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# **Probe Card Troubleshooting Techniques**



# Probe Card Troubleshooting Techniques

## Motivation

- **Multiple instances of continuity test failures and functional test failures due to high contact resistance**
- **Frustrated test development engineers causing damage to probe cards in attempts to get them to work**
- **Repeated “No Trouble Found” in probe card analyzer on site and at vendor**
- **Difficulty in isolating failure and obtaining vendor support**

# Probe Card Troubleshooting Techniques

## Signal Path Buildup

- **Probing signal path consists of multiple elements, each of which could be from a different vendor**
  - **Tester**
  - **Wafer Interface Board**
  - **Pogo Tower**
  - **Probe Card**
  - **Bump**
  - **Wafer**
- **In order to fully activate vendor support system, conclusive evidence of source of failure is sometimes necessary.**

# Probe Card Troubleshooting Techniques

## Application of TDR

- **Time Domain Reflectometry (TDR) is very useful for characterizing a signal path. The probing signal path is typically a 50 ohm transmission line for the bulk of its length.**
- **TDR applies a step voltage input into a transmission line and then measures reflected return signal as a function of time.**
- **Impedance mismatches show up as change in reflected signal**
  - **Reduced impedance => Reduced signal**
  - **Increased impedance => Increased signal**

# Probe Card Troubleshooting Techniques

## Essential TDR Equations

- Formula for signal amplitude

$$V_{total} = V_{in} \{ 1 + (Z - Z_0)/(Z + Z_0) \}$$

- Short Circuit => 0 amplitude
- Open Circuit => Double Amplitude
- We can isolate the location of open circuit continuity failures by measuring where (in time) the return signal rises to double amplitude. The distance along the signal path can then be determined by converting the distance in time to the distance in inches.
- High Resistance paths can show up as DC loss on the reflected signal – reduces amplitude of signal.

# Probe Card Troubleshooting Techniques

## Essential TDR Equations

- Six inches = ~1 nanosecond of propagation delay time in materials used for probe card build (FR4, MLC, Probe Head).
- TDR measures round trip delay, so expected delay measurement is twice the propagation delay.

- Some example components of signal path and their round-trip delay times:

<u>Component</u>	<u>Round Trip Delay</u>
3 inch PCB Trace	1 nanosecond
400 mil MLC Trace	135 picoseconds
220 mil probe tip	75 picoseconds

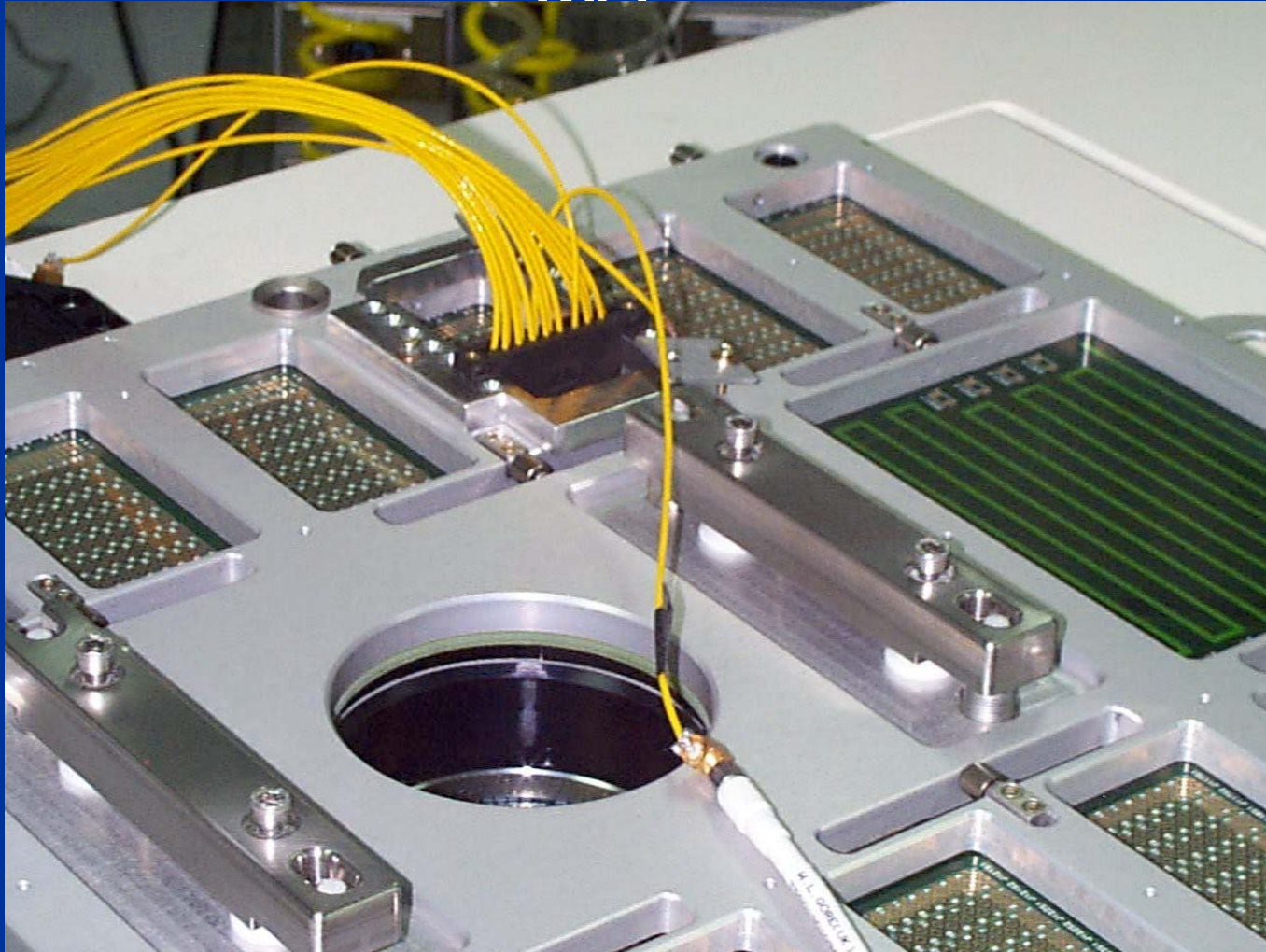
# Probe Card Troubleshooting Techniques

## Signal Path Buildup through TDR

- **A piece-wise image via TDR is built by taking TDR measurements on the signal path as components are added.**
- **The final composite image can then be easily examined for impedance mismatches and potential problems.**
- **Once the signal path is better understood, it is easy to focus on the problem area.**

# Probe Card Troubleshooting Techniques

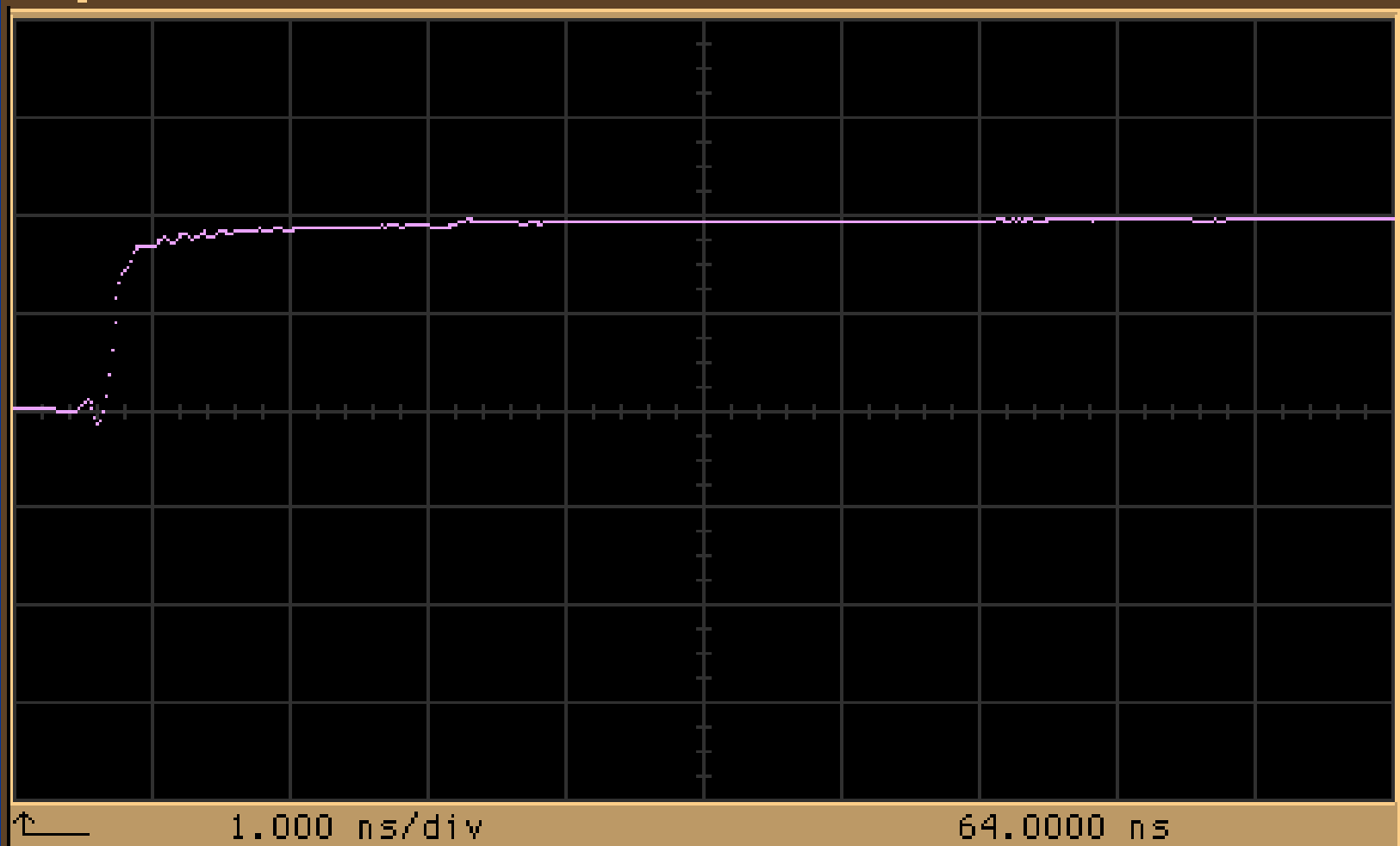
## Specialized Test Fixture – Modified Pin Electronics





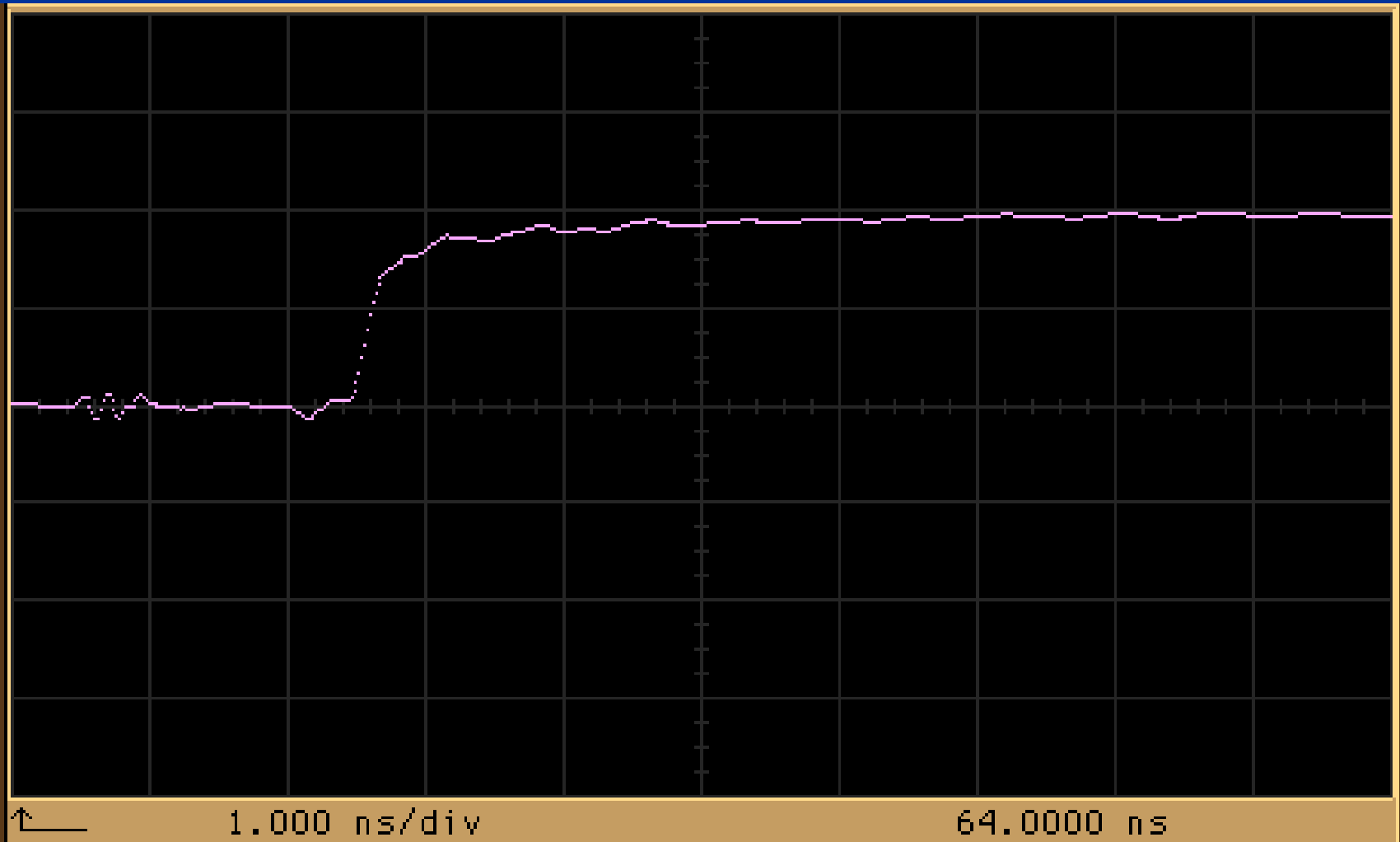
# Probe Card Troubleshooting Techniques

## Pin Electronics Wiring and Pogo Block Only



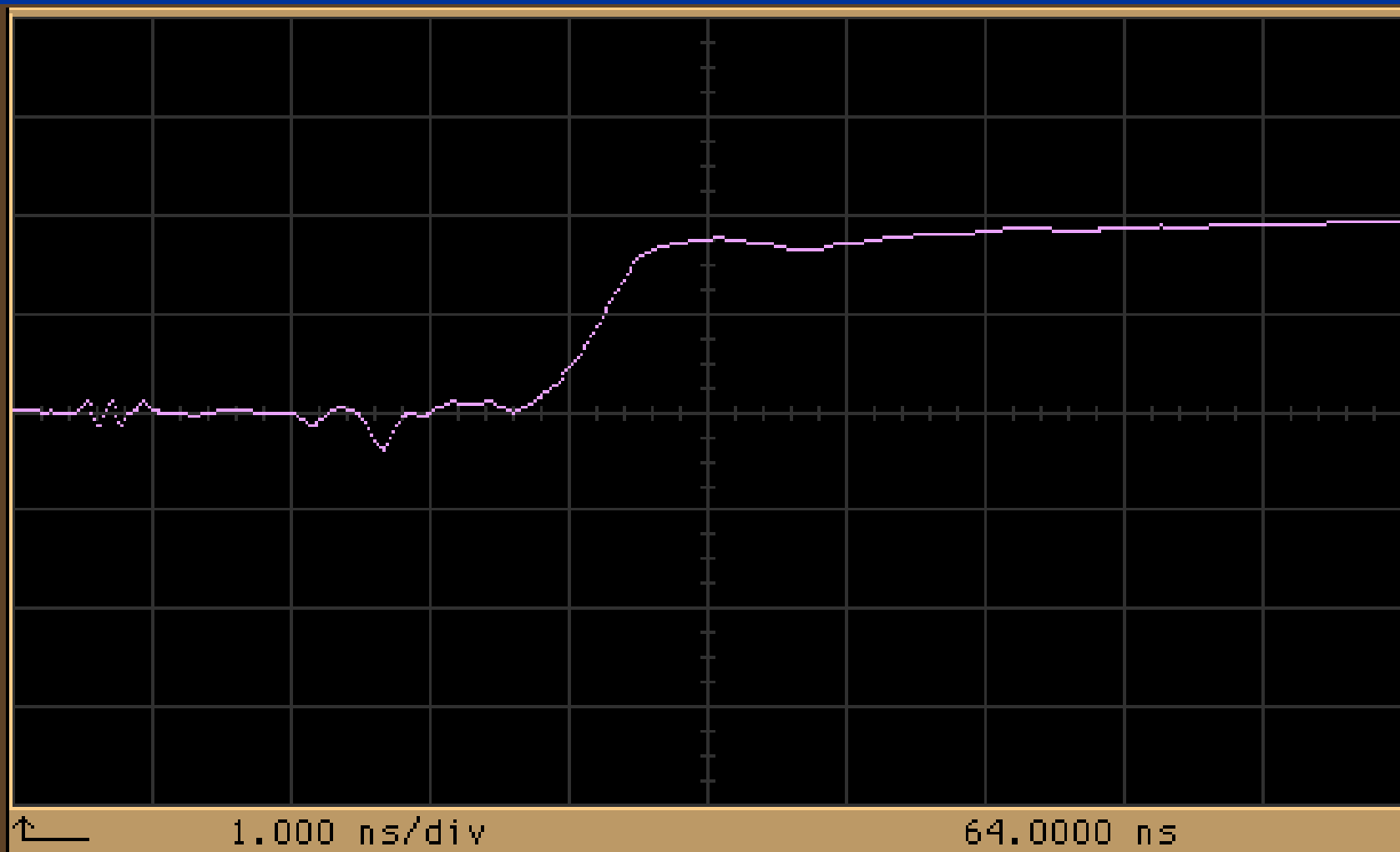
# Probe Card Troubleshooting Techniques

## Pin Electronics Wiring plus Pogo Tower



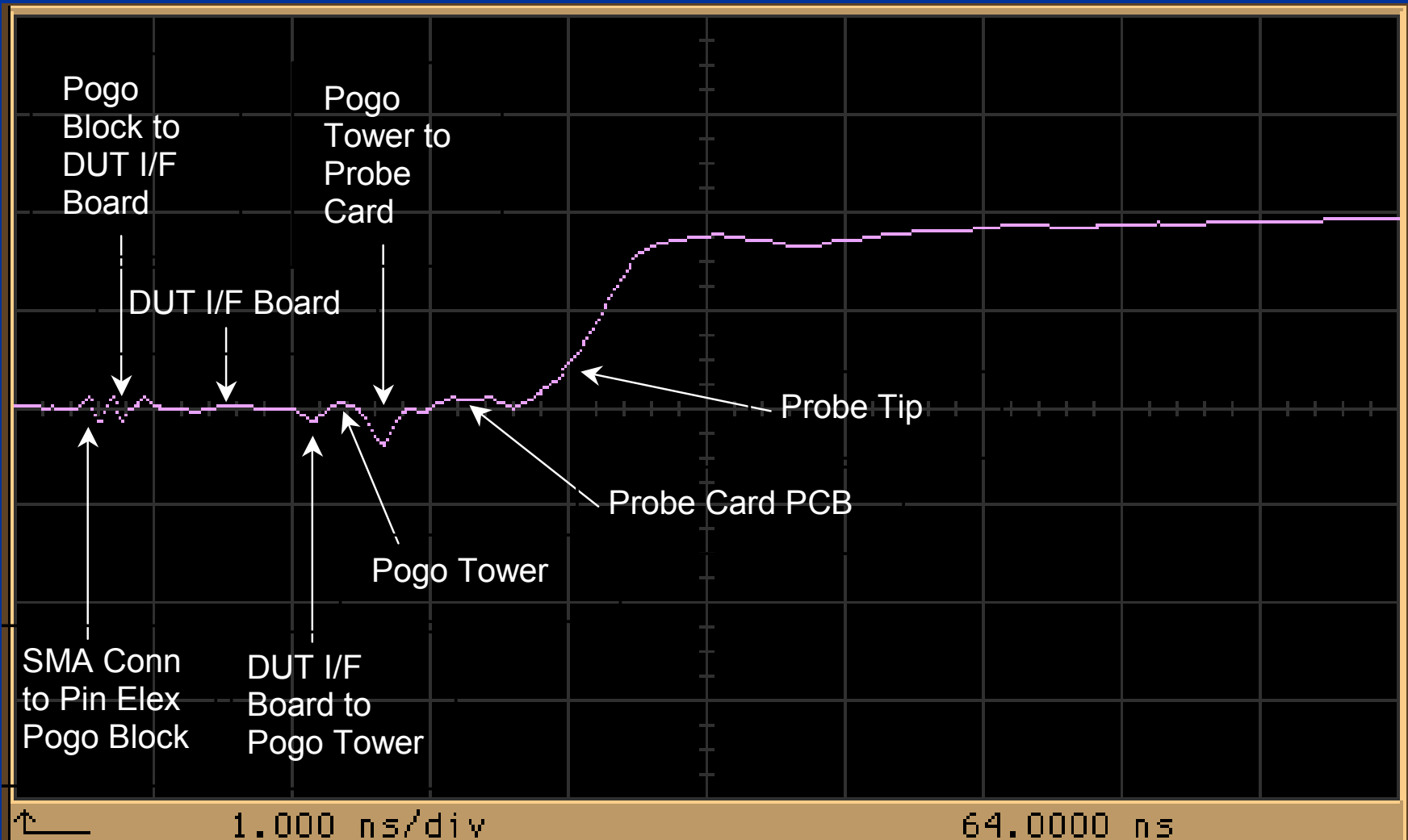
# Probe Card Troubleshooting Techniques

## Entire Signal Path



# Probe Card Troubleshooting Techniques

## Complete Signal Path TDR



# **Probe Card Troubleshooting Techniques**

## **An Example of Application of TDR**

- **Cobra-Style Probe card exhibited intermittent continuity failures**
- **No Trouble Found when tested on Probe Card Analyzer at both test site and vendor.**
- **When removed, cleaned and re-installed, the card would function again for several touchdowns before failing .**
- **Performance continued to degrade, causing increasing yield loss.**
- **Multiple cards exhibited similar, but not identical, behavior**
- **No conclusive evidence of source of problem – could have been in tester, probe card, or wafers**
- **Probing team could not isolate problem using standard methods (PCA, wafer inspection, repeatability experiments)**

# Probe Card Troubleshooting Techniques

## An Example of Application of TDR

- Based on previous experience in another industry, it was decided to attempt to use TDR to isolate the failure.
- Critical factor was conclusively determining which component in probing system had the problem in order to fully activate support system. A problem in probe card buildup was suspected but conclusive evidence was needed.
- TDR setup was connected to pogo tower and repeatability experiment was designed to compare good and bad channels and attempt to determine location of open circuit.
- Non-conductive wafer was installed in prober and used to apply overdrive to probe tips.
- Intent was to replicate probing environment as closely as possible while taking measurements.

# Probe Card Troubleshooting Techniques

## Example #1 – Good Channel, Probe Head Removed, Repeated Card Dock/Undock



# Probe Card Troubleshooting Techniques

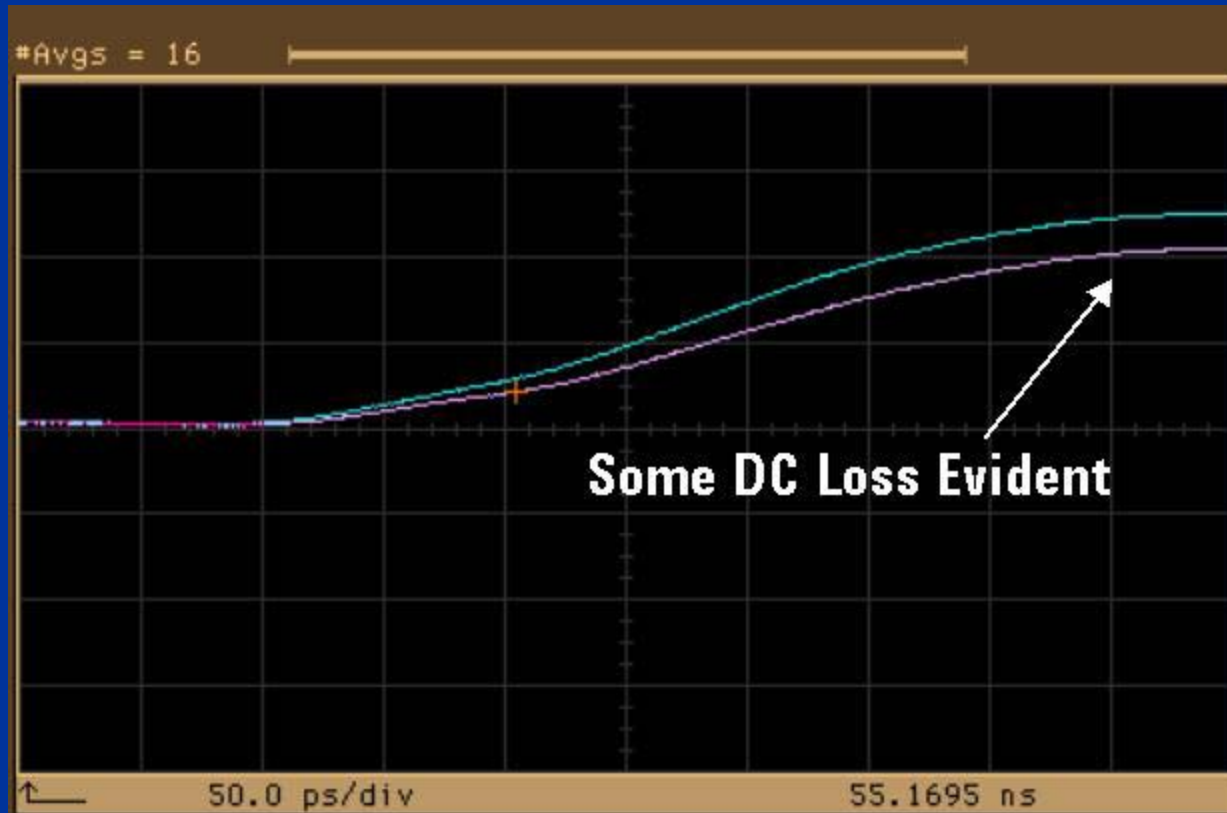
## Example #1 – Bad Channel, Probe Head Removed, Repeated Card Dock/Undock





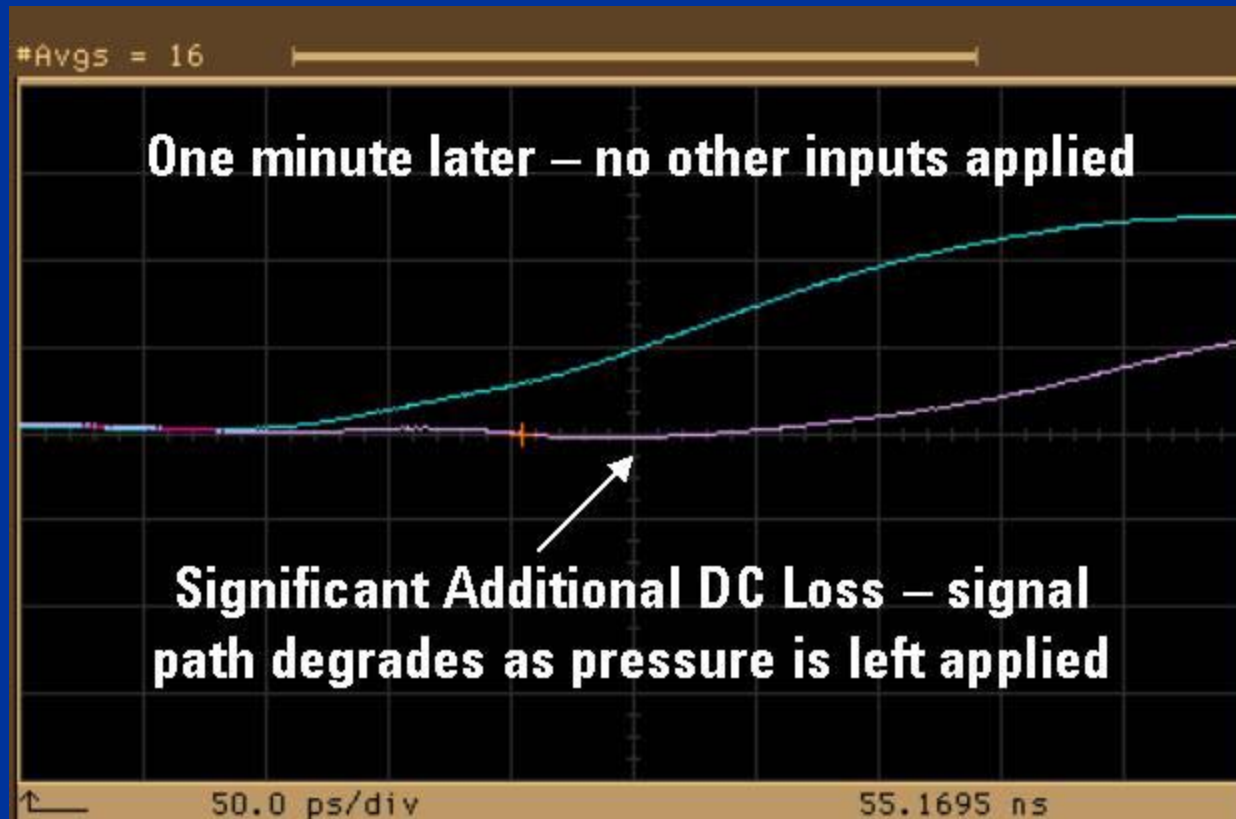
# Probe Card Troubleshooting Techniques

## Example #1 – Gross DC Loss – Bad Channel, Probe Head Installed, Z down/Z up



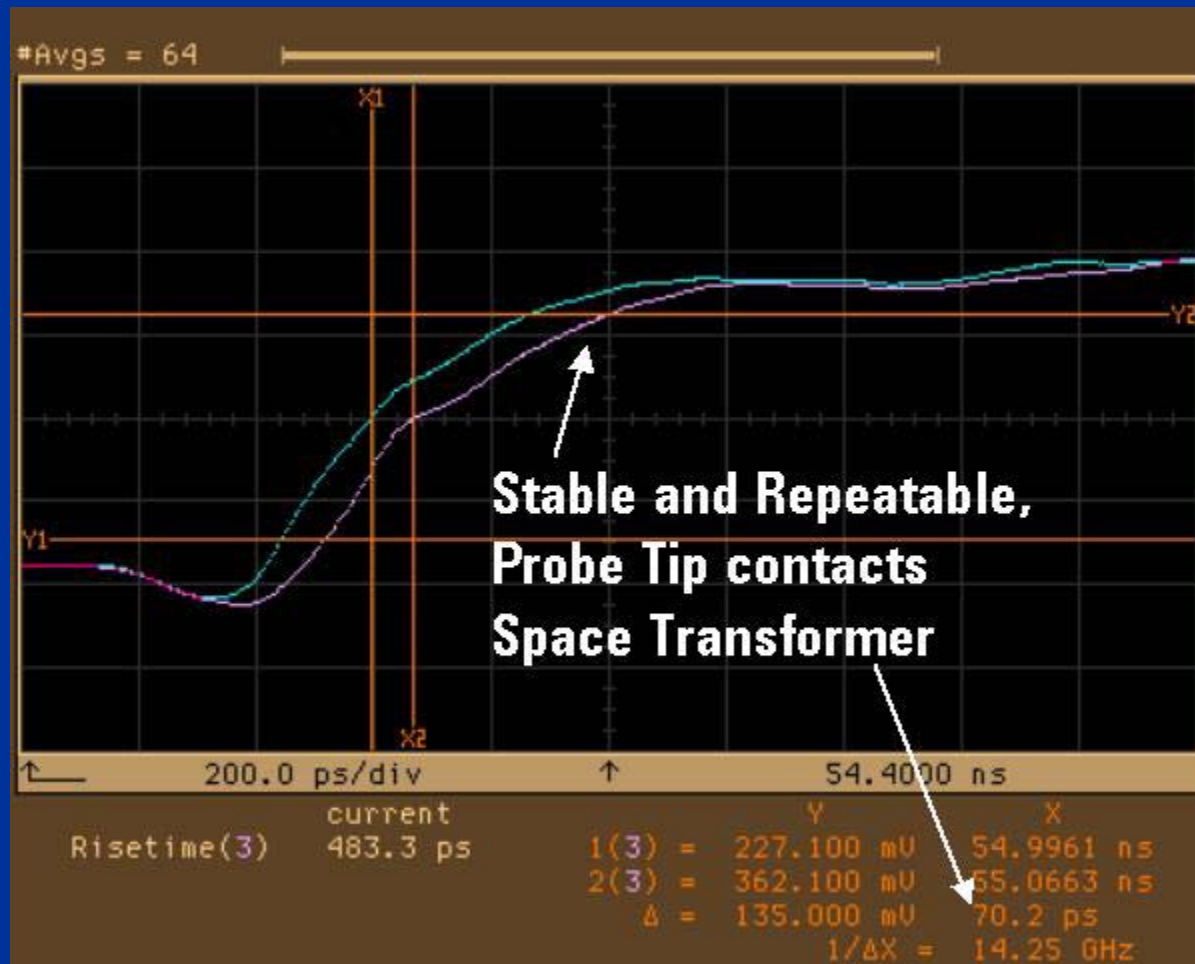
# Probe Card Troubleshooting Techniques

## Example #1 – Gross DC Loss – Bad Channel, Probe Head Installed, One Minute Later



# Probe Card Troubleshooting Techniques

## Example #1 – Good Channel, Probe Head Installed, Zup / Zdown



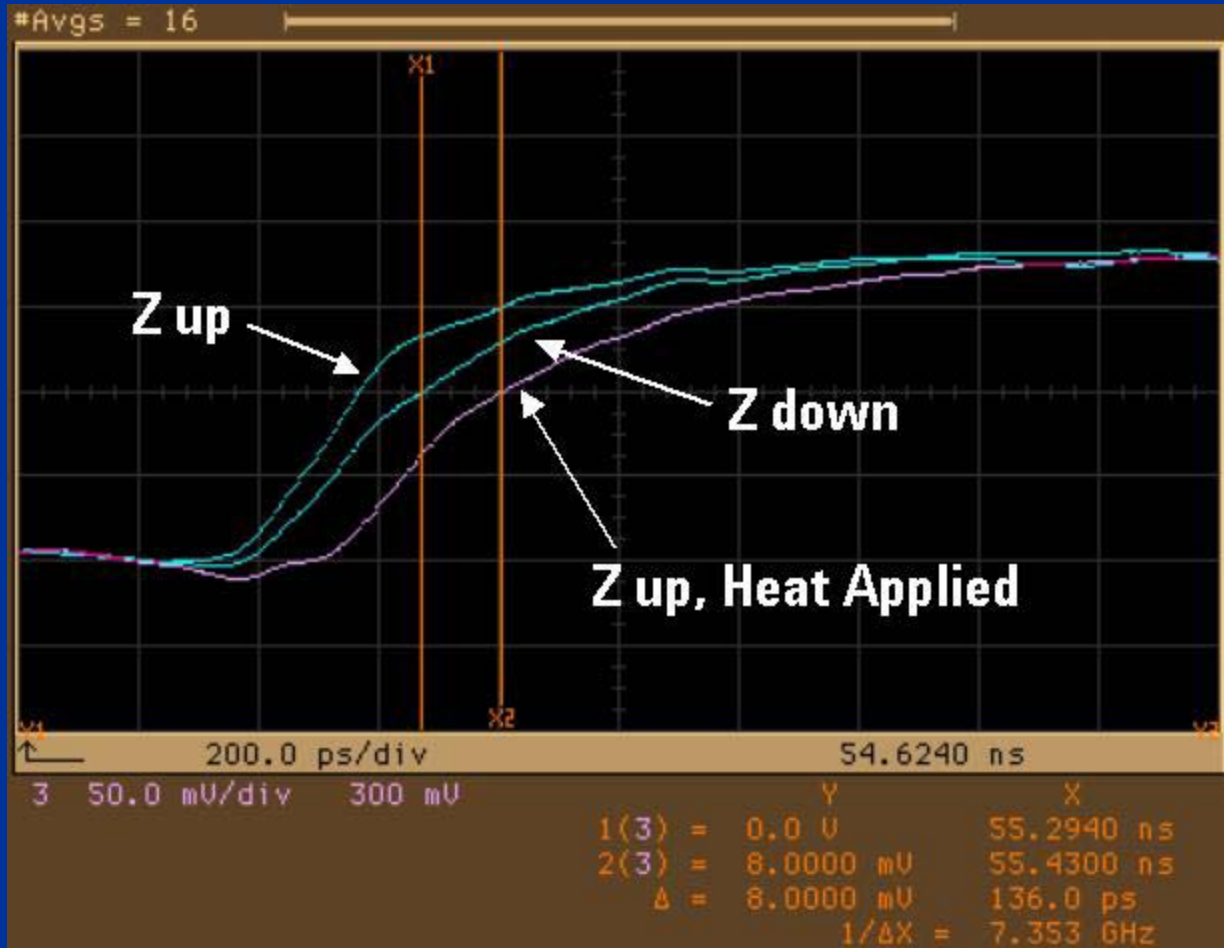
# Probe Card Troubleshooting Techniques

## Example #1 – Bad Channel, Probe Head Installed, Zup / Zdown



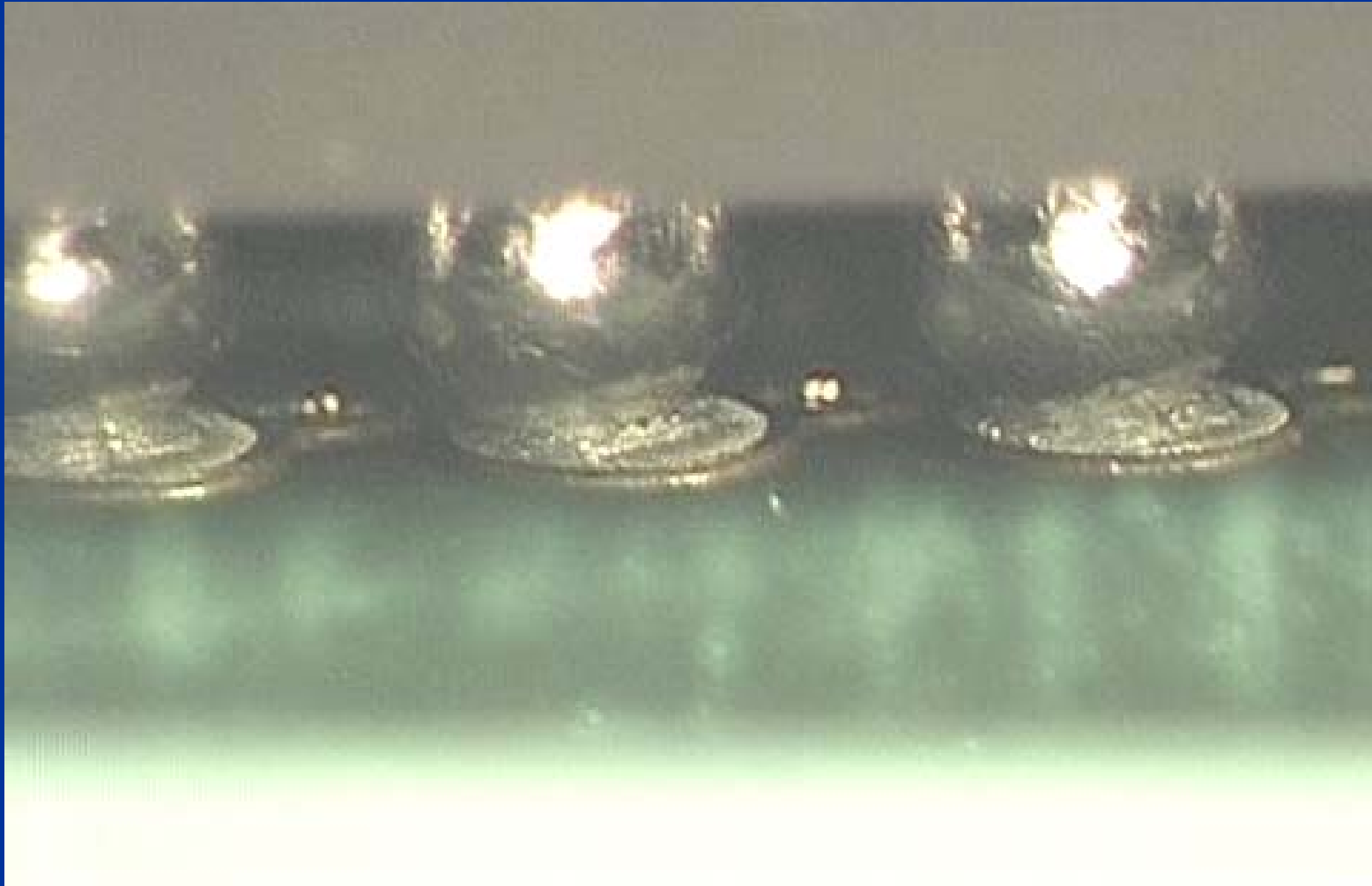
# Probe Card Troubleshooting Techniques

## Example #1 – Bad Channel, Probe Head Installed, Zup / Zdown, Heat Applied



# Probe Card Troubleshooting Techniques

## Example #1 – Source of Failure



# Probe Card Troubleshooting Techniques

## Example #1 – Source of Failure



# Probe Card Troubleshooting Techniques

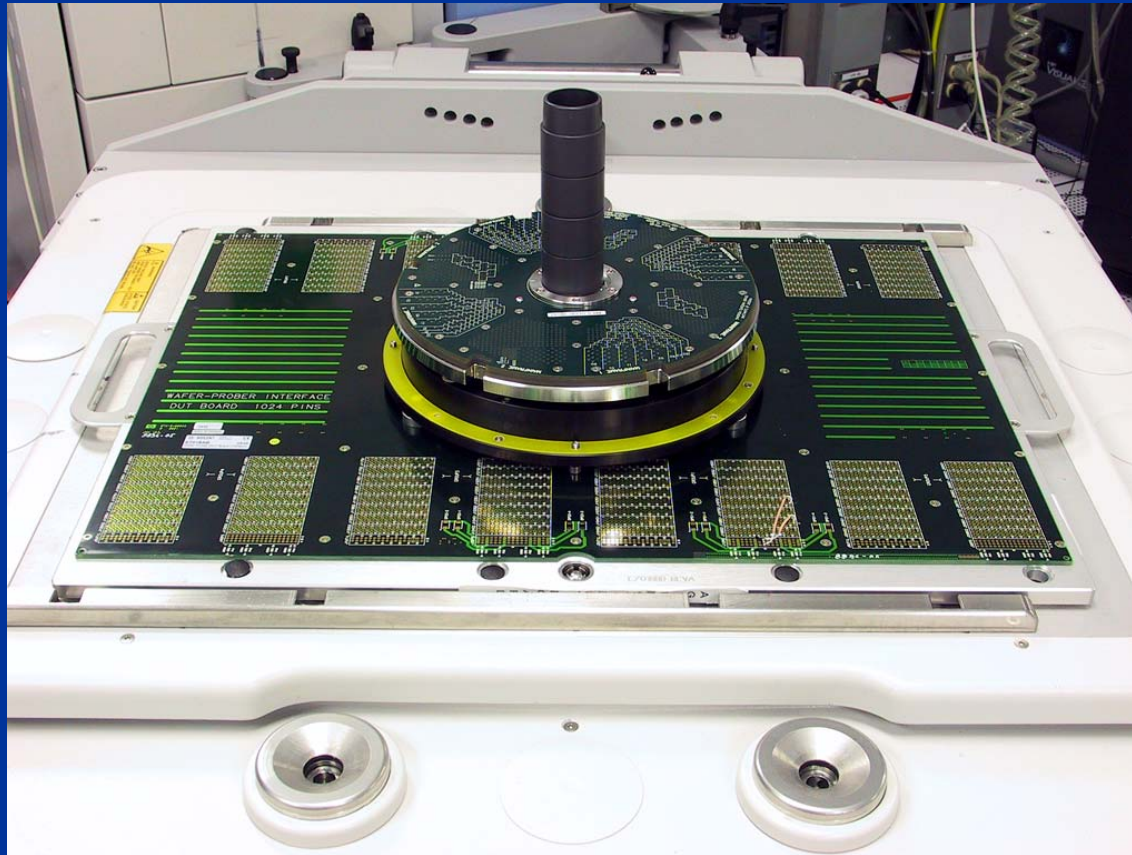
## Second Example of Application of TDR

- **Another problem occurred that resembled the previously described problem; failures were contact-sensitive tests instead of continuity.**
- **Due to labor-intensive nature of the previously detailed method, a simpler approach was desired.**
- **It was decided to utilize internal tester TDR to attempt to isolate the problem.**
- **Concept: Utilize channel attributes calibration data to locate source of open circuit failures.**
- **Drawback: Less fidelity; high-resistance paths may be overlooked or indicate failure in wrong location.**
- **Channel attributes were taken with load applied to probe card and no load. Delay times were compared to determine where open circuit was located.**



# Probe Card Troubleshooting Techniques

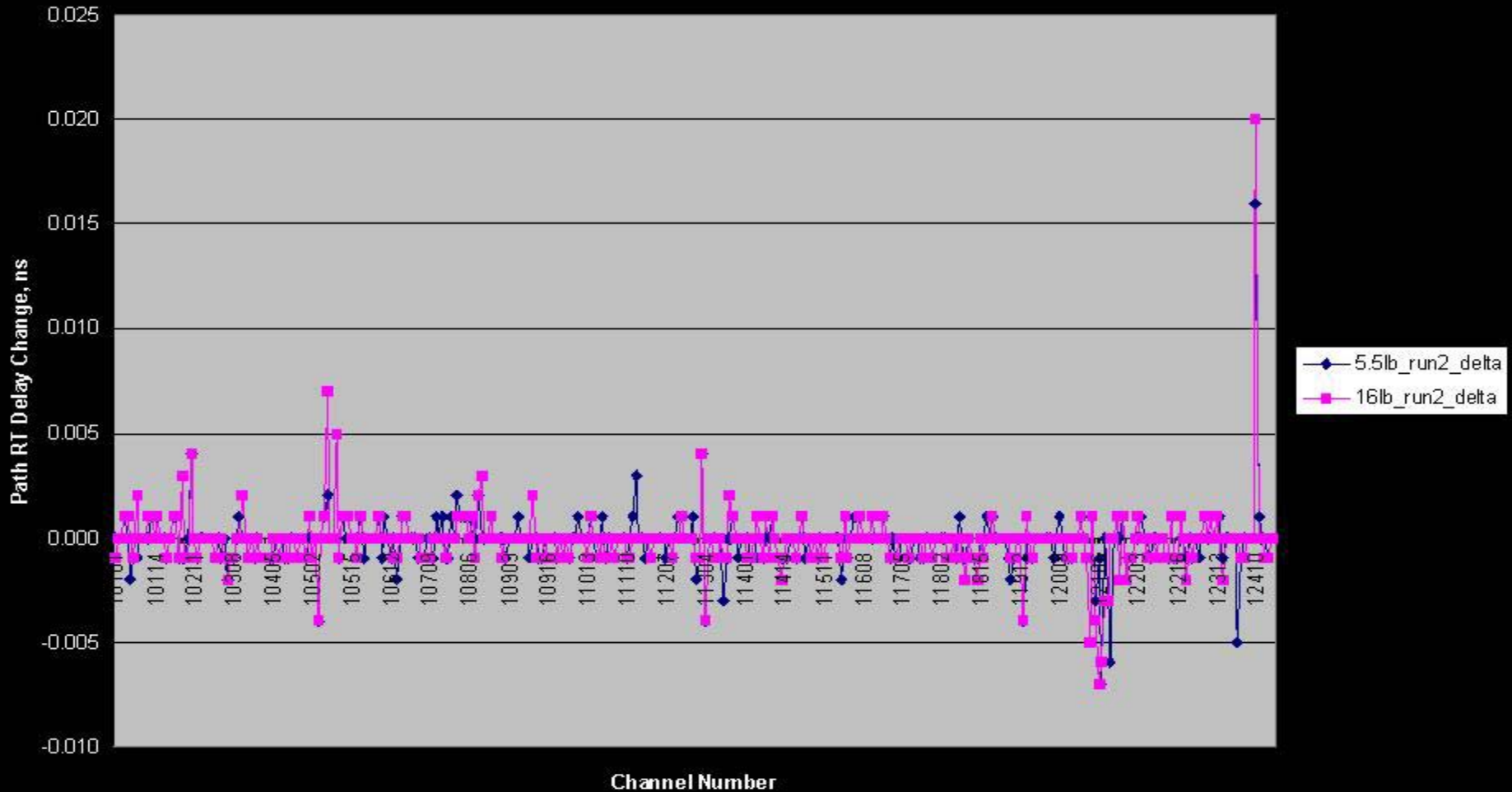
## Example #2 Test Setup



**Replica of test setup**

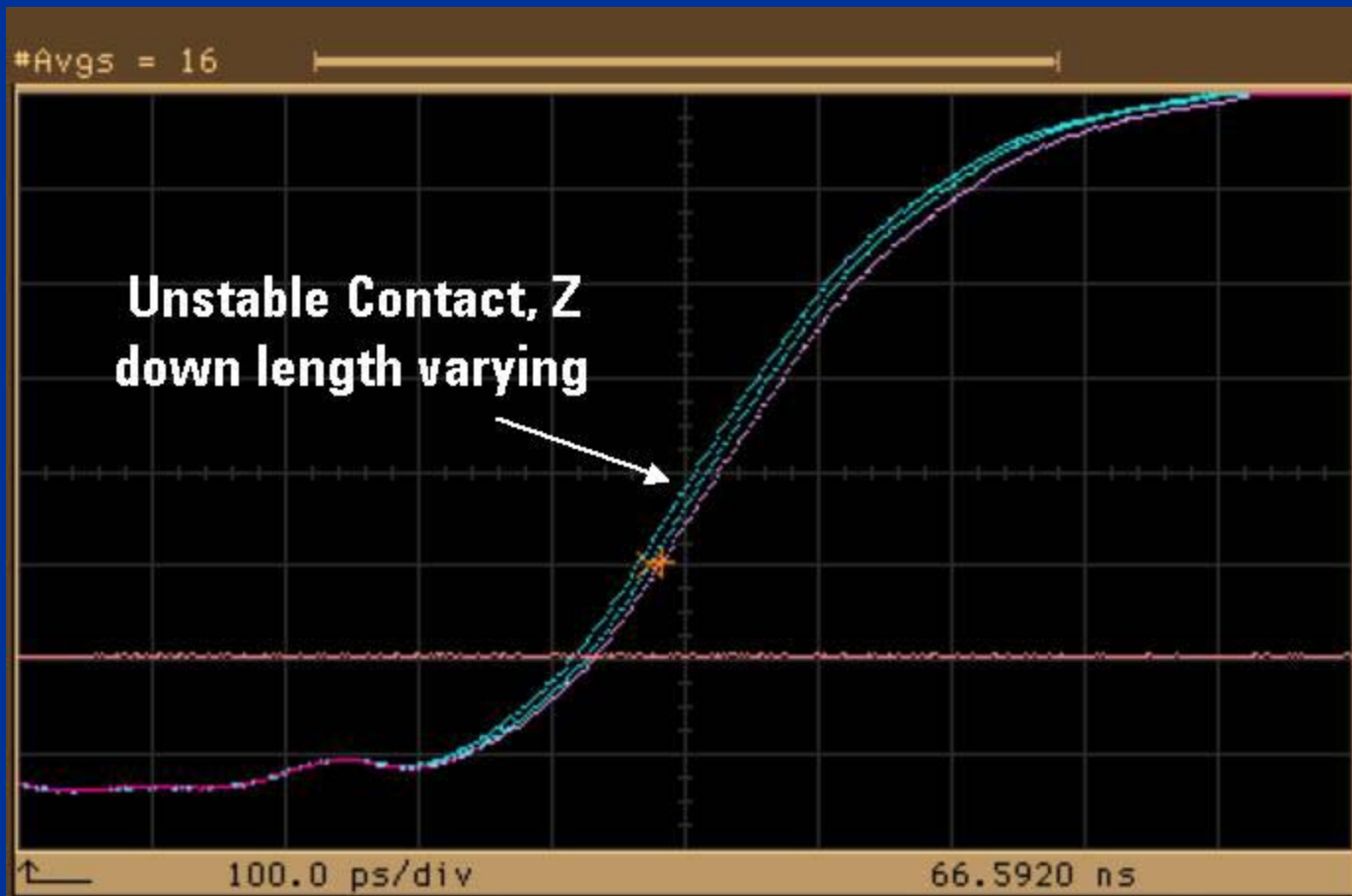
# Probe Card Troubleshooting Techniques

## Example #2 – Internal Tester TDR



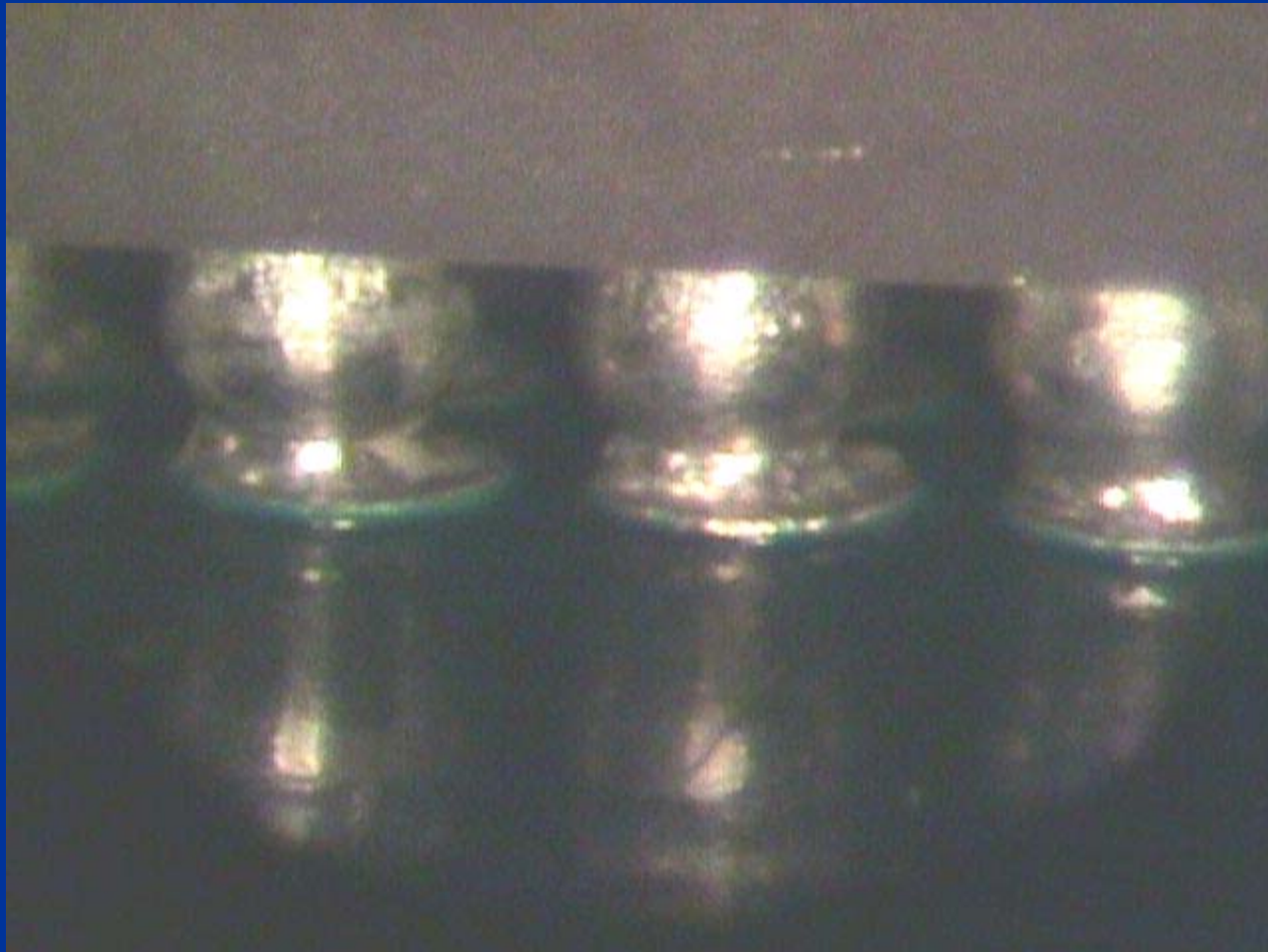
# Probe Card Troubleshooting Techniques

## Example #2 – External TDR Corroborating Data



# Probe Card Troubleshooting Techniques

## Example #2 – Source of Failure



# Probe Card Troubleshooting Techniques

## Future Enhancements

- **Utilize Tester TDR for detailed path measurements instead of relying on external TDR**
  - **Utilizes internal TDR just like external to collect detailed path characterization data**
  - **Provides adequate fidelity of measurement for this type of troubleshooting**
  - **Provides ultimate replication of test environment**
  - **Allows for rapid setup and troubleshooting**
  - **Offers possible application to preventative maintenance**
  - **look for wear internal to probe cards**

# Probe Card Troubleshooting Techniques

## Conclusion/Acknowledgements

- Application of TDR to probing signal path troubleshooting can be very useful.
- TDR can identify both open circuit and high-resistance failures.
- Once signal path is understood, TDR can be used to rapidly isolate the failure to a single piece of hardware or interface.
- Opportunities exist to expand the application of TDR to initiate rapid in-situ troubleshooting of signal path.
- I would like to acknowledge Minh Quach and Will Olsen, Agilent Technologies, Fort Collins for their significant work on this topic.