Probe Card Improvements to Resolve Customer-Specific Issues

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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
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)

- **Overshoot**
- **Ringing**
- **Plateau**
- **Undershoot**
• **Crosstalk:**
  – Source of Crosstalk:
    • Capacitive Coupling
    • Inductive Coupling
    • Radiation
  – Crosstalk Types
    • NEXT (TL Delay Time Related)
    • FEXT ($t_r$ and $t_f$ related)
Noise Sources & Bandwidth

- Crosstalk:

![Graph of NEXT and FEXT signals with labels for time and amplitude](image)

Coupled Lines

Input, Output NEXT & FEXT Signals

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Noise Sources & Bandwidth

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

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VCC Drop Jitter

Ground Bounce
Noise Sources & Bandwidth

- Power/GND Noise:

Port1
GND Pin
PWR Pin
Port2
ST
Short
Noise Sources & Bandwidth

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

\[
f_c = \frac{1}{2\pi\sqrt{LC}}
\]

**TL Equivalent Circuit Model**

**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

MST Rev01

MST Rev02

100Ω Differential

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- Measurements:
  - TD Analysis (Eye Diagram)

1GBPS

MST Rev01

MST Rev02

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- Measurements:
  - TD Analysis (Eye Diagram)

2GBPS

MST Rev01

MST Rev00

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- Measurements:
  - TD Analysis (Eye Diagram)

50Ω

500MBPS

MST Rev02
MST is the Solution

• Measurements:
  – TD Analysis (Eye Diagram)

MST Rev02

500MBPS

20Ω

Oscillation

Plateau

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

  - High Supply Line Inductance
  - MST Low Inductance for Both Return & Supply line
  - High Return Path Inductance

Test Setup

PWR/GND Spring Pin

MST DUT Side (Shorted)
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

PH
MST
PCB

Probe Card
## Probe Pin

- **P7 & PP Properties Comparison:**

<table>
<thead>
<tr>
<th></th>
<th>Palinney 7</th>
<th>PowerPlus™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistivity</td>
<td>32 $\mu\Omega$-cm</td>
<td>12 $\mu\Omega$-cm</td>
</tr>
<tr>
<td>Oxidation at 25°C</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Oxidation at 150°C</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Melting Temp</td>
<td>1015°C</td>
<td>960°C</td>
</tr>
</tbody>
</table>
PP VS P7

• Performance Comparison:

Path Resistance Measurement
PP VS P7

- CCC Measurement Comparison:

![Graph showing Current Carrying Comparison (P7 & PP)](image)

10% Force Drop Methodology
Customer Measurement

- MST (PP) VS WST (P7) Data

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 problem resolved!
Probe Card Improvements to Resolve Customer-Specific Issues

Thank you

Mohamed Eldessouki