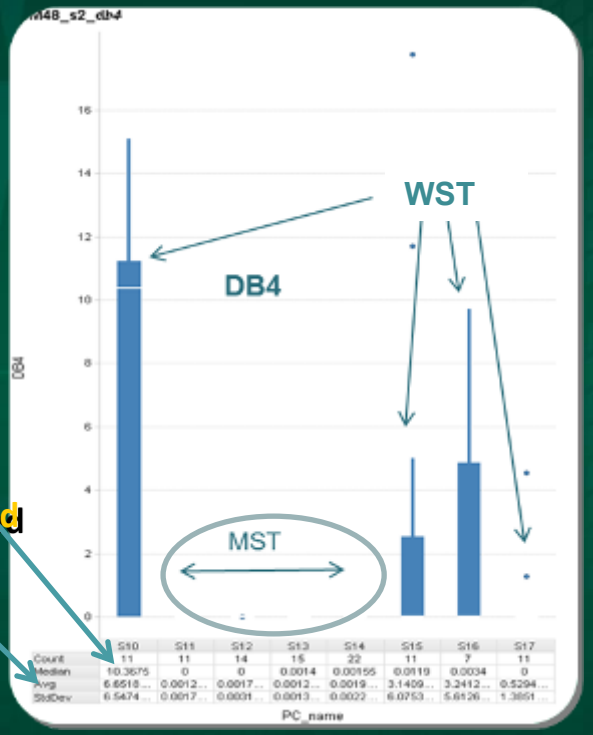
- **MST (PP) VS WST (P7) Data**



98M48 Sort-1 DB13

Number of Wafer Tested

Avg. Yield Loss



98M48 Sort-2 DB4

- The Average Yield Loss was Reduced from 3.83% to Almost *Negligible*

Summary & Conclusion

- **Summary**
  - ST Enhancement
    - MST Shown to Overcome WST Drawbacks
      - Reduce Discontinuities
      - Establish a Return Path for Signal Channels
      - Reduce Path Resistance
      - Reduce Inductance Between Decoupling Caps & GND
  - PH Enhancement
    - Increase Current Carrying Capacity
    - Reduce Path Resistance

Summary & Conclusion

- **Conclusion**
  - Reduce Discontinuity
    - Minimize Reflection Noise
    - Increase Bandwidth
  - Establish a Return Path
    - Minimize Crosstalk Noise Caused by Radiation
    - Minimize Signal Loss by Radiation
    - Minimize Reflection Noise
  - Decoupling Caps Close to the DUT
    - Reduce Path Resistance & Reduce PWR Drop (SSN)

Summary & Conclusion

- **Conclusion**
  - Connecting Coupling Cap GND to MST Reference GND
    - Reduce GND Inductance & Minimize GND Bounce (SSN)
  - Reduce Pin Resistivity
    - Increase CCC
    - Reduce Voltage Drop

With the implementation of MST & PowerPlus™ probes, significant performance improvements were made to the probe card which resulted in higher yield at customer site.

Customer Issue Resolved!

IEEE SW Test Workshop
Semiconductor Wafer Test Workshop
June 9 - 12, 2013 | San Diego, California

Probe Card Improvements to Resolve Customer-Specific Issues

Thank you

Mohamed Eldessouki