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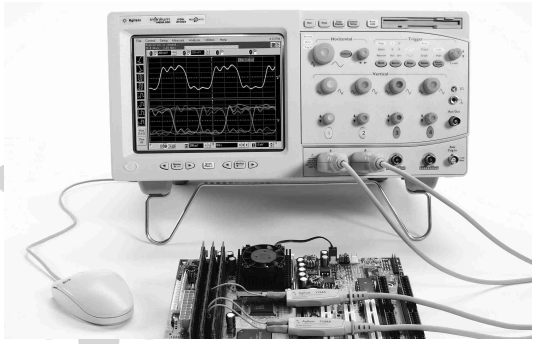
2004 High-Speed Digital Design Seminar

Presentation 6

Why Probing is Important in Multi Gb/s Designs



Why Probing is Important in Today's Multi Gb/s Designs

Seminar Objective

Learn about the performance effects of connecting an active probe to a high-speed digital signal using various use-model connections, and compare the measurement results between a traditional active probe technology to a new probe-head topology approach that delivers higher bandwidth and higher fidelity connections and measurements.

High Bandwidth Probes

In a Perfect World…

- Probes don't load your circuit
- Probes accurately reproduce signals under test with high fidelity

Realities in the Real World…

- Probes have been the "weak link" in the measurement chain when making high bandwidth signal integrity measurements
- All probes will load the circuit under test to some degree
- Probing accessories can degrade performance significantly
- If your probe limits your bandwidth to less than the scope's bandwidth, you've wasted money on your high bandwidth scope

Page 3

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Agenda - Higher Bandwidth Connectivity

- Traditional Active Probing Technology
  - Modeling
  - Usability Tradeoffs
  - Measured Response
- InfiniiMax Active Probing Technology
  - Modeling
  - High-Bandwidth Connectivity Options
  - Measured Response
- System Bandwidth
  - Maximally Flat versus Gaussian Response
  - Sample rate and aliasing
  - Required System Bandwidth versus Measurement Accuracy

Page 4

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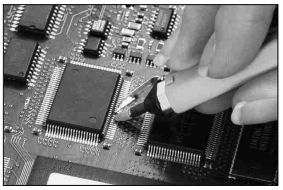
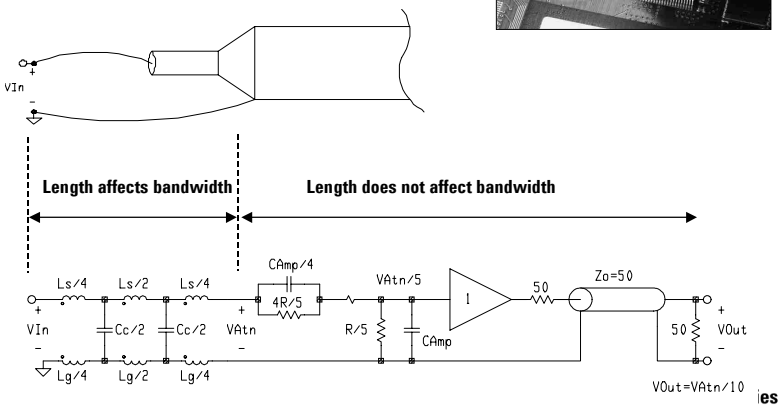
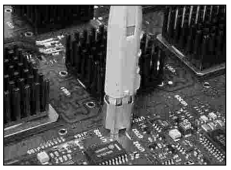
Traditional Active Probing Technology

The performance of an active probe is dominated by the connection to the point being probed

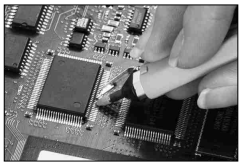




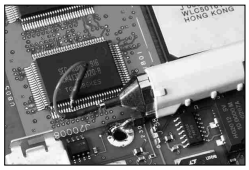
Probing Use Models and Tradeoffs



4 GHz coaxial ground socketed connection requires 'keep-out' space.



3.5 GHz "browsing" connection with variable ground spacing.

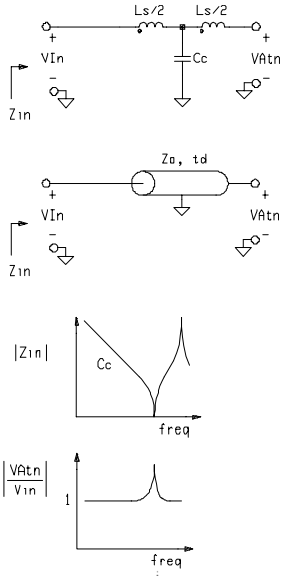


1.5 GHz 5 cm wire extender connection allows for hands-free probing and access to hard-to-reach points.

The connection dominates the probe system's performance

Probe Input Model (connection dominated)

- The connection can be modeled as an LC tank circuit or as a piece of transmission line
- Input impedance resonates low at 1/4 wave frequency of transmission line
- Transmitted response resonates high at same frequency



Page 7

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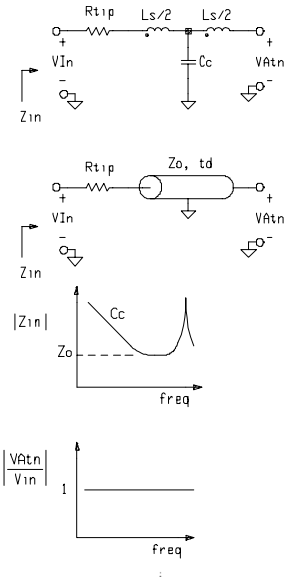
Probe Input Model (properly damped)

- Can be modeled as properly damped LC tank or source terminated transmission line
- Input Impedance:
  Doesn't resonate low,
  never goes below R_{TIP}
- Transmitted Response:
  Flat is where it's at!



Page 8

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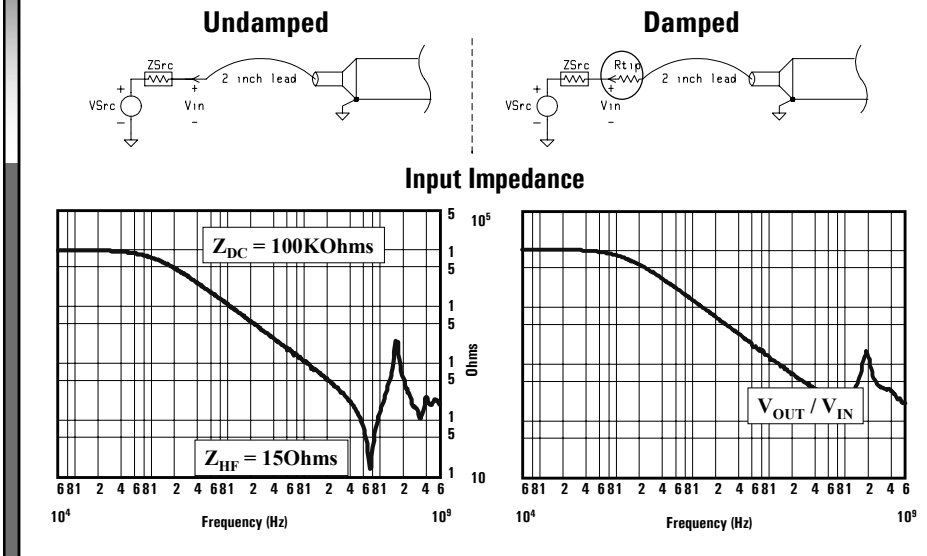
4GHz Active Probes w/ 5cm Connection Accessory



Page 9

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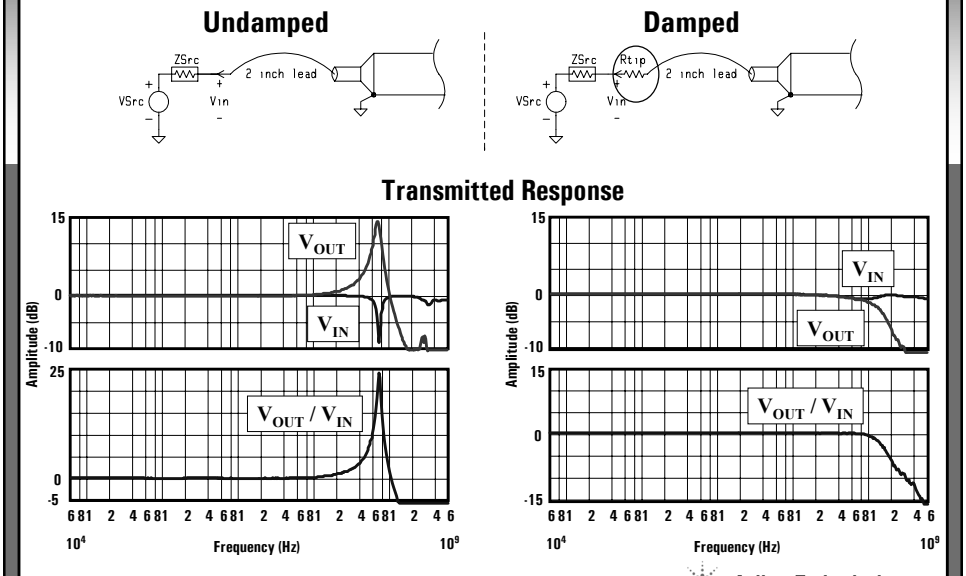
4GHz Probes w/ 5cm Connection Accessory



Page 10

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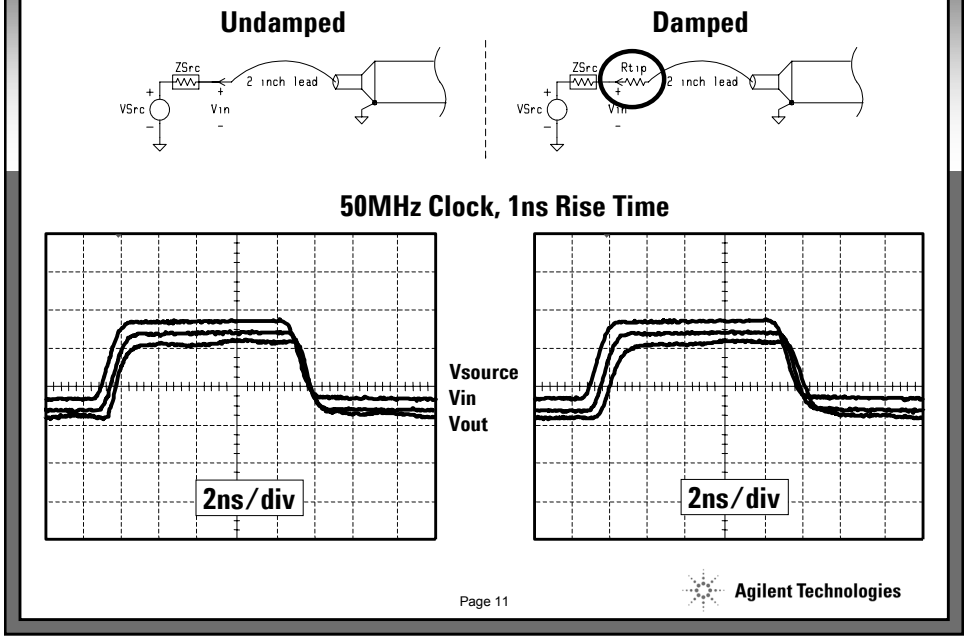
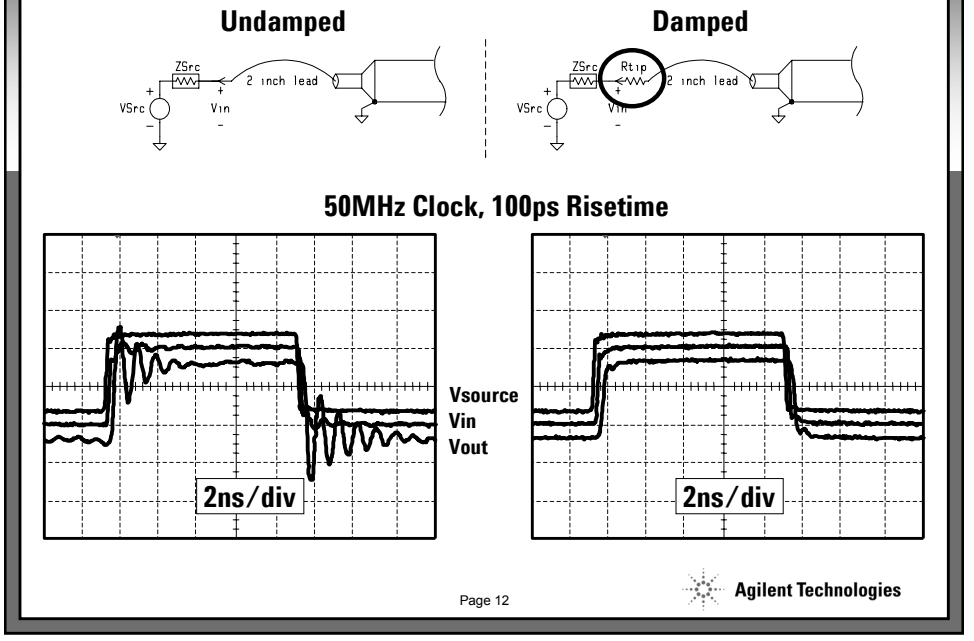
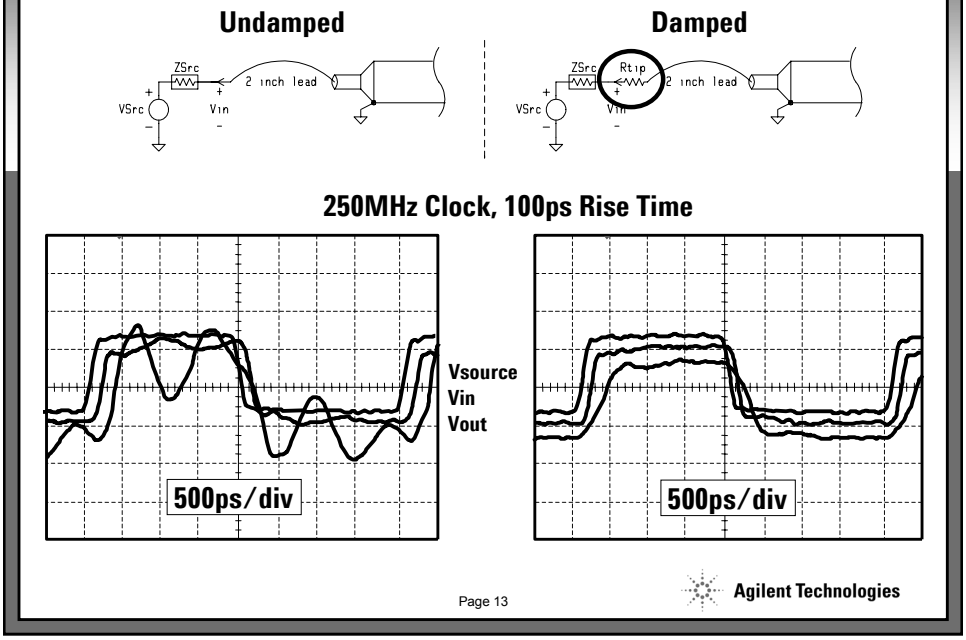
4GHz Probes w/ 5cm Connection Accessory



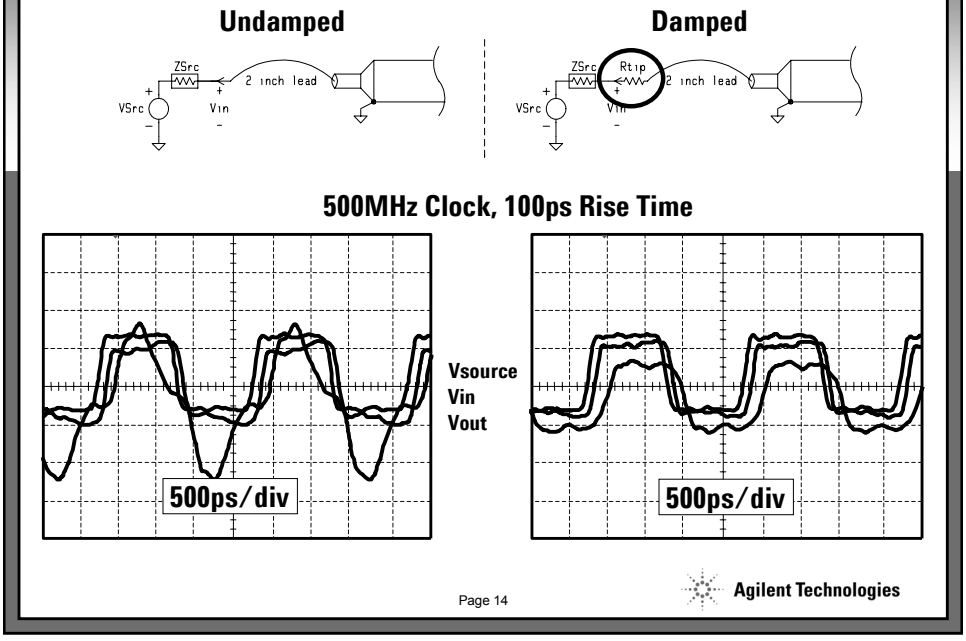
4GHz Probes w/ 5cm Connection Accessory



4GHz Probes w/ 5cm Connection Accessory



4GHz Probes w/ 5cm Connection Accessory



Probe Tip Damping Resistor Summary

Eliminates In-band Resonance

- Reduces high frequency impedance loading problem
- Significantly improves signal fidelity problem

Damping resistor probe tip technology does NOT solve bandwidth limitation problem due to connection accessory length!

Page 15

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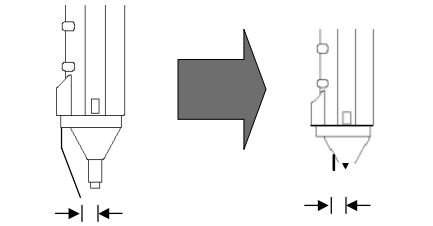
"Squeezing" Out Additional Bandwidth

Design Techniques to Improve Bandwidth Performance

- Increase amplifier bandwidth
- Reduce amplifier size
- Position amplifier close to blunt probe tip
- Reduce probe tip (fixed tip) & ground lengths
- Limit probe tip & ground to fixed spacing (2mm)



Results

- Increased bandwidth
- Browsing use model only
- Reduced usability
- No BW improvement for solder-in or socketed use models

Page 16

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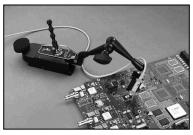
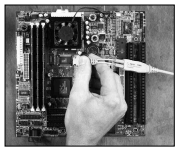
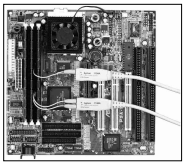
The Ideal High Bandwidth Active Probe

- Probe bandwidth ≥ oscilloscope's bandwidth
- Optimized for all probe use models
  - ✓ Browsing by hand
  - ✓ Browser in probe stand
  - ✓ Socketed connections
  - ✓ Solder-in connections
- Allows flexible connection options ***without a performance trade-off***
- Can make high bandwidth single-ended or differential measurements

Page 17

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Agilent's InfiniiMax Probe Design Approach

- Abandon traditional active probe topology approach
- Don't attempt to position amplifier close to probe point
- Replace "uncontrolled" transmission line connection with a "controlled" transmission line probe head connection
- Employ superior differential active probing technology

Page 18

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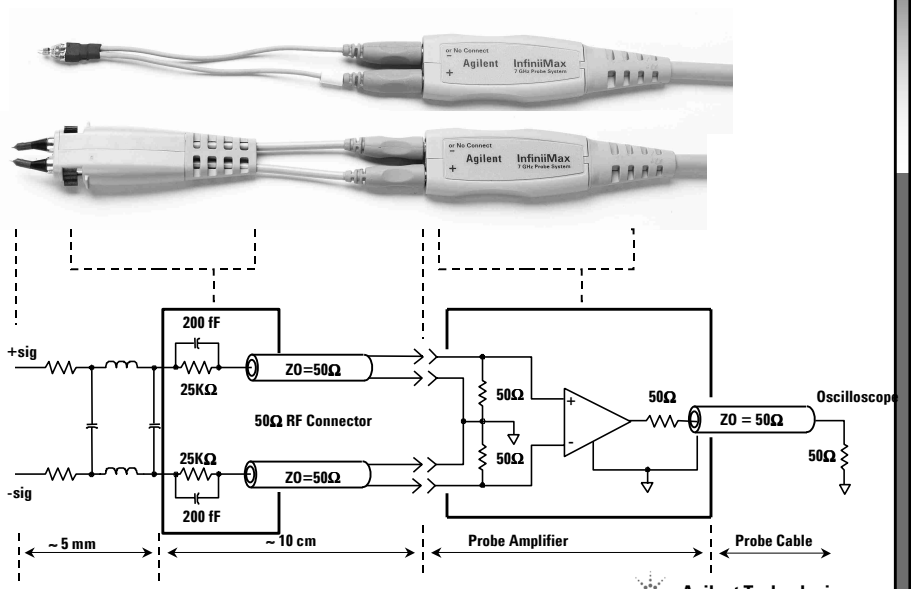
Agilent's New InfiniiMax Architecture



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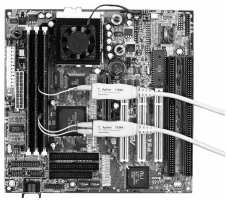
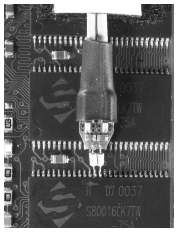
Higher Bandwidth Connectivity Solutions

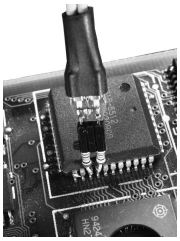
- **InfiniiMax probing system offers the following options:**
  - **Solder-in probe head**
  - **Socketed probe head**
  - **Versatile differential browser**
  - **Differential and single-ended**



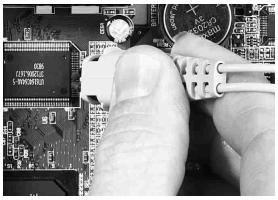
Differential & single-end connectivity kits



10 cm solder-in probe head



10 cm socketed probe head



Differential browsing probe head

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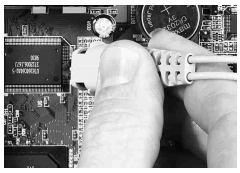
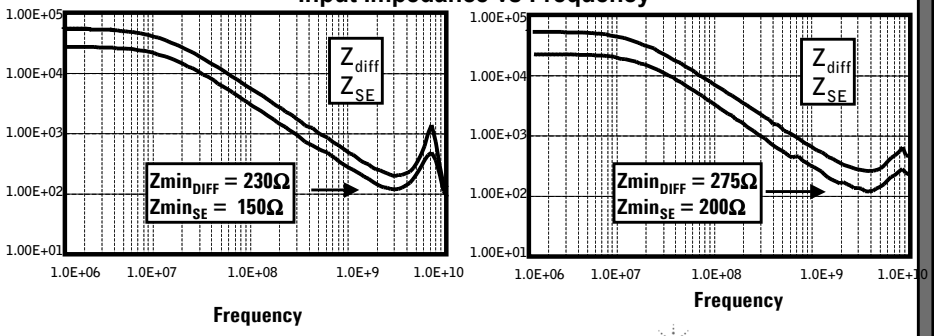
Impedance for "browser" and 10cm solder-in probe heads

Browser Probe Head



10cm solder-in Probe Head

Input Impedance vs Frequency



Page 21

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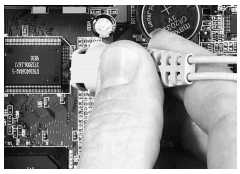
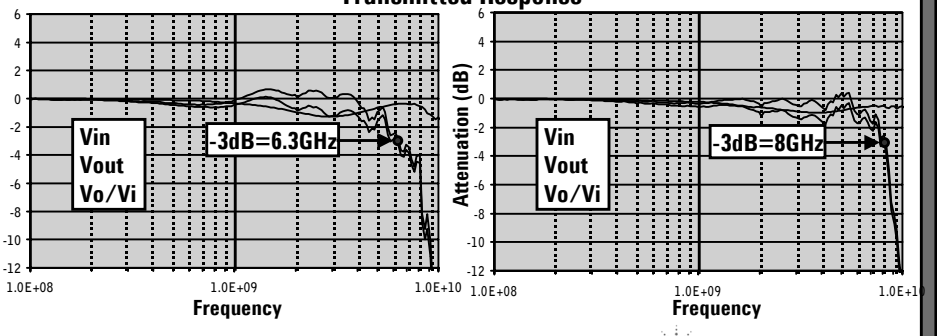
Transmitted Response for "browser" and 10cm solder-in probe heads

Browser Probe Head



10cm solder-in Probe Head

Transmitted Response



Page 22

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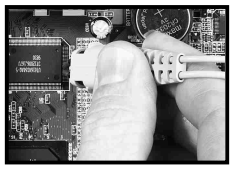
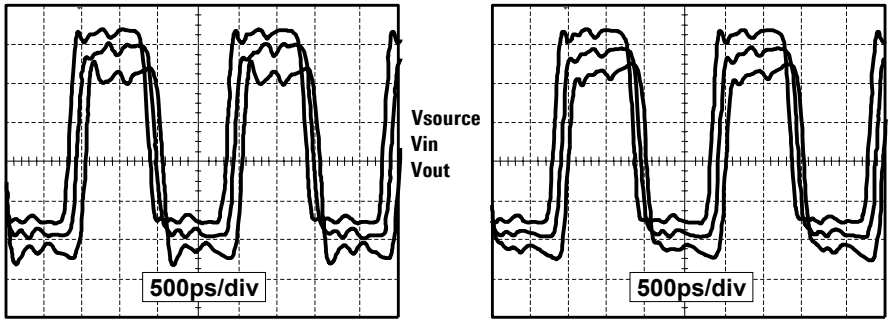
Pulse Response for Browser & 10cm solder-in probe heads

Browser Probe Head



10cm solder-in Probe Head

500MHz Clock, 100ps Risetime



Page 23

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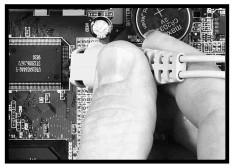
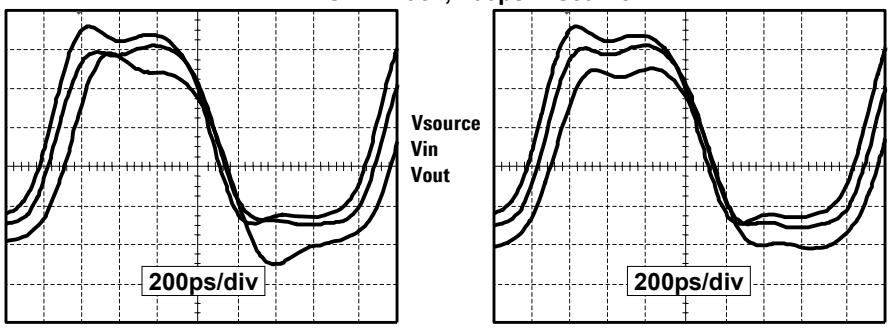
Pulse Response for Browser & 10cm solder-in probe heads

Browser Probe Head



10cm solder-in Probe Head

1.2GHz Clock, 100ps Risetime



Page 24

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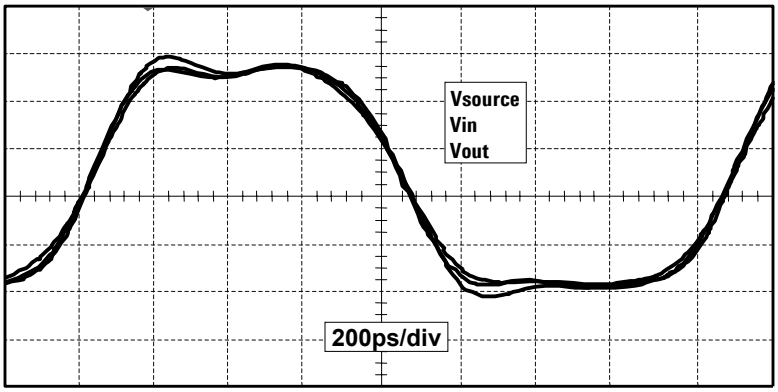
Pulse Response for 10cm solder-in probe head

1.2GHz Clock, 100ps Risetime



Page 25

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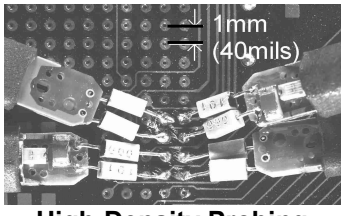
Differential versus Single-ended Active Probe for Single-ended Measurements

Differential Active Probe Advantages

- Higher bandwidth (virtual ground plane)
- Variable spaced probe tips (with minimal response change)
- Higher common mode rejection
- Ease-of-use (eliminates interchanging probes)
- Better repeatability (reduces outer mode phenomena)

Single-end Active Probe Advantages

- Smaller probe heads
- Lower cost



High-Density Probing

Page 26

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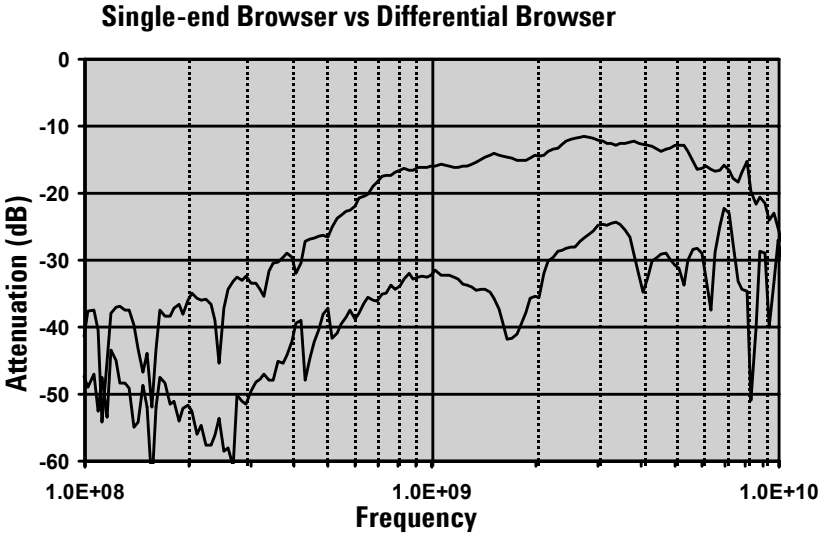
Common Mode Rejection



Page 27

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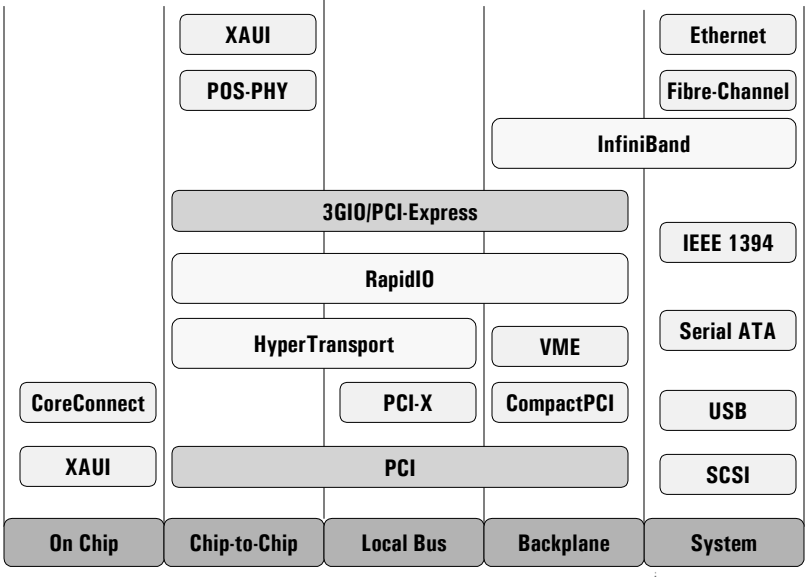
Computer Interconnect Standards



Page 28

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High-Speed Signaling Standards

Standard	Data Rate (Gb/s)	Driver Edge Rate (ps)	Receiver Sensitivity	Receiver Eye Opening or Setup/Hold
Serial				
PCI Express (3GIO)	2.5			
RapidIO Serial	3.125			
10GbE XAUI	3.125	50ps to 140ps	200mVpp to 400mVpp	100ps to 140ps
Fibre Channel 2125	2.125			
Infiniband	2.5			
Serial ATA	1.5			
Parallel				
RapidIO 8/16	2			
HyperTransport	1.6			

- ✓Edge rates are decreasing below 100ps
- ✓Differential voltage swings are shrinking

Page 29

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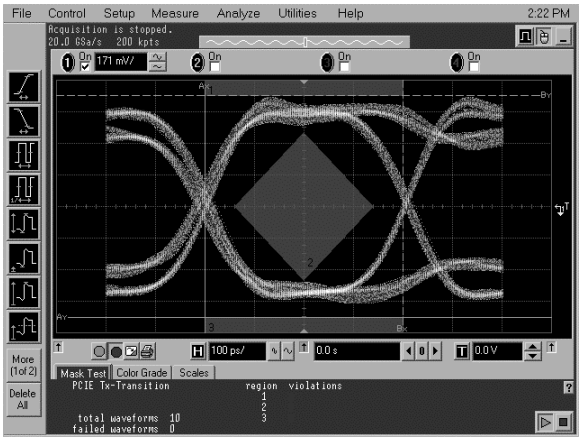
PCI-Express Transmitter Probing Example



PCI-Express real-time mask test leaves little margin for probe infidelity.

Page 30

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InfiniiMax Probe Design Approach Summary

- InfiniiMax' "controlled" transmission line probe head topology
  - Minimizes circuit loading
  - Maximizes probe system performance for multiple use models
  - Maximizes usability for multiple use models
- Differential active probing delivers superior results for both single-ended and differential measurements
- Most newer high-speed buses are fast, differential, serial, and with low voltage swings (LVDS)

Page 31

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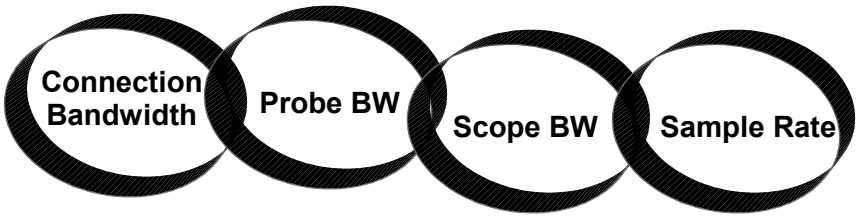
Weakest "Link" Determines Bandwidth



System bandwidth can be viewed as a chain reaction, where the lowest performance component in the measurement system will limit the bandwidth of the measurement.

Page 32

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System Bandwidth Considerations

- Lower bandwidth scopes have a Gaussian response
  - ✓ $BW = 1/\sqrt{(1/BW^2_{scope} + 1/BW^2_{probe} + ...}$
- Higher bandwidth scopes have a "maximally flat" response
  - ✓ $BW = Weakest\ Leak_{BW}$ (1^{st} approximation)

Page 33

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System Bandwidth Considerations Cont.

- Maximally flat systems result in:
  - ✓ More accurate timing measurements
  - ✓ Less aliasing
- For real-time scopes, sample rate directly affects bandwidth and measurement accuracy

Page 34

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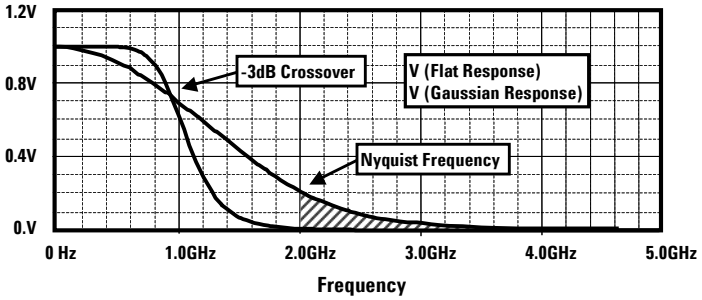
Sampling Alias Error

- Gaussian response oscilloscopes have a slow rolloff in their frequency response. Frequency content above the Nyquist rate that is not significantly attenuated will manifest itself as a lower frequency signal component, creating unwanted measurement error (aliasing) in the form of edge 'wobble'.



- Flat response oscilloscopes eliminate alias errors by quickly attenuating frequency content above the Nyquist sampling frequency.

Page 35

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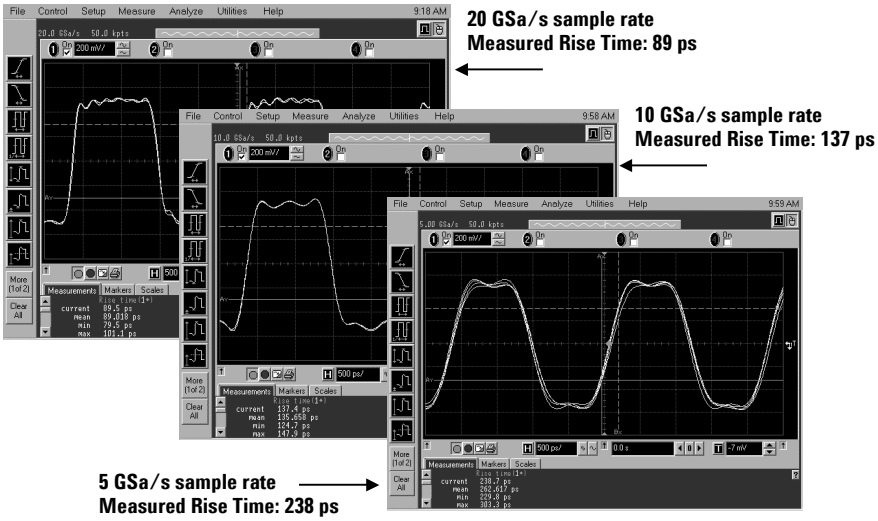
When You Need to Verify Signal Integrity…



Page 36

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System Bandwidth

- The oscilloscope bandwidth required for accurate measurements is primarily dependent on the signal's risetime, not its frequency.

Oscilloscope Bandwidth and Accuracy		
Determine Maximum Signal Frequency (Fmax)	0.5 / Signal Risetime (10%-90%) OR 0.4 / Signal Risetime (20%-80%)	
Determine Oscilloscope Response Type	Gaussian Response	Flat Response
Risetime Measurement Error	Oscilloscope Bandwidth	
20%	1.0 Fmax	1.0 Fmax
10%	1.3 Fmax	1.2 Fmax
3%	1.9 Fmax	1.4 Fmax
Minimum Sample Rate	4 x Bandwidth	2.5 x Bandwidth

- Flat response oscilloscopes with a bandwidth that is 1.4 times the highest frequency content in the signal will make accurate risetime measurements.

Page 37

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System Bandwidth Calculation

Example

- Determine the minimum required bandwidth and sample rate of a flat frequency response oscilloscope to measure a 100ps risetime (20-80%) to an accuracy of 3%:

F_{max} = (0.4/100ps) = 4.0 GHz

Required oscilloscope bandwidth = 1.4 * 4.0 GHz = 5.6 GHz

Minimum Sample Rate = 2.5 * 5.6 GHz = 14.0 GSa/s

Page 38

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Summary

- Traditional active probing topology has restrictive use limitations, and is near the end of its performance range.
- InfiniiMax probe head technology allows probing in tight spaces without performance degradation, and allows the versatility to quickly move from one node to the next.
- Differential measurements allow for better common mode rejection on both single-ended and differential signals.
- Measurement accuracy is a combined function of the frequency responses of the probing system and the oscilloscope, including sample rate.

Agilent 54850 Infiniium Performance Series

www.agilent.com/find/infiniimax

2.5GHz to 6GHz

- 4 channels
- Up to 32 MB deep memory
- Up to 20 GSa/s sample rate/channel
- MEGAZoom technology
- Infiniium award-winning usability
- Timing Interval & Jitter Analysis Software

Model	BW	Channels	Sample Rate Per Channel	Standard Mem/Ch	Optional Mem/Ch
54853A	2.5GHz	4	20GSa/s	256K	1M/32M
54854A	4 GHz	4	20 GSa/s	256K	1M/32M
54855A	6 GHz	4	20 GSa/s	256K	1M/32M

InfiniiMax High Performance Probe System

Configuring an InfiniiMax Probe System

1. **Choose a probe amplifier based upon performance needed**

Model	Bandwidth	Price
1131A	3.5 GHz	$2,450
1132A	5.0 GHz	$3,700
1134A	7.0 GHz	$5,100

2. **Choose one or both connectivity kits.**

- Differential (E2669A) $3,450

- Better measurement quality for differential and single-ended signals
- Interchangeable parts reduce setup time

- Single-ended (E2668A) $1,400

- More cost effective for single-ended only

www.agilent.com/find/infiniimax

Page 41

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Differential Connectivity Kit

E2669A Differential Connectivity Kit

Differential Browser
- 6 GHz Bandwidth
- Input Resistance, 50kΩ / 25kΩ
- Input Capacitance, .32pF / .57pF
- Variable tip spacing, replaceable tips
- Dual tip Z-axis compliance

Ergonomic browser sleeve comes standard!

Differential Socket
- 7 GHz Bandwidth
- Input Resistance, 50kΩ / 25kΩ
- Input Capacitance, .34pF / .56pF
- 100 mil socket spacing, accepts standard 20-mil round resistor leads

Differential Solder-In
- 7 GHz Bandwidth
- Input Resistance, 50kΩ / 25kΩ
- Input Capacitance, .27pF / .44pF
- 8 mil tip leads are flexible

Page 42

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Single-Ended Connectivity Kit

E2668A Single-Ended Connectivity Kit

Single-Ended Browser
- 5.5 GHz Bandwidth
- Input Resistance, 25kΩ
- Input Capacitance, .67pF
- Variable tip spacing, replaceable tips

Ergonomic browser sleeve comes standard!

Differential Socket
- 7 GHz Bandwidth
- Input Resistance, 25kΩ
- Input Capacitance, .56pF
- 100 mil socket spacing, accepts standard 20-mil round resistor leads

Single-Ended Solder-In
- 5.2 GHz Bandwidth
- Input Resistance, 25kΩ
- Input Capacitance, .50pF
- 8 mil tip leads are flexible

Page 43

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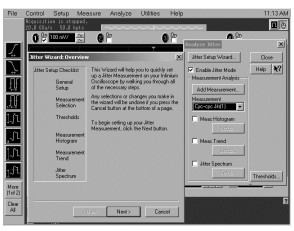
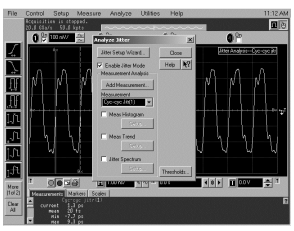
Jitter Analysis - Easy to Use, Easy to Understand

- Key measurements include: cycle-cycle jitter, n-cycle jitter, period jitter, time interval error, setup and hold time, measurement histograms, measurement trending and jitter spectrum
- Integrated into the oscilloscope application
- Setup Wizard guides the user on setup of the jitter measurement, describes what the measurement does and tells you when to use it





Page 44

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Additional Resources

Application Notes

- **Restoring Confidence in Your High-BW Probe Measurements, Application Note: 5988-7951EN**
- **Understanding Usability Versus Performance on High-BW Active Scope Probes, Application Note: 5988-8005EN**
- **Performance Comparison of Differential & Single-ended Active Voltage Probes, Application Note: 5988-8006EN**

Page 45

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Thank You for Attending

Achieving Higher Bandwidth Connectivity with High-Speed Active Probes

Page 46

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