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

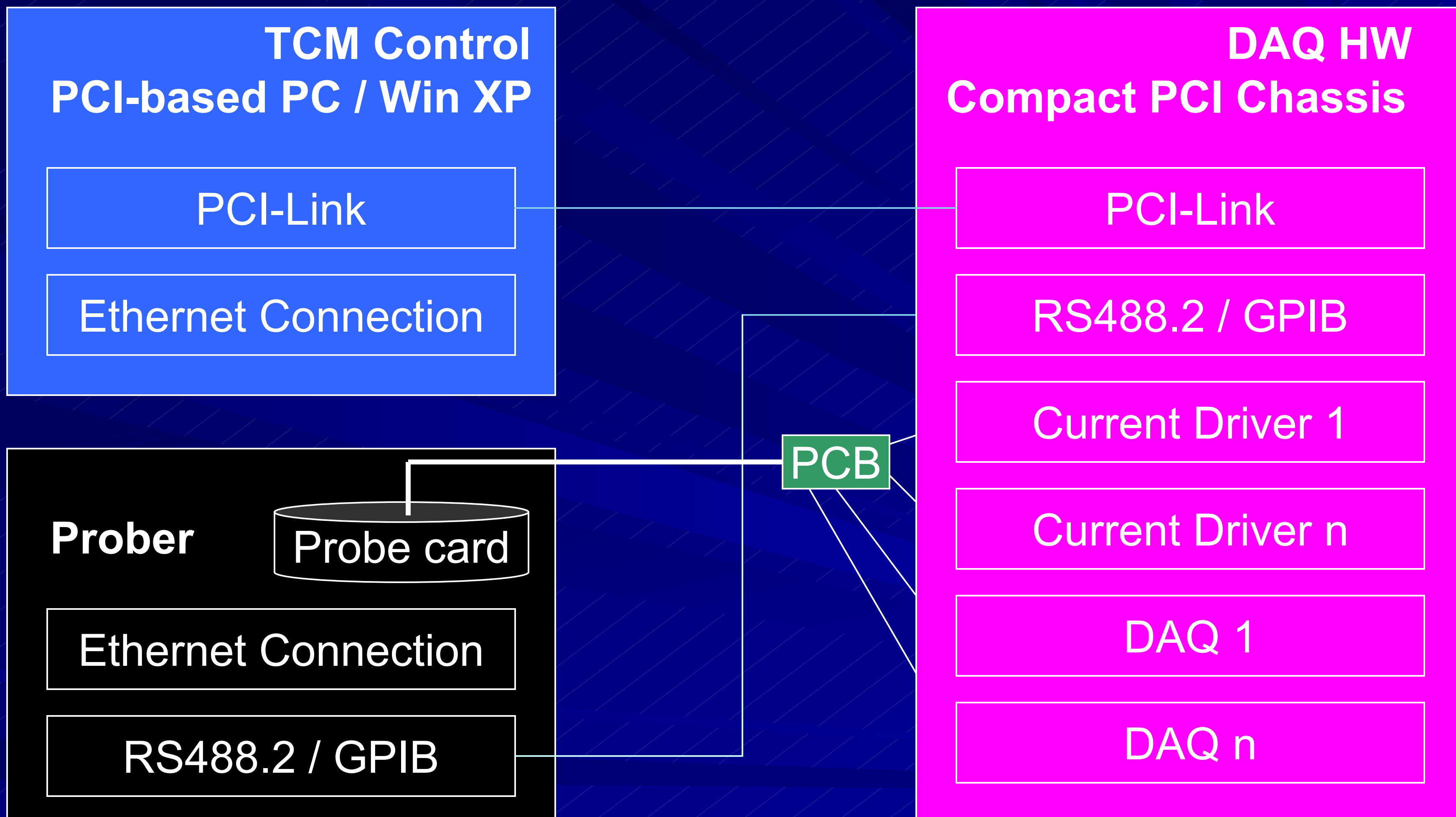
Basic Requirements

- Accuracy within 1/10th 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)

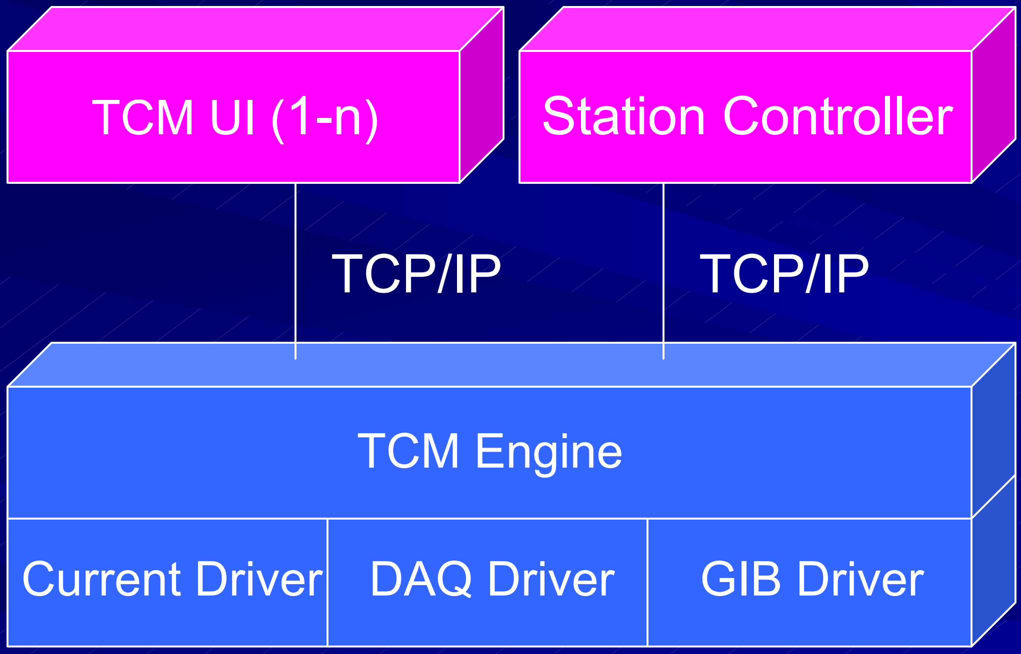


Same size as Desktop PC

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

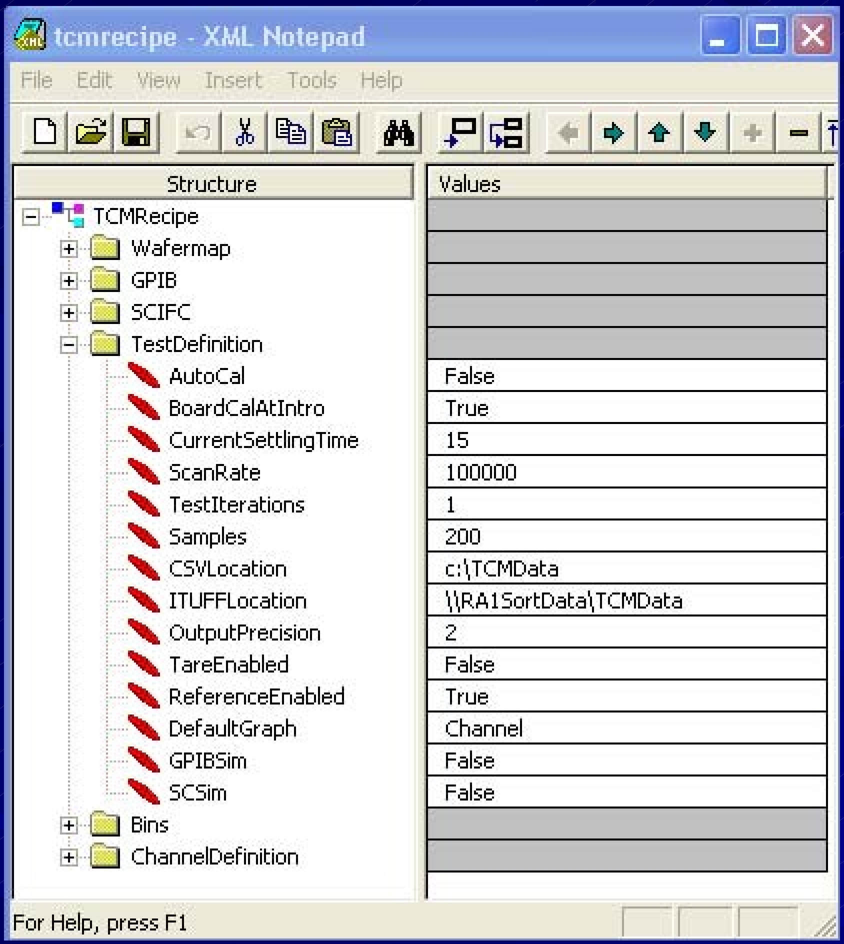


TCM Engine:
- SC Listener
- GPIB Listener
- Optional Prober Control
- DAQ
- Current Driver
- UI Data
- Saves Results Data

Key TCM Features

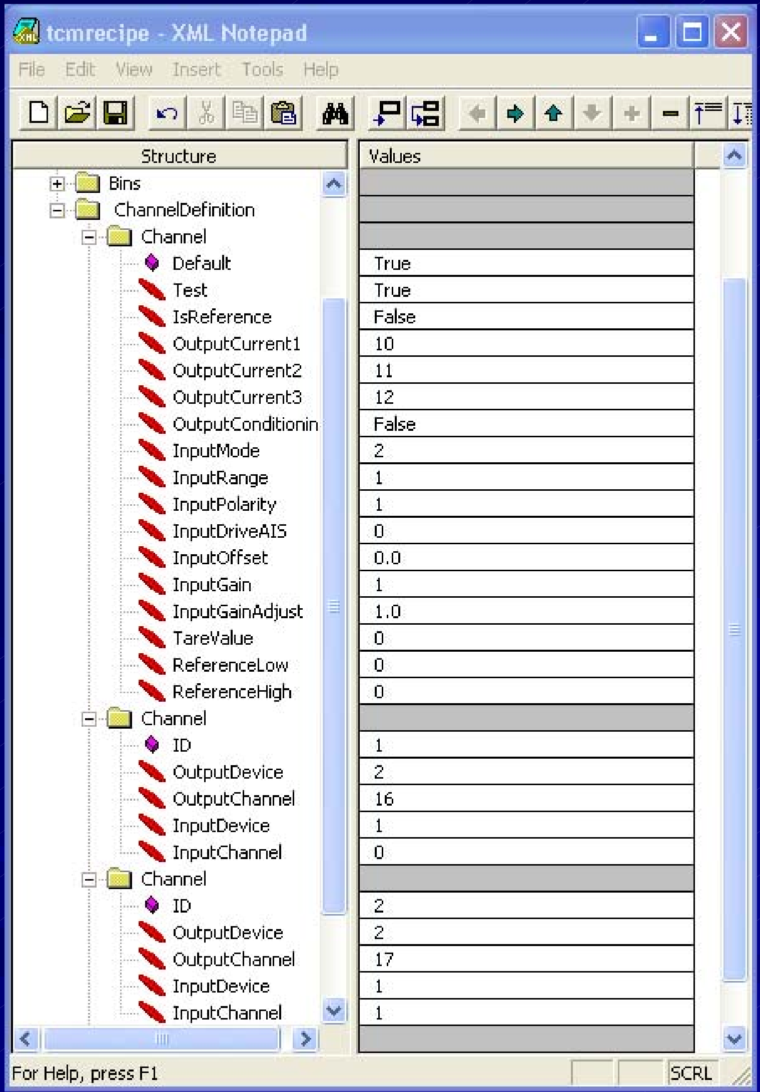
- Automatic HW calibration before each lot introduction
- Configurable number of channels
- Channel-level configuration of DAQ I/O
- Channel-level compensation for total path resistance (single-ended mode)
- Configurable bin assignments based on opens, shorts, and CRES ranges
- Fully automated test capability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

Configuration



- 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.

Configuration, continued …



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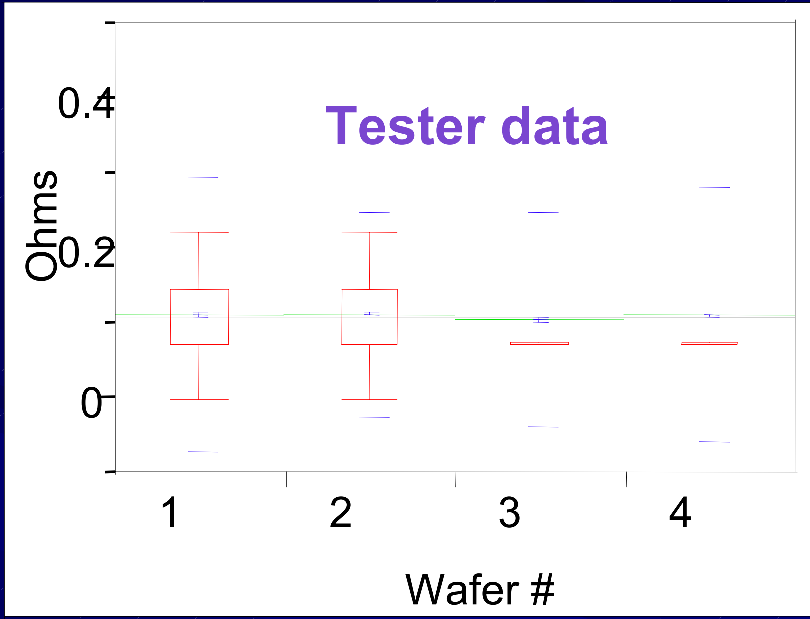
    - Etc.
  - Bin
    - CRES range mapping
    - Errors to Bin mapping
    - Opens, Shorts, Etc.

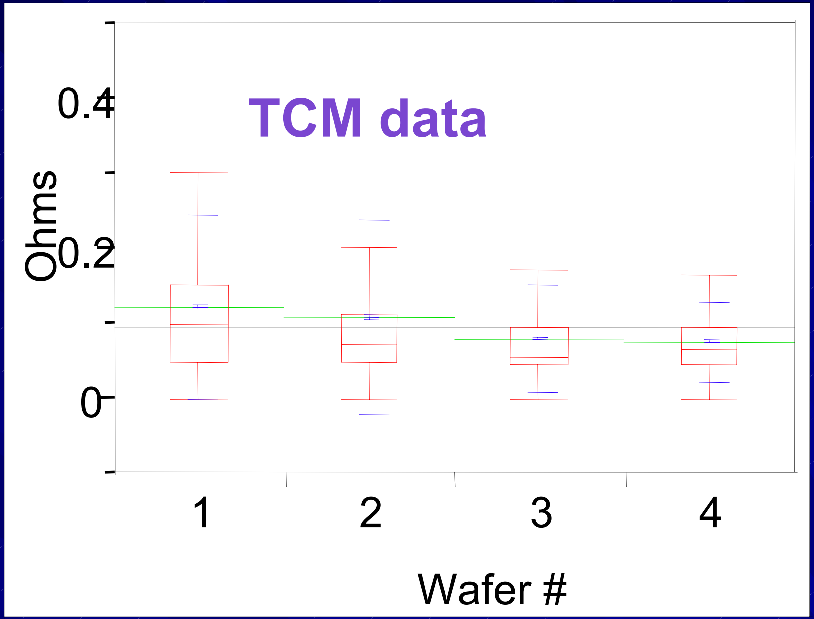
Initial Validation

- 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



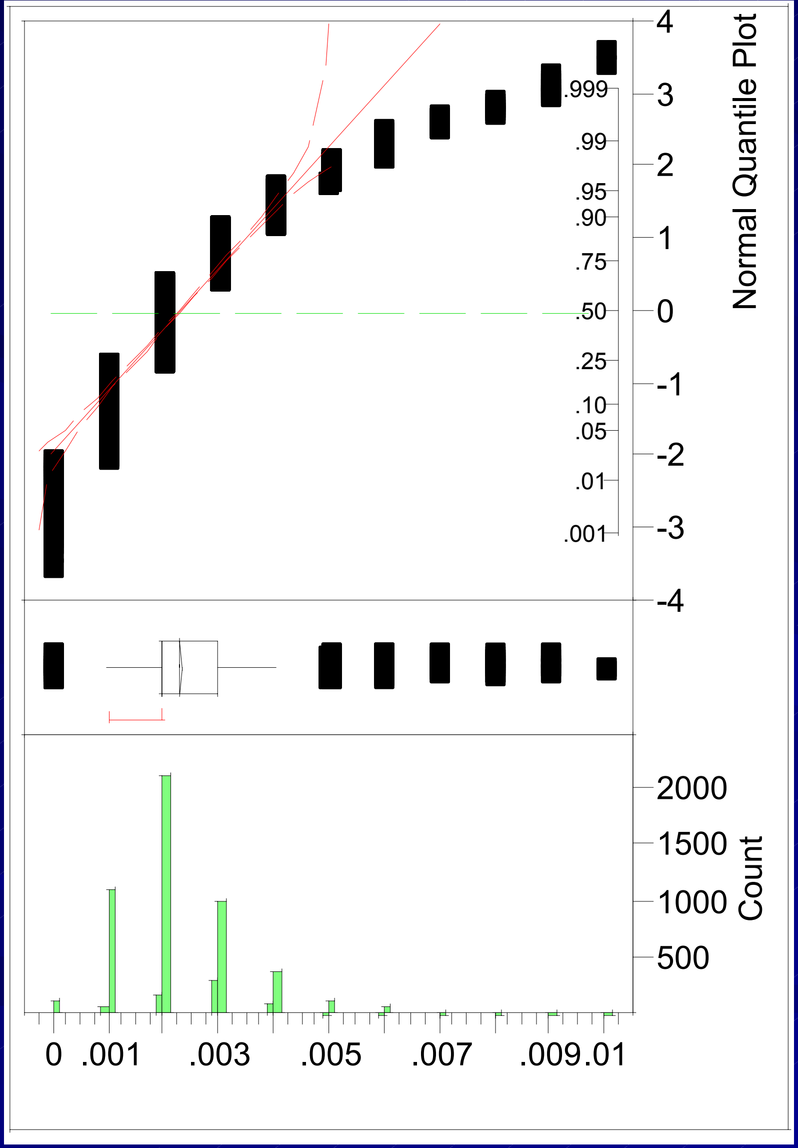
Wafer	Mean	Std Dev
W001	0.111867	0.183908
W002	0.111940	0.137013
W003	0.104789	0.143574
W004	0.110892	0.169242



Wafer	Mean	Std Dev
W001	0.122259	0.122908
W002	0.108477	0.129604
W003	0.079705	0.071401
W004	0.076153	0.05298

Tester and TCM Measurements are Similar.

Distribution of Measurements on 16 Shorted Channels



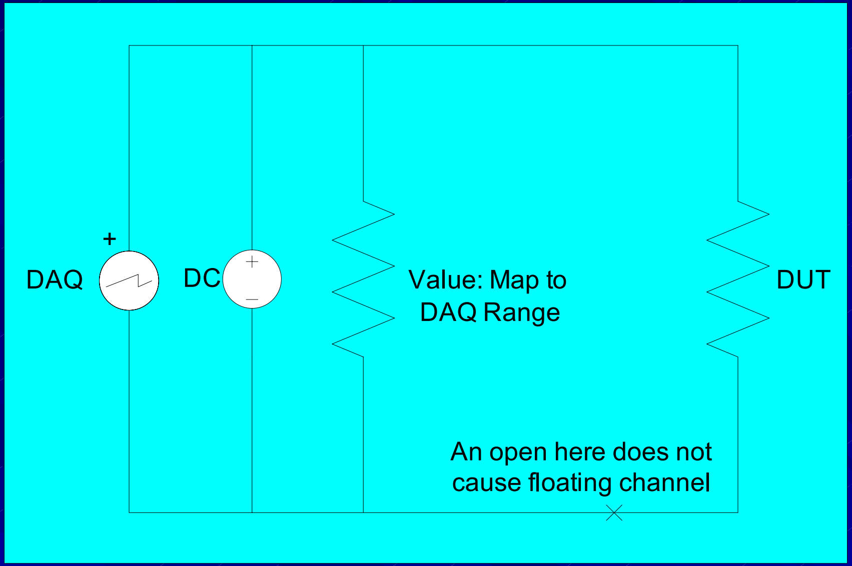
Resistance data was also collected on 16 shorted channels (TCM system. These numbers indicate that the equipment variation is minimal.

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

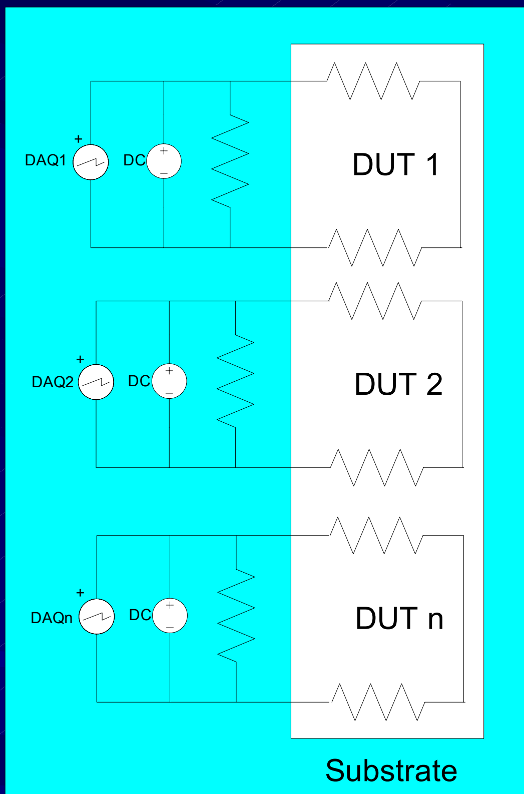
- For output, voltage is increased until desired current level is reached, up to 10V maximum (implementation-specific)
- When measuring opens, voltage rises above 10V maximum
  - Output channel shuts down
  - As a result, input channel floats
  - DAQ measurement on floating channel yields bogus data
- 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



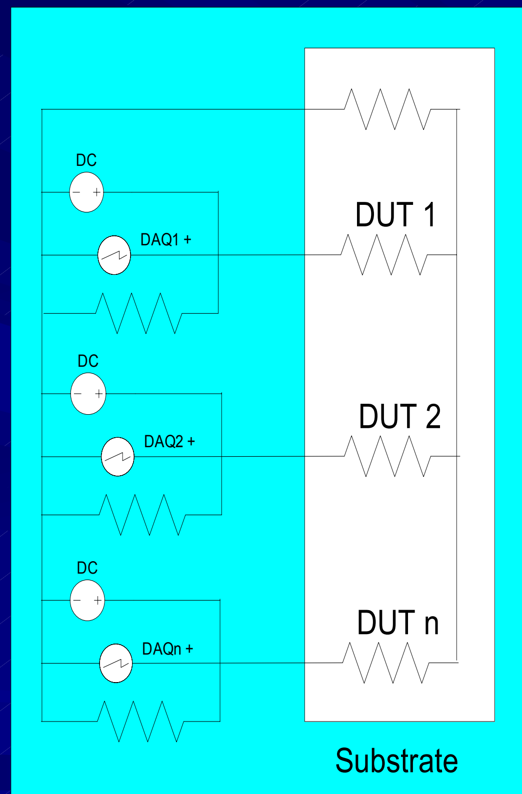
To compensate: We use resistors in-line with cabling to ensure we never read an open. Note: All other components available off-the-shelf

Single-end configuration surprises

Differential:
Ideal



Single-ended:
Possible, but not ideal



Single-ended yields higher channel density

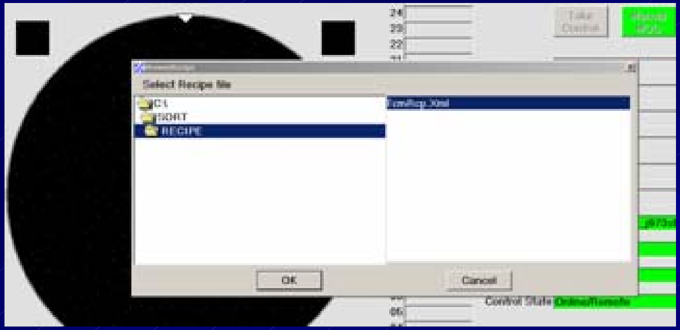
- Balance between performance, cost, and accuracy
- For single-ended
  - Ground loop issues may arise. Check wiring and configuration (i.e., mode)
  - Use fewer "hot" channels when sharing common ground; better accuracy, but must consider 15ms current settling time impact
  - Must factor path resistance

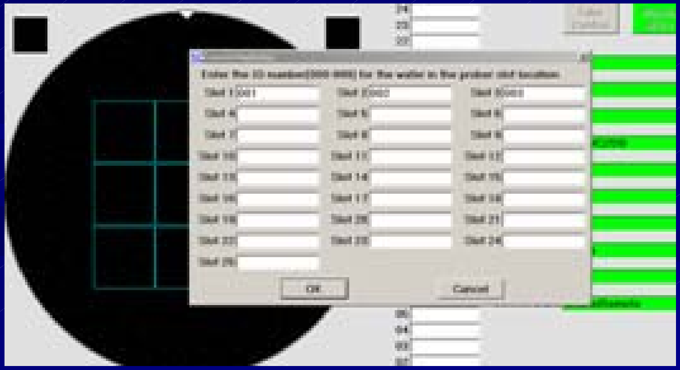
Summary

- We developed a low-cost test solution meeting our success criteria
  - 1/10th Ohm accuracy
    - actual was 1/20th 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

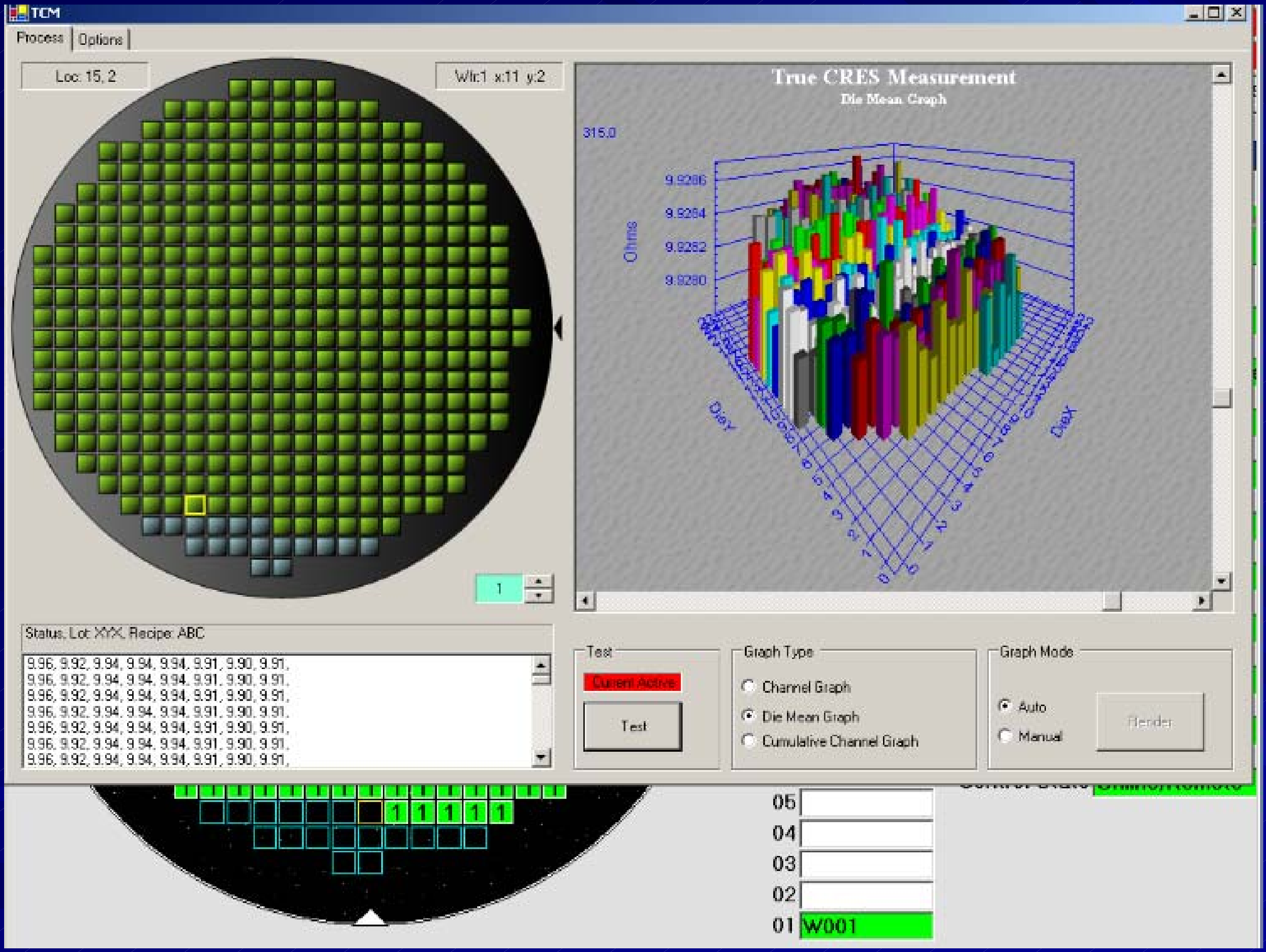
Introducing a Lot





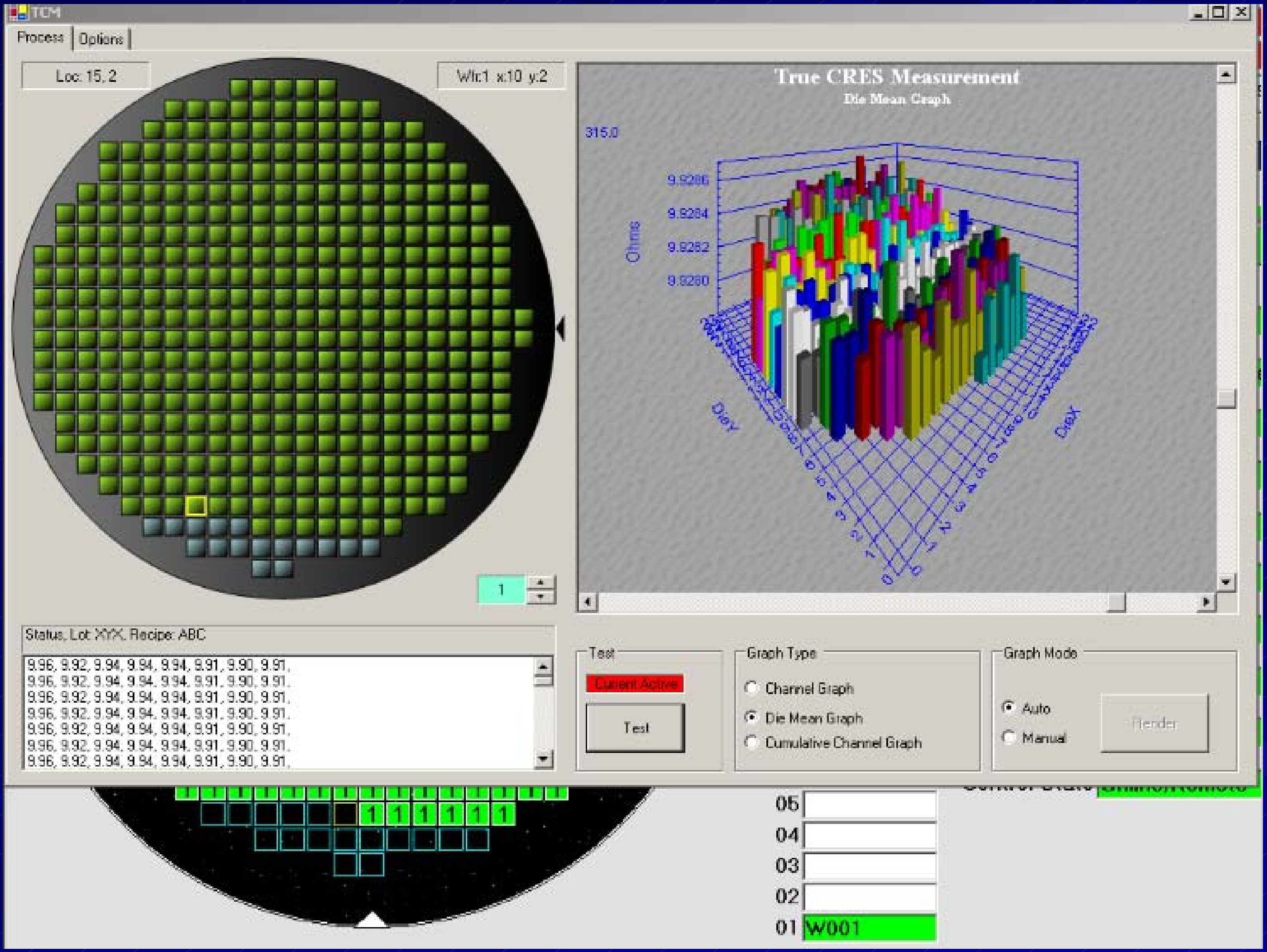
- Station controller views TCM as a standard tester platform
- Lot introduction uses standard dialogs for lot, recipe, and slot selection
  - Or integrates with other automation systems for these data

TCM w/Die Mean Graph (1)



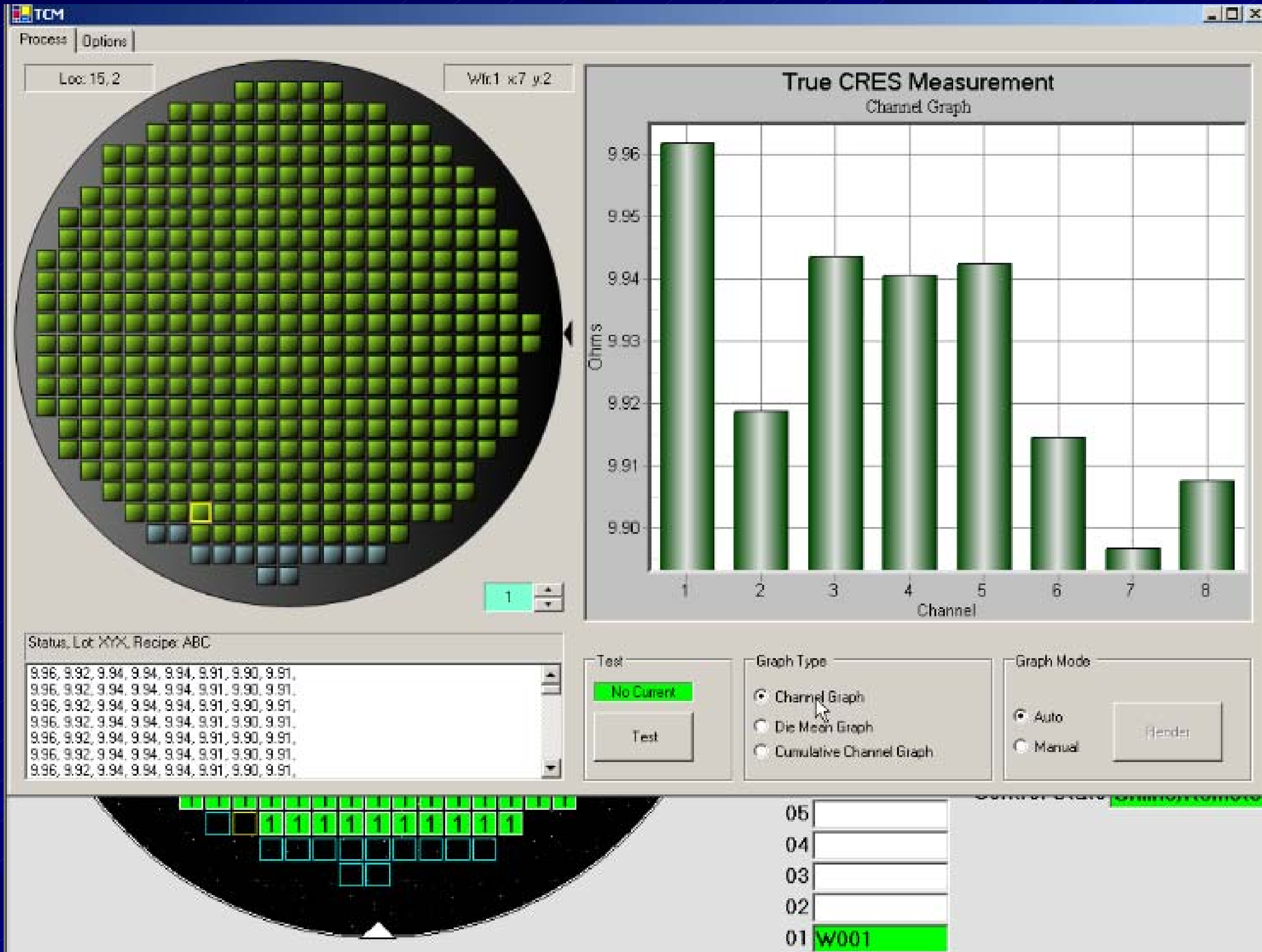
Note: measuring resistors of known value

TCM w/Die Mean Graph (2)



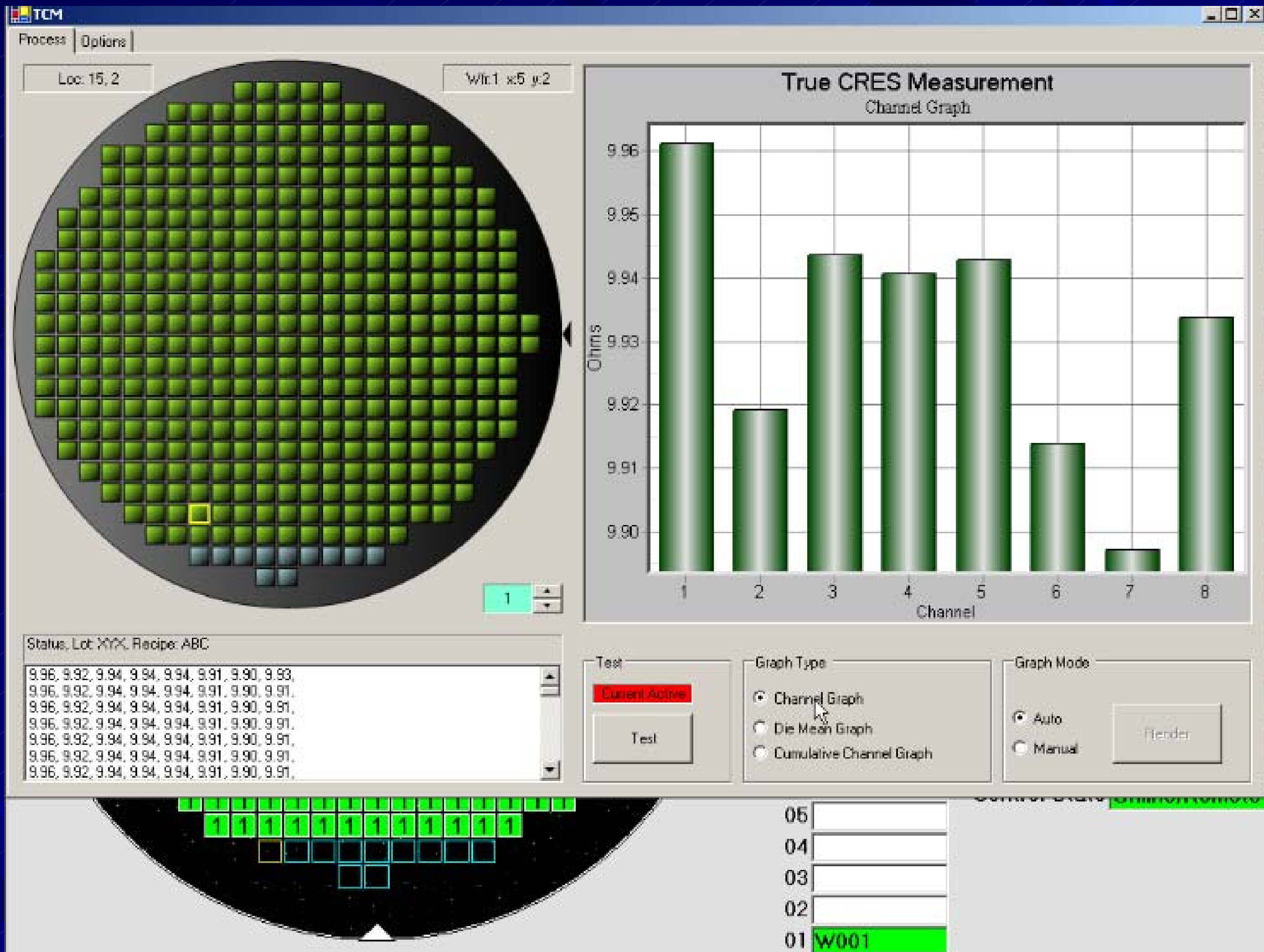
Note: measuring resistors of known value

TCM w/Channel Graph



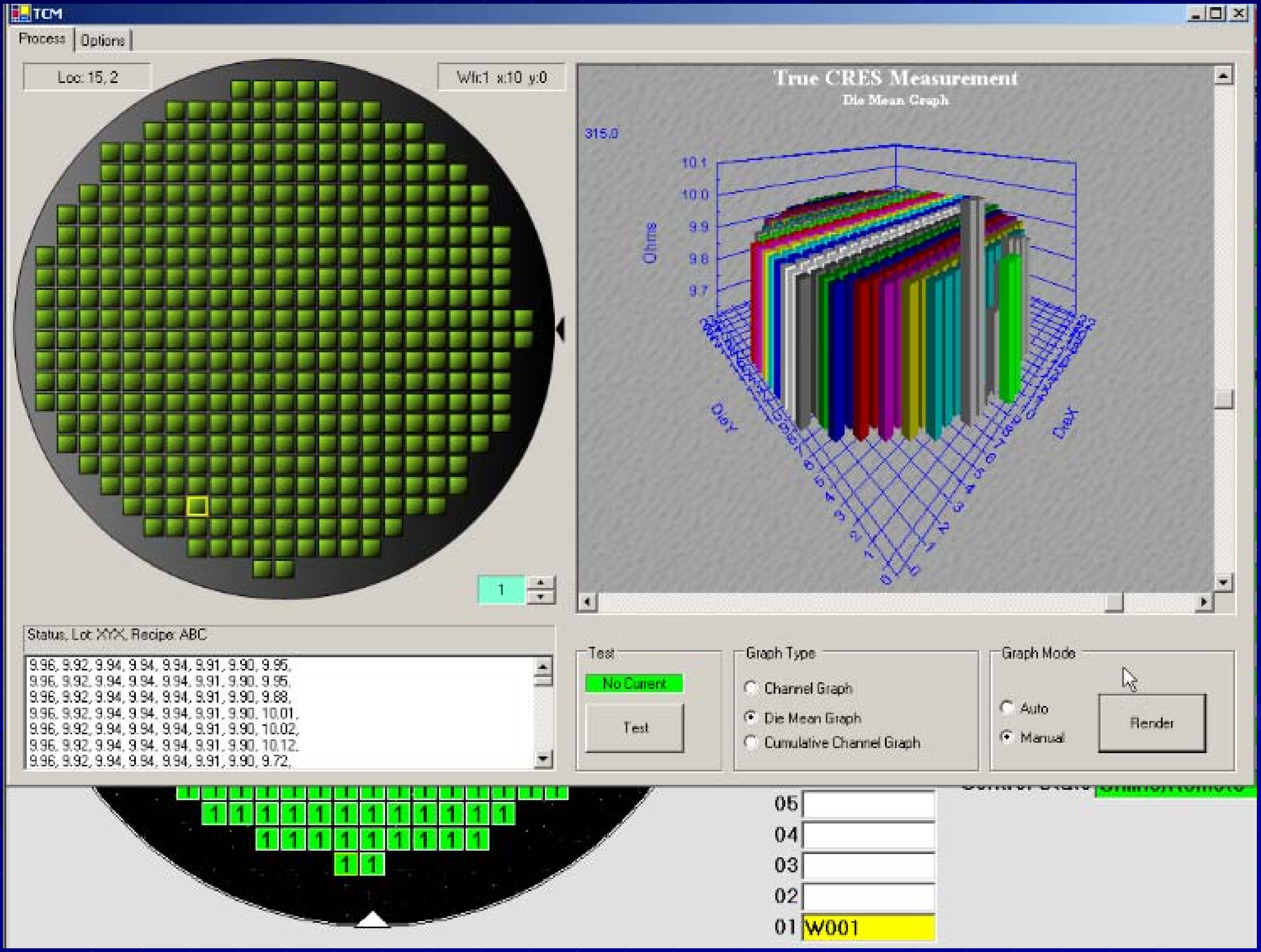
Note: measuring resistors of known value

TCM / Adjusting Channel 8

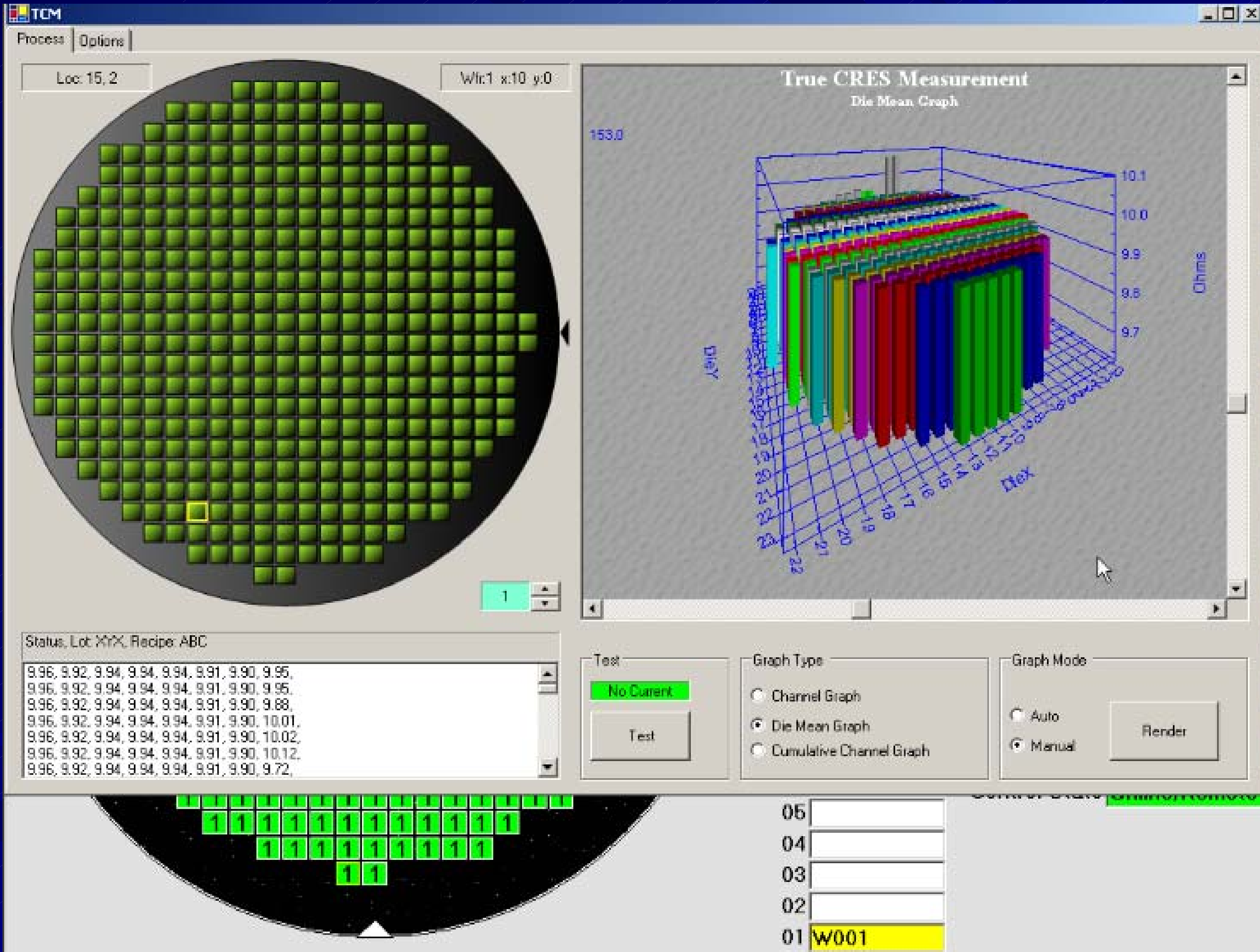


Channel 8 wired with variable resistor

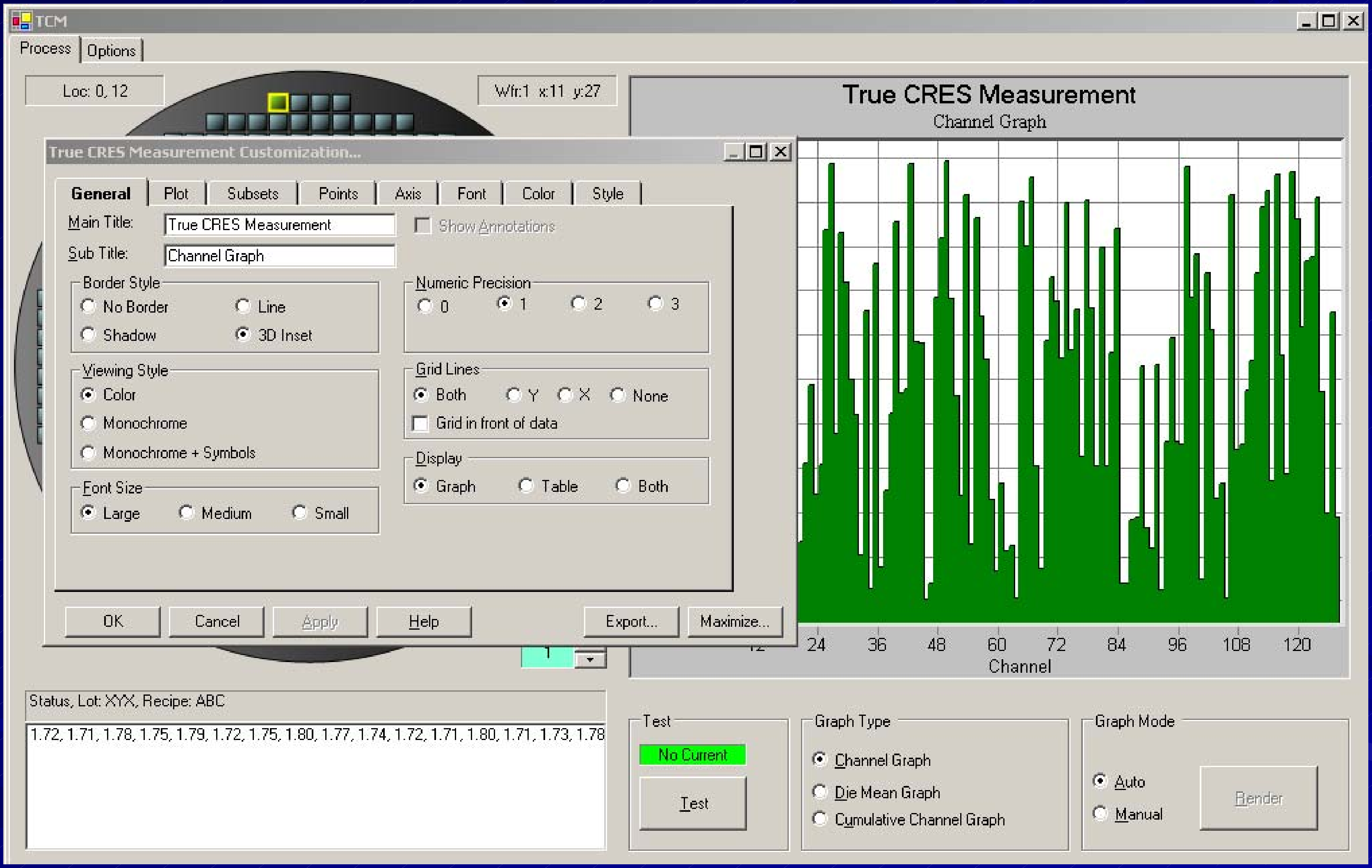
TCM / Rotating Die Mean Graph (1)



TCM / Rotating Die Mean Graph (2)

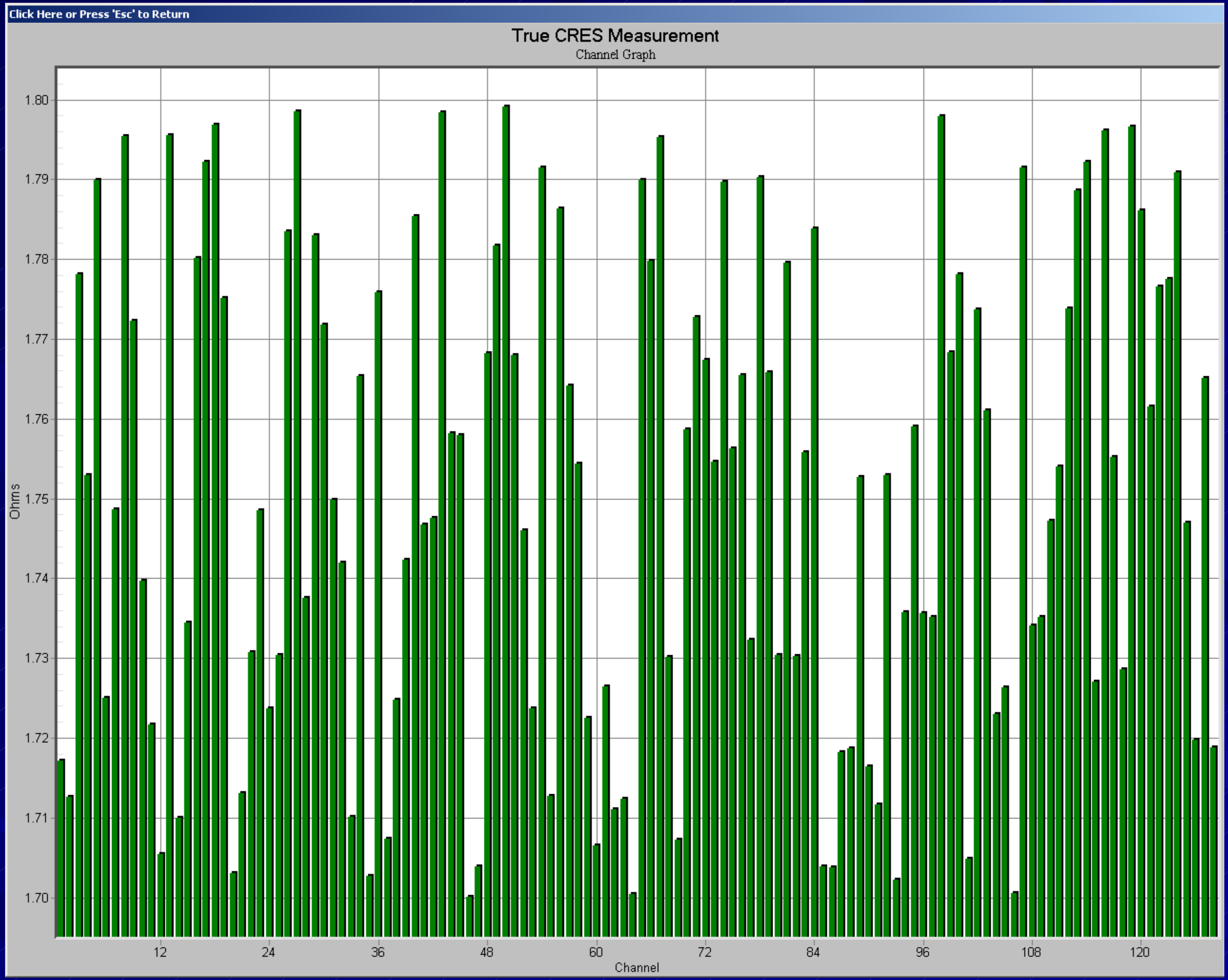


TCM / Graph Options



Note: simulated data on this slide

TCM / Maximized Graph



Note: simulated data on this slide

Questions?

Backup

Hardware (Inline)