Fully Integrated True CRES Measurement for Probe Cards and Probing Process Characterization

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Introduction

- Fast, reliable, and accurate characterization of probe cards and probing process is a fundamental requirement of developing a robust probing process and consequently a reliable test methodology.

- The efficiency of development effort has been limited by capabilities of toolset:
  - Channel density
  - Accuracy and speed of data acquisition HW
  - Difficulties interfacing data acquisition system with prober
  - Data storage and analysis capability

- Tool cost and availability constraints is often a limiting factor in process development.
Agenda

Intel developed True CRES Measurement (TCM) capability providing a low-cost probe card and process characterization tool
- Built upon a scalable platform
- Fast and accurate
- Fully integrated and easy to use
- Low cost

In this presentation, we cover the following:
- Requirements
- Hardware configuration
- Software (integration and features)
- Key challenges
- Validation
- TCM Screen Shots
- Q&A
Basic Requirements

- Accuracy within $1/10^{th}$ Ohm, each measurement
- Initial 128 channels, scalable
- Able to run stand-alone or in-line with existing tester module
- Maximum 500ms measurement time per die
- Robust system, including out-of-control monitors, etc.
- Easy access to measurement data for both real-time and offline analysis
  - Multiple output formats, including .CSV
Boundary Conditions

- Must integrate with existing automation systems
  - Material handling
  - Data collection
  - Same interface to station controller as other tester platforms

- Must utilize existing prober configuration
  - No requirement to reconfigure and power cycle prober
  - Must support both GJG and GPIB protocols

- Must not impose performance penalty when running inline with existing tester platform

- Must support stand-alone (no tester) mode
Hardware (Stand-alone)

TCM Control
PCI-based PC / Win XP

PCI-Link
Ethernet Connection

Prober
Probe card
Ethernet Connection
RS488.2 / GPIB

DAQ HW
Compact PCI Chassis

PCI-Link
RS488.2 / GPIB
Current Driver 1
Current Driver n
DAQ 1
DAQ n

Same size as Desktop PC
Software

TCM UI:
• May run local or remote
• May run multiple instances

Station Controller:
• Overall process control
• Lot Introduction
• Interfaces to automation systems
• Manages material handling

TCM Engine:
• SC Listener
• GPIB Listener
• Optional Prober Control
• DAQ
• Current Driver
• UI Data
• Saves Results Data
Key TCM Features

- Automatic HW calibration before each lot introduction
- Configurable number of channels
- Channel-level configuration of DAQ I/O
- Channel-level compensation for total path resistance (single-ended mode)
- Configurable bin assignments based on opens, shorts, and CRES ranges

- Fully automated test capability driven from station controller
- Manual test capability using UI
- Multiple tests per die using different current levels
- Treatment of opens using specialized cabling and software compensation
- Real-time system health-check using reference resistor
- Configurable wafer map
TCM uses XML for configuration. Main groupings:

- **Test**
  - Scan rate
  - Current settling time
  - Etc.

- **Channel**
  - Current level
  - Input to output pairing
  - Etc.

- **Bin**
  - CRES range mapping
  - Error to Bin mapping
  - Etc.
TCM uses XML for configuration. Main groupings:

- **Test**
  - Scan rate
  - Current settling time
  - Etc.

- **Channel**
  - Current level
  - Input to output pairing
  - Etc.

- **Bin**
  - CRES range mapping
  - Errors to Bin mapping
  - Opens, Shorts, Etc.
Initial Validation

- Measured 2-Ohm precision resistor (tolerance, .001%)
  - Measured result: 2.0025 ohms
  - Consistent when measuring 16 simultaneous channels (differential) versus just 1
  - The measured value + expected drift (between calibration) well within requirements

- Induced noise by wrapping unshielded cabling around monitor, then (separately) around running electric drill
  - Noise negated by averaging multiple samples (200) per measurement (250K S/s DAQ cards mitigate performance impact)

- Compared results using two measurement methods (standard tester platform)
Analysis of Ohms By Wafer using 4 TV wafers

Tester data

<table>
<thead>
<tr>
<th>Wafer</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>W001</td>
<td>0.111867</td>
<td>0.183908</td>
</tr>
<tr>
<td>W002</td>
<td>0.111940</td>
<td>0.137013</td>
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<tr>
<td>W003</td>
<td>0.104789</td>
<td>0.143574</td>
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<tr>
<td>W004</td>
<td>0.110892</td>
<td>0.169242</td>
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</tbody>
</table>

TCM data

<table>
<thead>
<tr>
<th>Wafer</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>W001</td>
<td>0.122259</td>
<td>0.122908</td>
</tr>
<tr>
<td>W002</td>
<td>0.108477</td>
<td>0.129604</td>
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<td>W003</td>
<td>0.079705</td>
<td>0.071401</td>
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<td>W004</td>
<td>0.076153</td>
<td>0.05298</td>
</tr>
</tbody>
</table>

Tester and TCM Measurements are Similar.
Resistance data was also collected on 16 shorted channels (TCM system. These numbers indicate that the equipment variation is minimal.

- **Mean**: 0.002305
- **Std Dev**: 0.0011832
- **Std Err Mean**: 0.0000159
- **upper 95% Mean**: 0.002336
- **lower 95% Mean**: 0.0022739
Challenges …
Measuring Opens

- For output, voltage is increased until desired current level is reached, up to 10V maximum (implementation-specific)
- When measuring opens, voltage rises above 10V maximum
  - Output channel shuts down
  - As a result, input channel floats
  - DAQ measurement on floating channel yields bogus data
- We built a PCB containing connector plugs and resistors to address this issue
  - We scan for opens (> 100 Ohm) for each die; added benefit: more accurate DAQ range mapping

To compensate: We use resistors in-line with cabling to ensure we never read an open.
Note: All other components available off-the-shelf
Single-end configuration surprises

- Balance between performance, cost, and accuracy
- For single-ended
  - Ground loop issues may arise. Check wiring and configuration (i.e., mode)
  - Use fewer “hot” channels when sharing common ground; better accuracy, but must consider 15ms current settling time impact
  - Must factor path resistance

Differential: Ideal

Single-ended: Possible, but not ideal

Single-ended yields higher channel density
Summary

We developed a low-cost test solution meeting our success criteria

- 1/10\textsuperscript{th} Ohm accuracy
  - actual was 1/20\textsuperscript{th} ohm for single-ended, a worse-case scenario
  - Path resistance was factored in software
- Tested 128 channels in less than 500ms
- Used scalable DAQ platform
- Full integration with prober
- Full integration with automation systems
- Multiple output formats, including simple Excel .CSV
- Included and validated out-of-control capability
- Real-time graphical data display

Development time was minimal

Tool allows performing probe card characterization in labs not previously equipped for such work

- Including internal Probe Card validation
- Including suppliers to characterize Probe Cards
TCM Screen Shots
Introducing a Lot

- Station controller views TCM as a standard tester platform
- Lot introduction uses standard dialogs for lot, recipe, and slot selection
  - Or integrates with other automation systems for these data
TCM w/Die Mean Graph (1)

Note: measuring resistors of known value
Note: measuring resistors of known value
TCM w/Channel Graph

Note: measuring resistors of known value
TCM / Adjusting Channel 8

Channel 8 wired with variable resistor
TCM / Rotating Die Mean Graph (1)
TCM / Rotating Die Mean Graph (2)
TCM / Graph Options

Note: simulated data on this slide
TCM / Maximized Graph

Note: simulated data on this slide
Questions?
Backup
Hardware (Inline)

TCM Control
PCI-based PC / Win XP
  PCI-Link
  Ethernet Connection

DAQ HW
Compact PCI Chassis
  PCI-Link
  RS488.2 / GPIB
  Current Driver 1
  Current Driver n
  DAQ 1
  DAQ n

Prober
Probe card
  Ethernet Connection
  RS488.2 / GPIB

To Station Controller