KEYSIGHT WORLD 2019

Key considerations in probing high speed digital signals

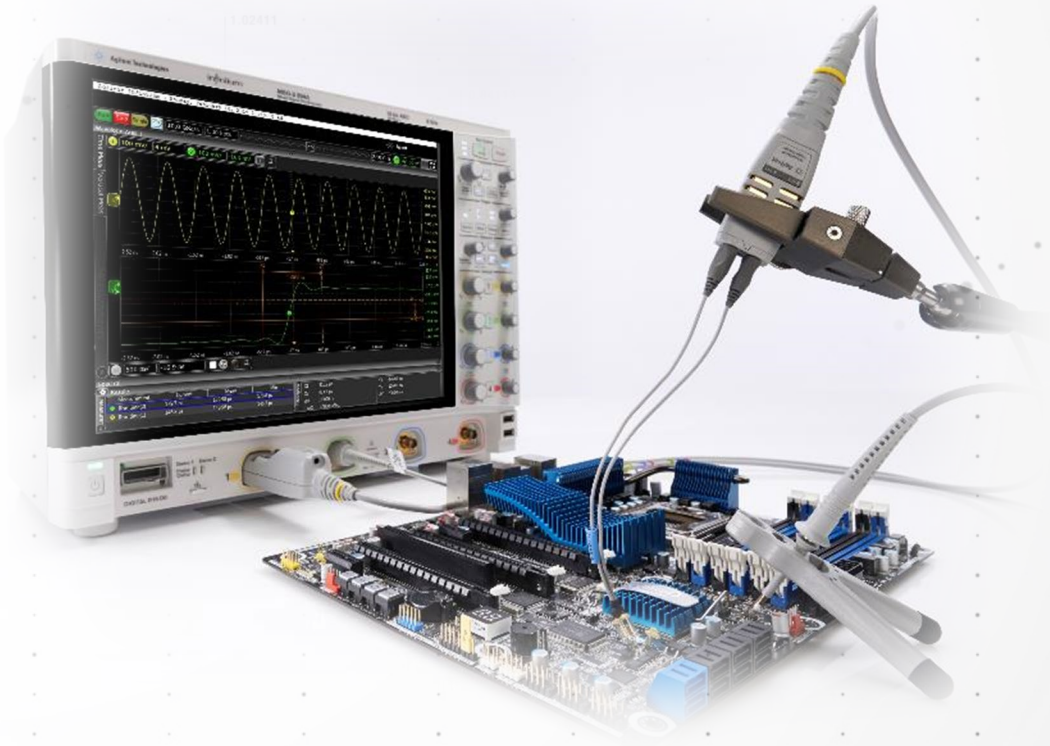
Product manager/ Keysight Technologies

Jae-yong Chang

Agenda

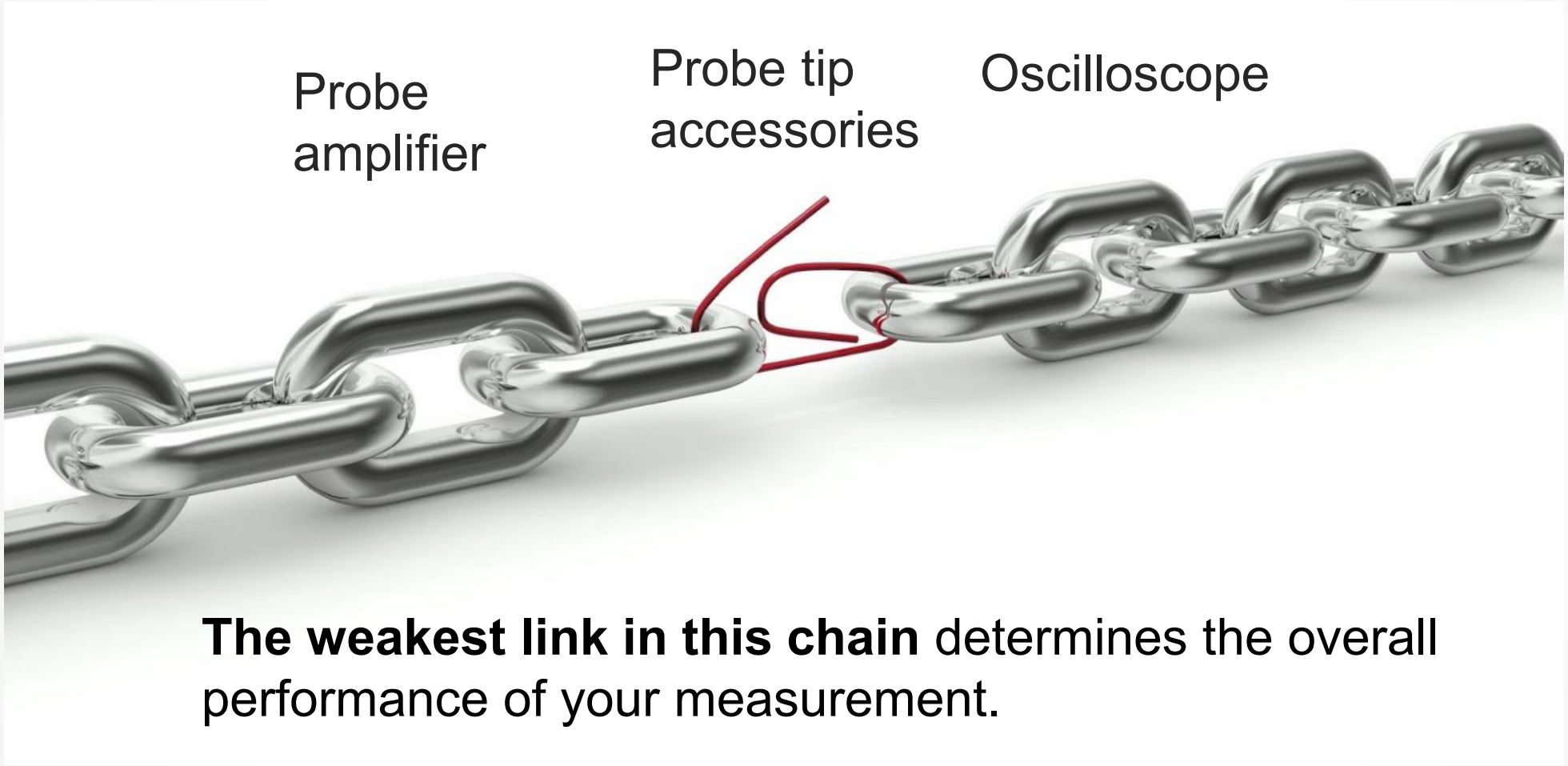
KEY CONSIDERATIONS IN PROBING HIGH SPEED DIGITAL SIGNALS

- Beware of uncontrolled input leads
- Probe loading considerations
- Probe response corrections
- Probing in extreme conditions



Beware of uncontrolled input leads

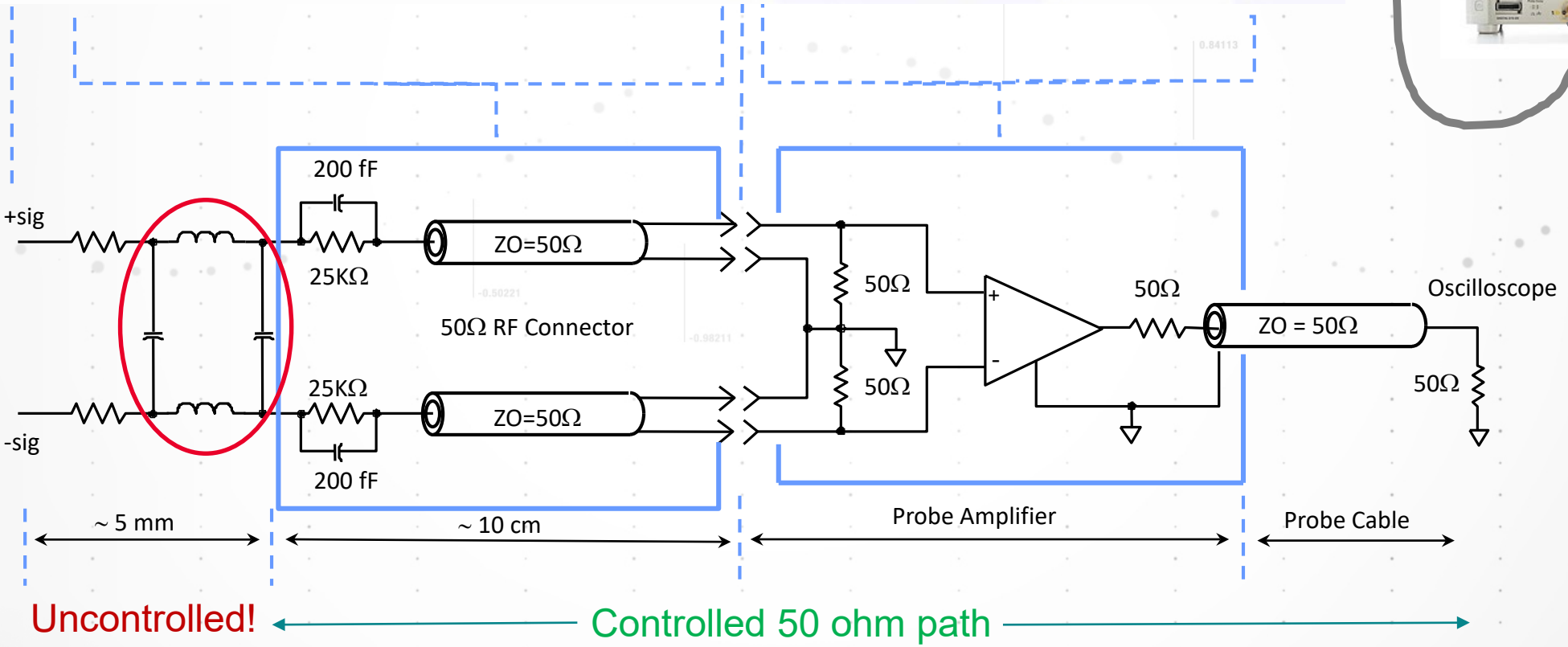
What's the weakest link in the chain?



The weakest link in this chain determines the overall performance of your measurement.

InfiniiMax I/II probe architecture

This uncontrolled ~4 mm tip leads may have a huge effect on the performance of your probe and the entire measurement system

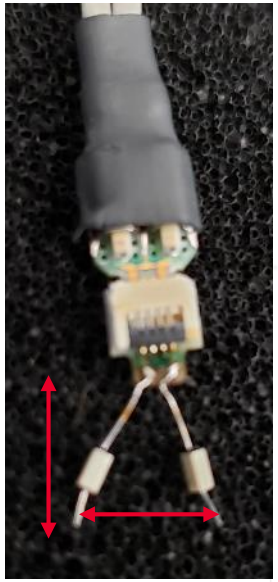


Varying lead length/span affects probe bandwidth

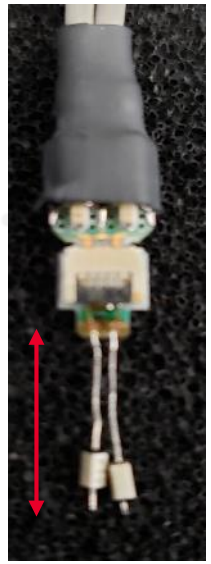
InfiniiMax II N5425B ZIF head + N5426A ZIF tips or N5451A Long-wire ZIF tips

2mm, 12.3 GHz

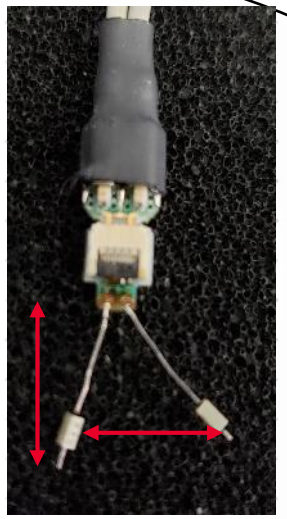
7mm, 9.9 GHz



7mm, 60 deg, 4.4 GHz



11mm, 0 deg, 5 GHz



11mm, 60 deg, 3.3 GHz

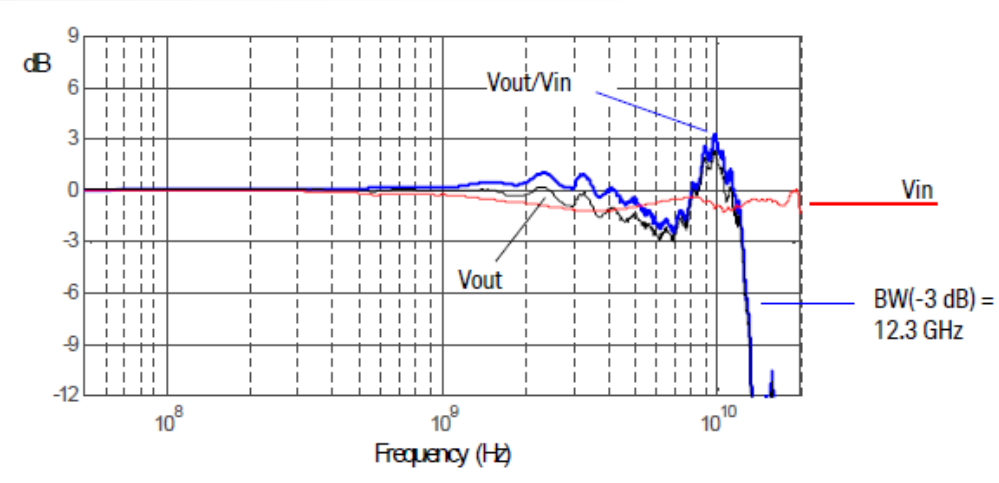
Longer lead wires

Wider pitch span

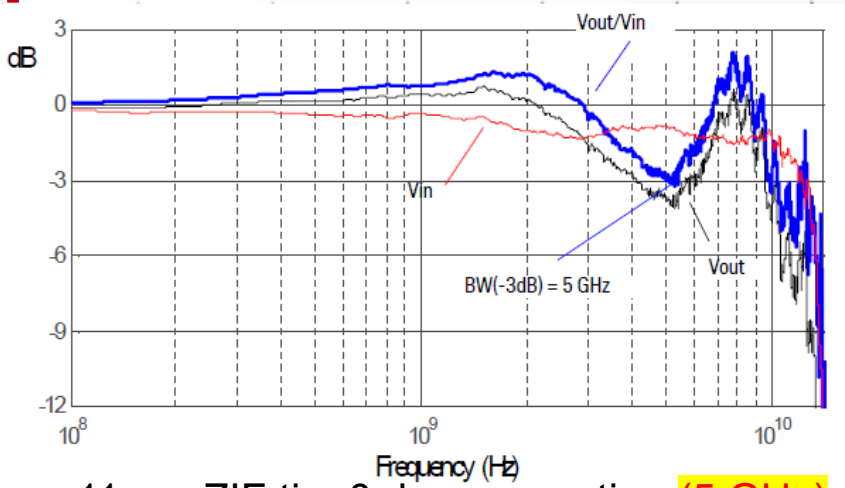
Lower bandwidth

Bandwidth is reduced with increased lead wire length and loop area created by two input leads. **Keep it short and a small loop area.**

Varying lead length/span can greatly affect the flatness of the frequency response

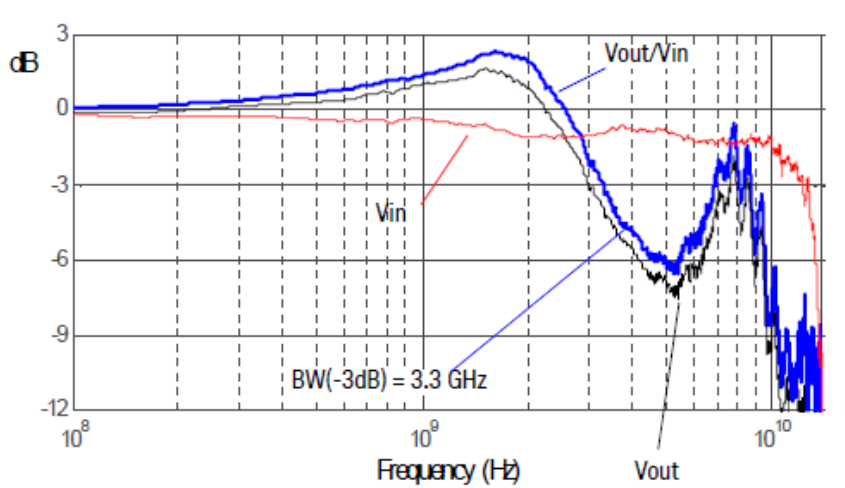


2mm ZIF tip, 0 deg separation (12.3 GHz)



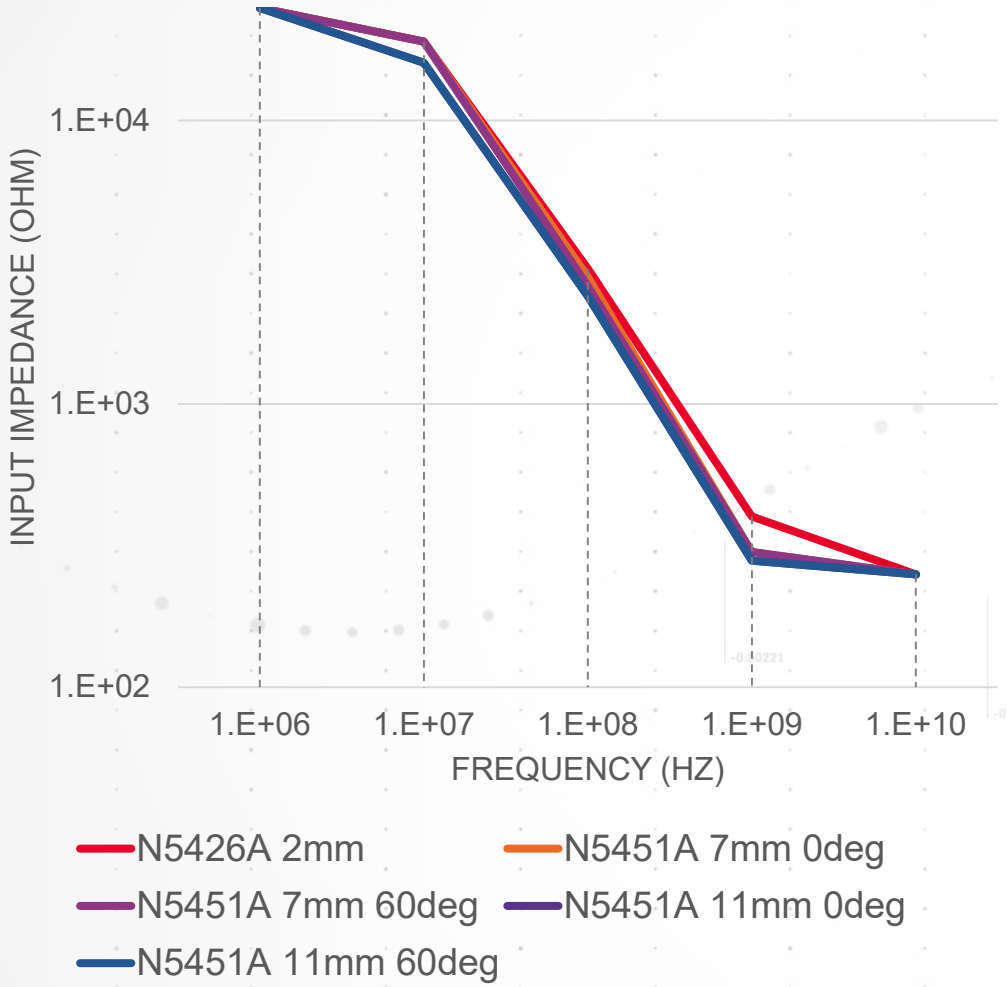
11mm ZIF tip, 0 deg separation (5 GHz)

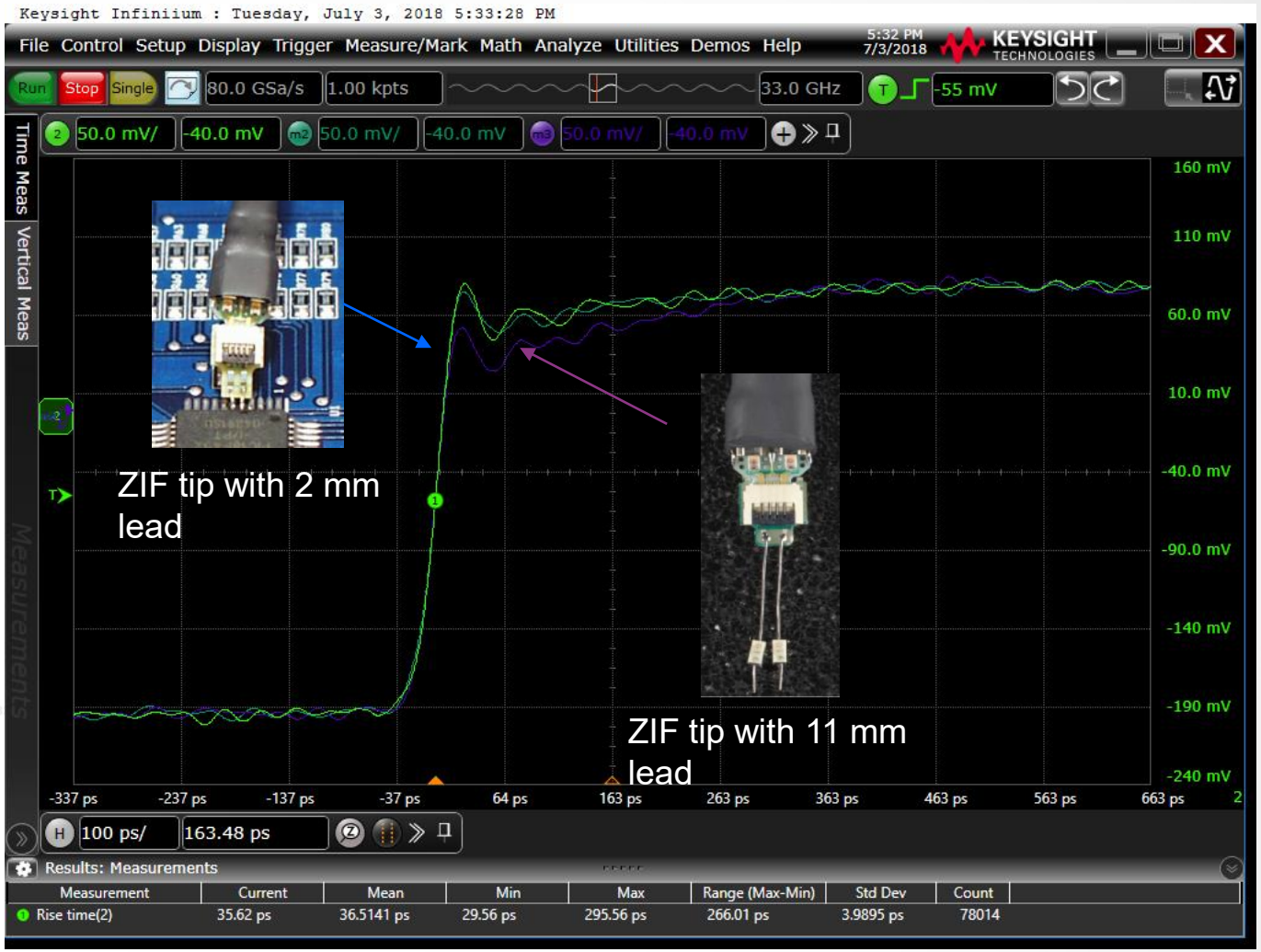
Longer input lead wire and wide loop area can cause **non-flat frequency response**.



11mm ZIF tip, 60 deg separation (3.3 GHz)

Varying lead length/span can affect the probe loading too





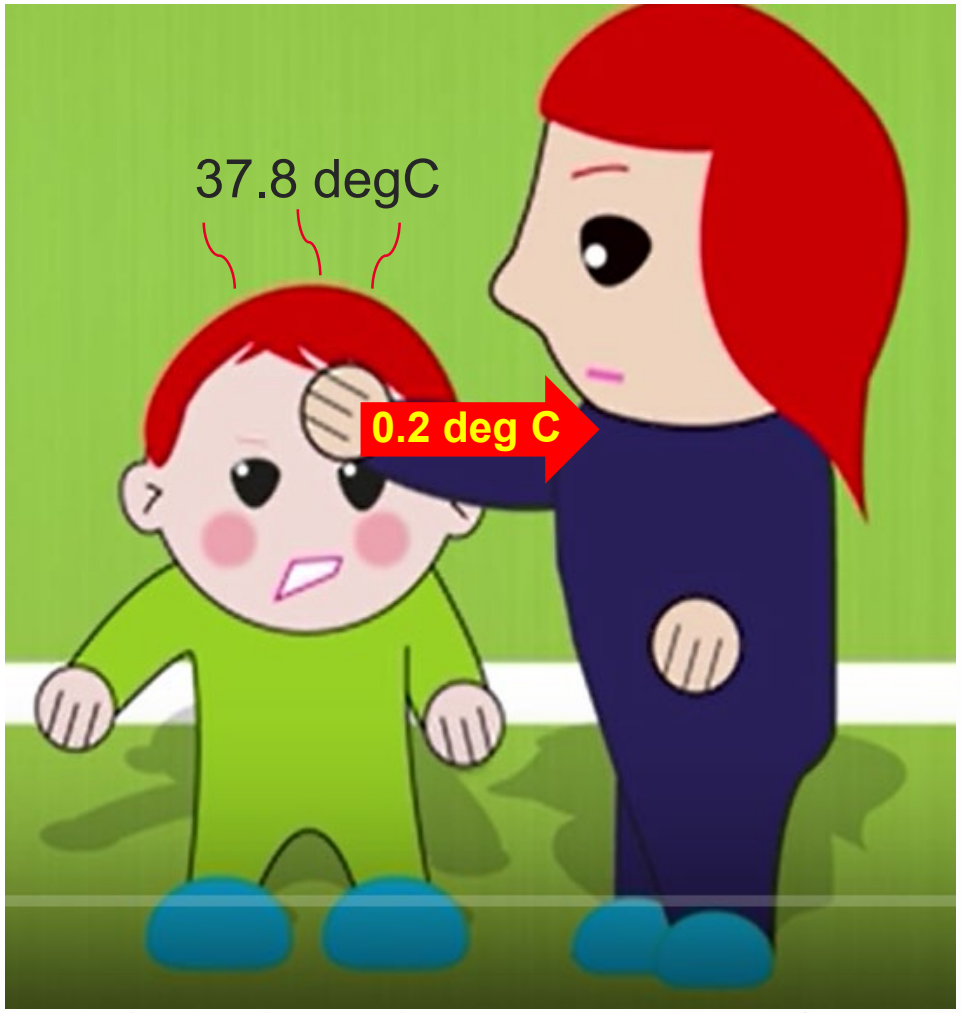
Longer input lead wire and wide loop area can cause **higher loading of the probe, as the probe head capacitance gets higher.**

Summary – beware uncontrolled input leads

- Probe accessories can greatly affect the overall bandwidth, frequency response and loading characteristics.
- Keep it short!
- Keep the loop area of the tips as small as possible.

Probe loading considerations

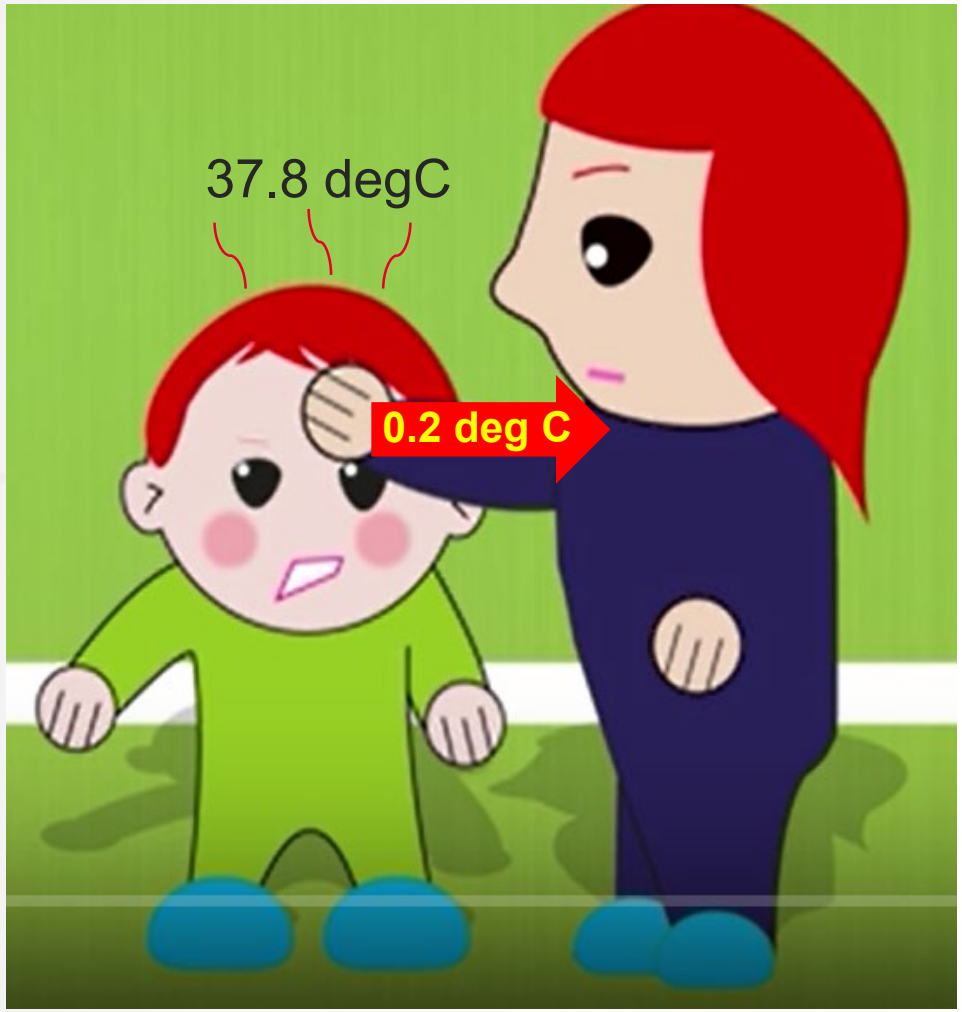
Probe loading in a nutshell



This child's body temperature drops as his mom places her hand. It changes his body temperature as his mom takes away the temperature.

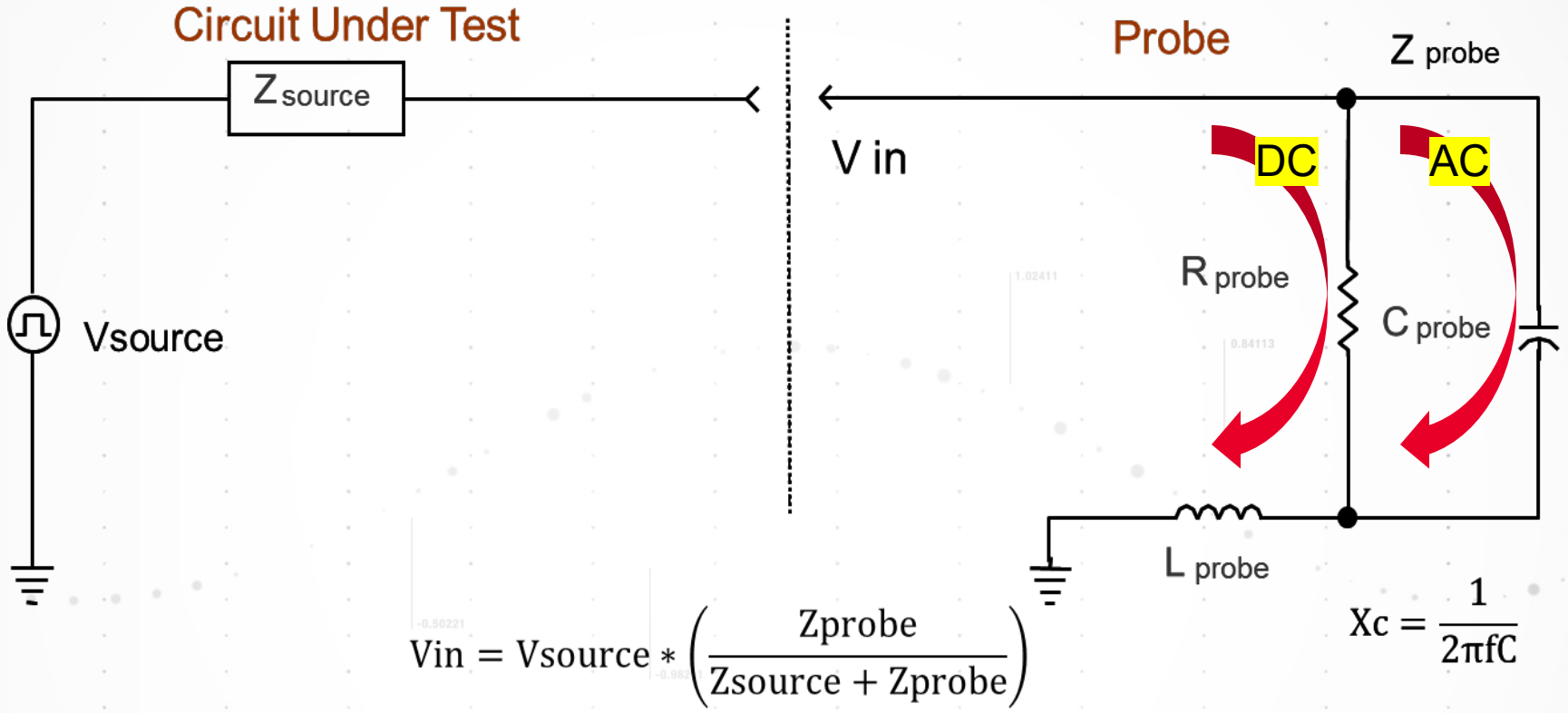
Probe loading is just like this. Connecting a probe to the DUT can change the circuit behavior (amplitude, rise/fall time, offset, time delay etc).

Why probe loading matters



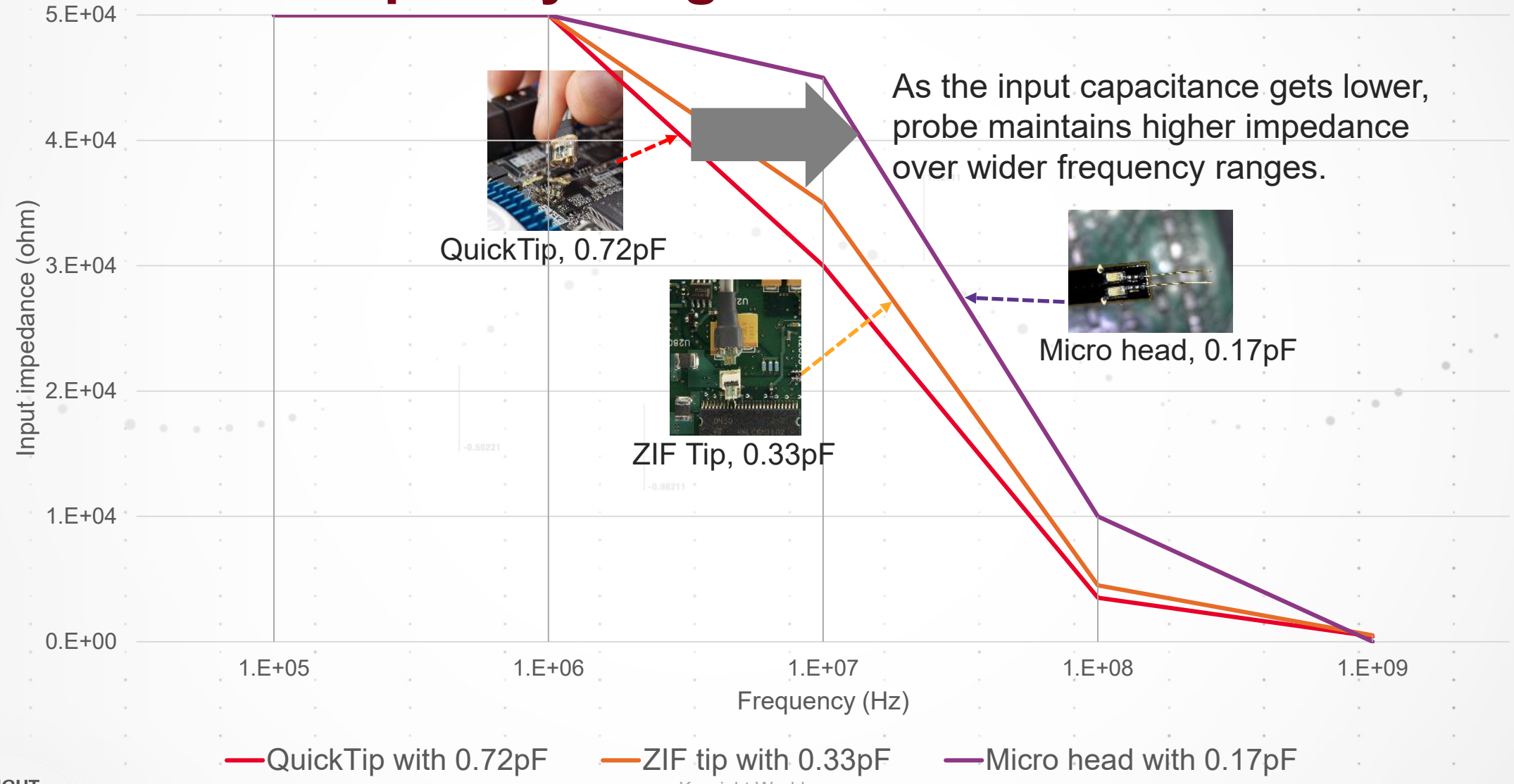
- As mom's hand is placed the boy's temperature drops to 37.8 degC.
- One may estimate it might have been 38 degC, but in reality, the temp is no longer 38 degC. It is 37.8 degC.
- A probe with poor loading characteristics may change your circuit behavior, regardless of the waveform the scope shows you.
- Keysight InfiniiMax probes are designed to show you the signal at the tip as loaded by probe.

Probe loading – a circuit level view

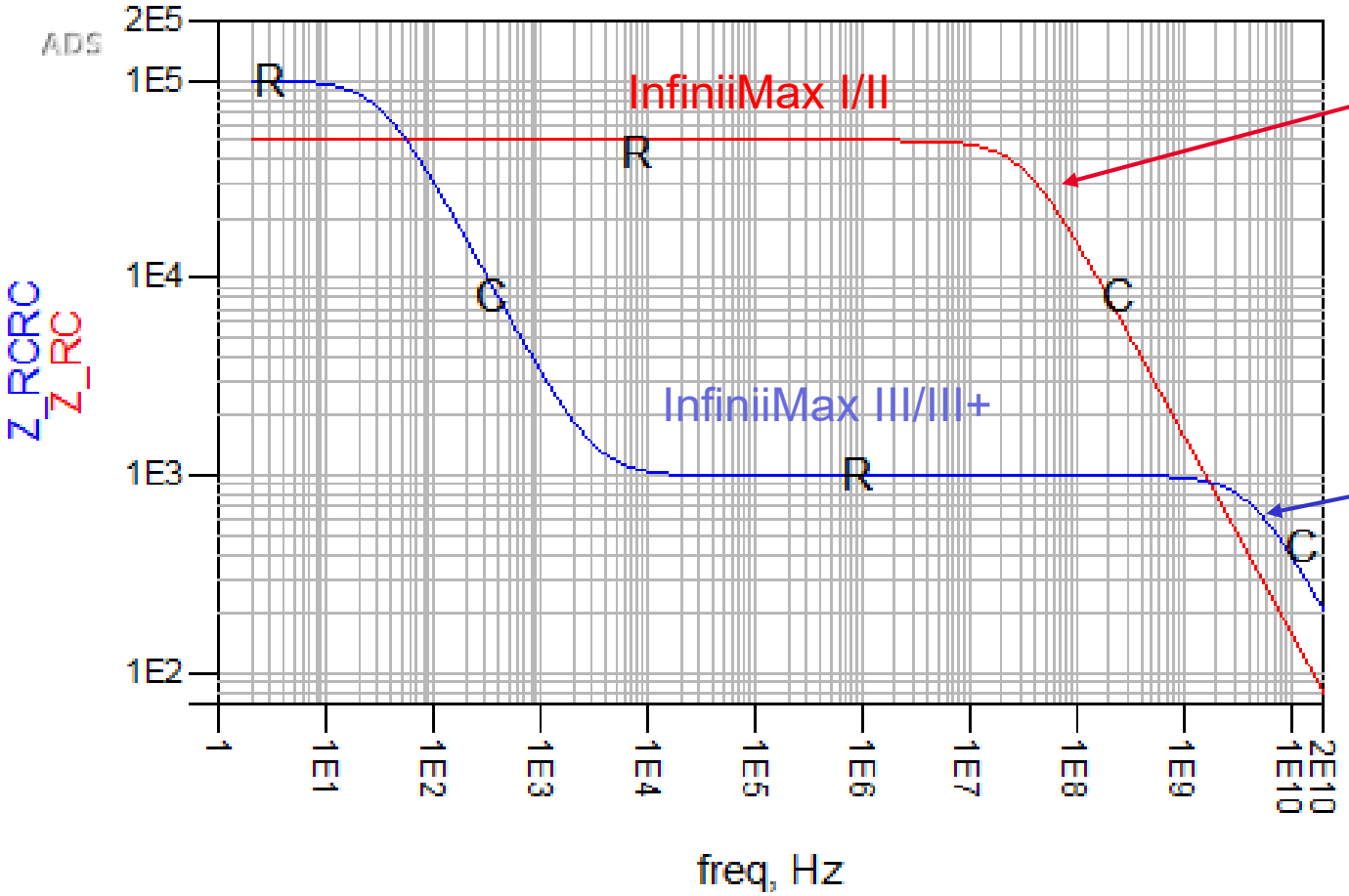


- Probe becomes an additional load driven by the signal source and can change the operation of the DUT.
- Resistive, capacitive and inductive loading effects must be considered.
- Pay careful attention to capacitive loading as your system bandwidth gets higher.

Lower capacitance lets you use higher impedance over wider frequency ranges



Two common probe impedance profiles



RC : Best for probing circuits with a higher source impedance or circuits whose source impedance changes from High Z to Low Z (e.g., bus that transitions in and out of high Z mode)

RCRC : Better for preserving high frequency wave shape of a low impedance, high frequency signals. Supports up to 30 GHz (with InfiniiMax III N2803A)

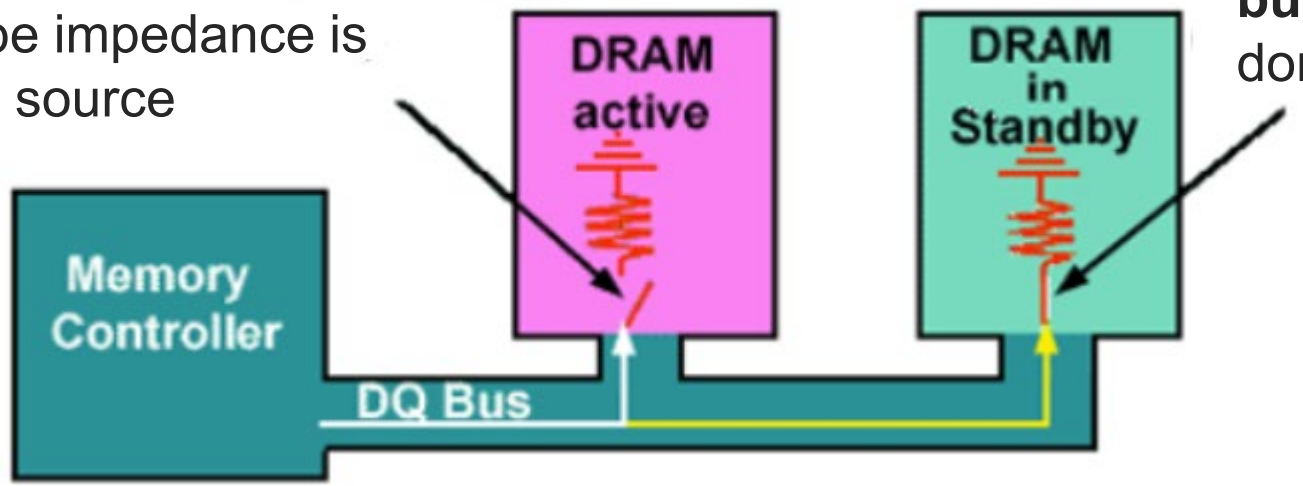
"RC" (red trace): traditional resistance – then capacitance impedance profile

"RCRC" (blue trace): High DC impedance, moderate mid-band impedance

DDR memory dynamic on-die termination (ODT) modes

How large is your probe input impedance relative to the source impedance?

ODT OFF (high impedance bus): Probe loading can be more pronounced depending on how large the probe impedance is relative to the source impedance.

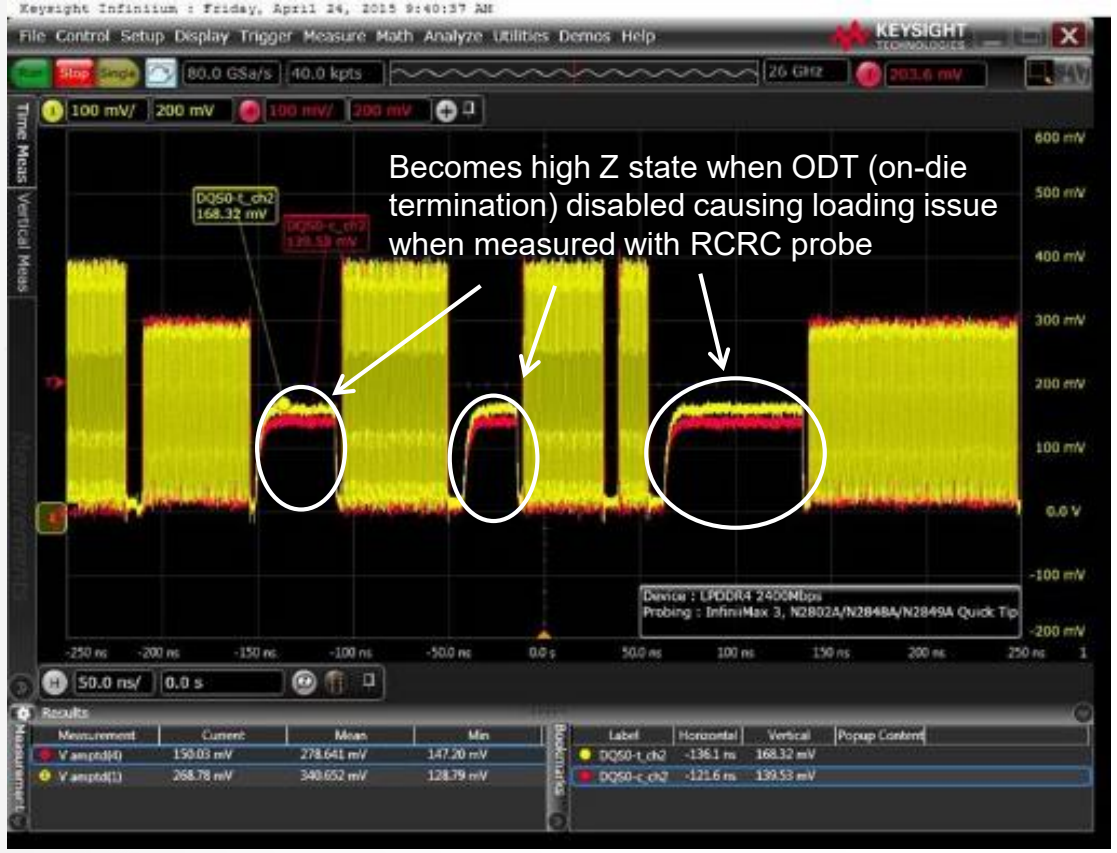


ODT ON (low impedance bus): The source impedance dominates loading.

Dynamic ODT enables the DRAM to switch between high or low termination impedance. When the termination impedance goes high, probe impedance needs to be high enough to reduce probe loading.

Probing a LPDDR4 memory bus with switching impedance

- Probe loading effect makes difference in two waveforms.
- RC probe is a better choice when probing buses that transition to a “high Z” state or when dealing with signal with high impedance.

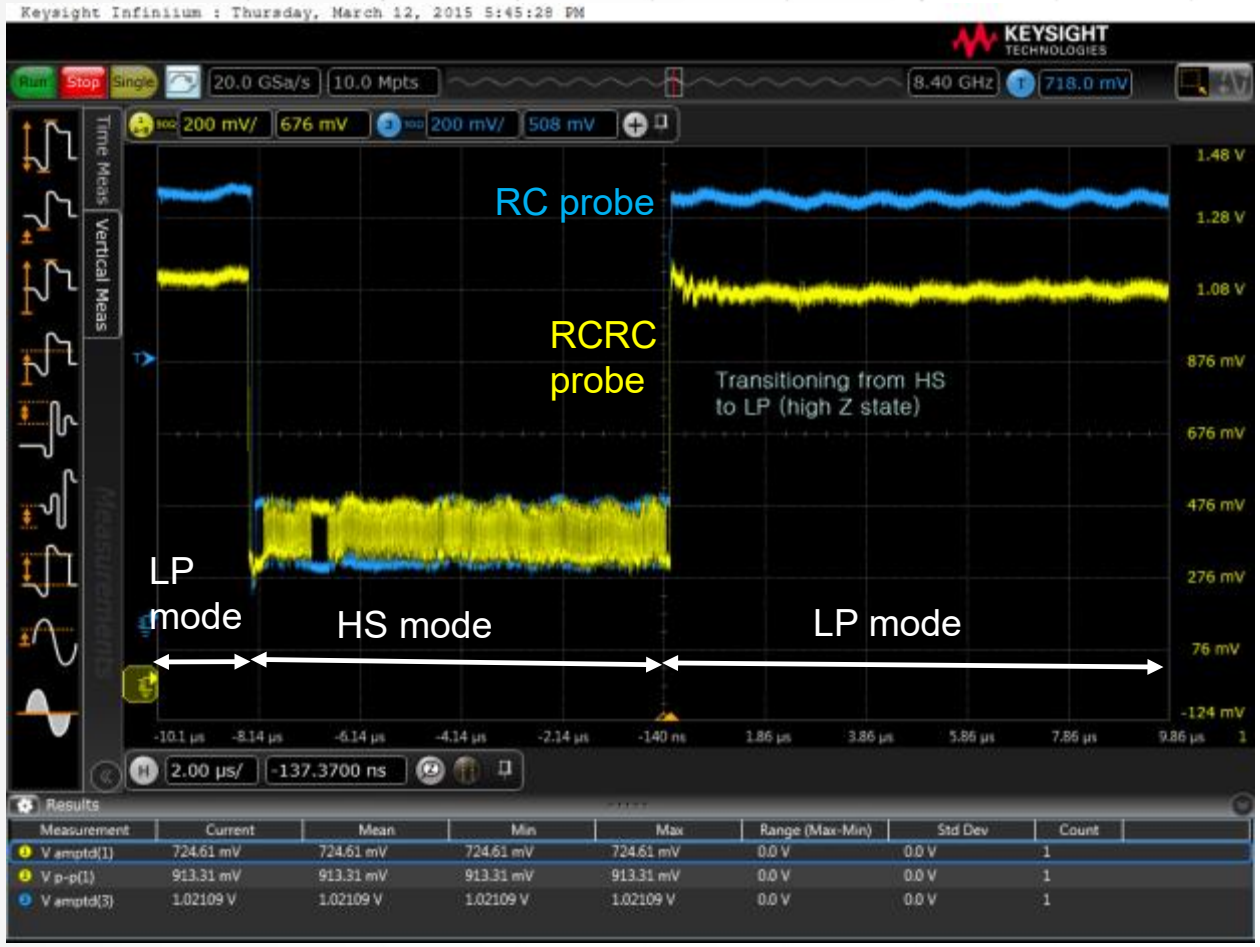


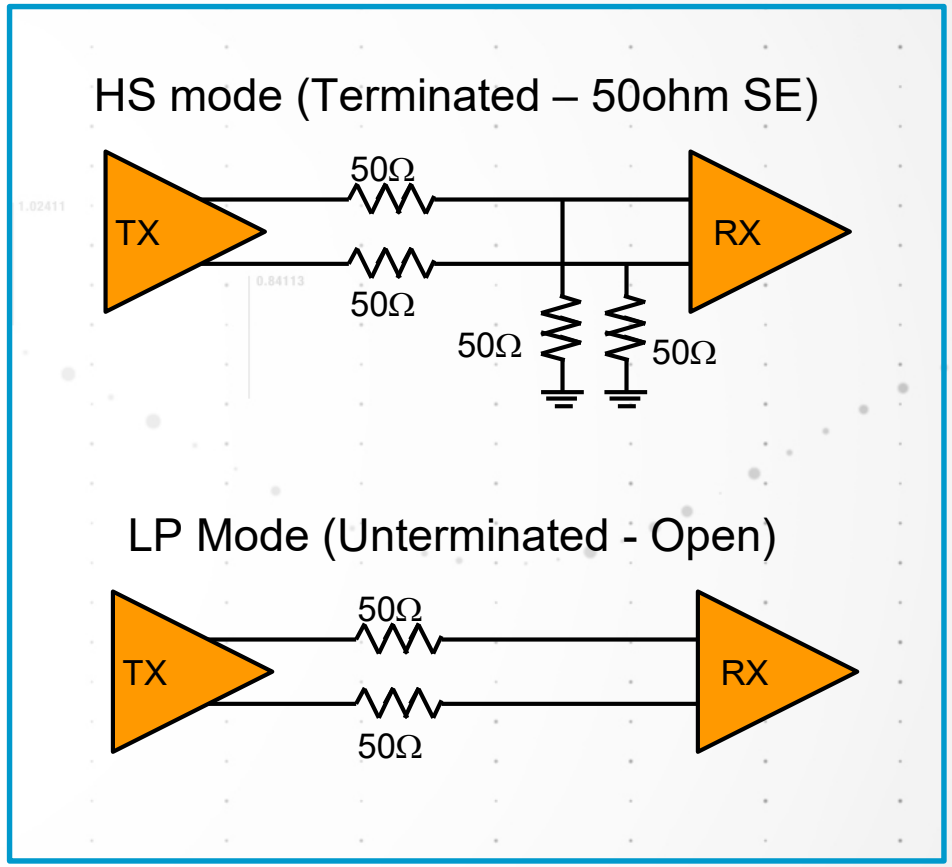
Measured with RCRC probe (N7003A)

Measured with RC probe (1169B)

Probe loading effect in measuring MIPI D-phy

For D-PHY HS mode, signals are terminated into 50-ohm single-ended to ground. For LP mode, the signals are unterminated or open to minimize current flow to save power.





Yellow = Keysight N2832A InfiniiMax III+ 13 GHz probe (RCRC)
Blue = Keysight 1169B InfiniiMax II 12 GHz probe (RC)

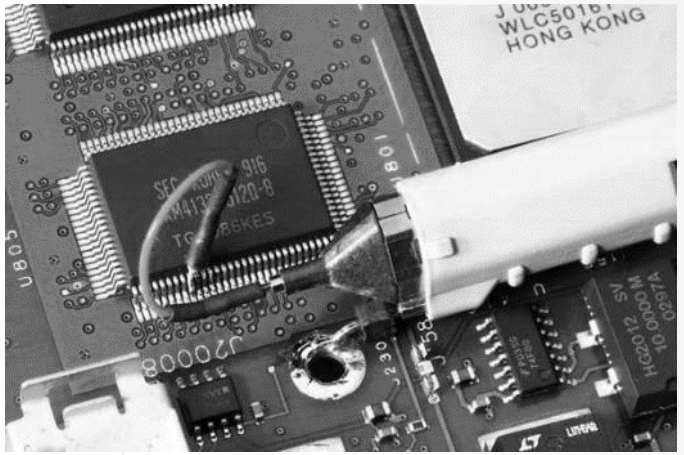
Summary – Probe loading

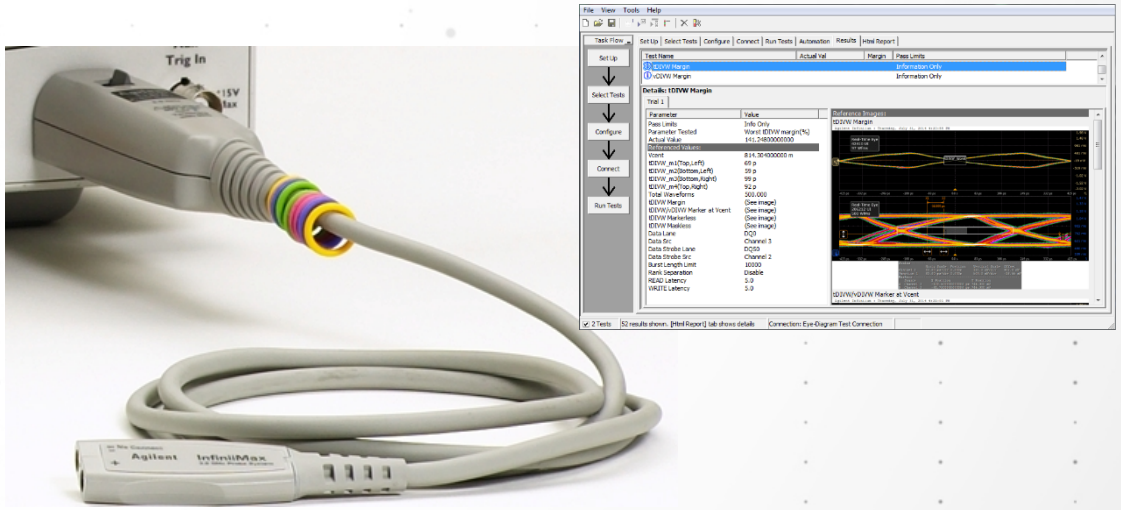
- Pay careful attention to capacitive loading as your system bandwidth gets higher.
- As the input capacitance gets lower, probe maintains higher impedance for wider frequency ranges.
- There are two types of loading characteristics for probes – RC vs RCRC profiles where RC probes being for more general purpose and RCRC probes for high BW, low impedance target.
- For InfiniiMax probes, probe input impedance is the function of probe head, not probe amp.
- Beware using the RCRC probe for the target with high input impedance or the source impedance switching between high and low values.

Probe Response Correction

Your probe… yesterday and today

- In the old days, the bandwidth and accuracy of the high-end probe relies on their inherent hardware response.
- It was typically enough for the performance levels needed at that time.
- However, as newer generation probes with higher bandwidth came along, the need for higher and more consistent accuracy has been growing to minimize the probe variation effect.



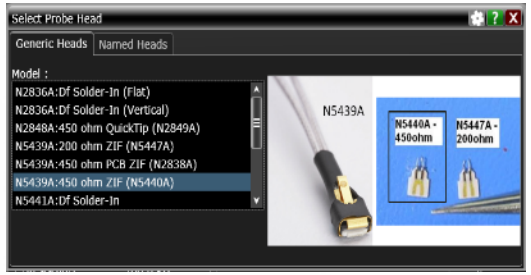


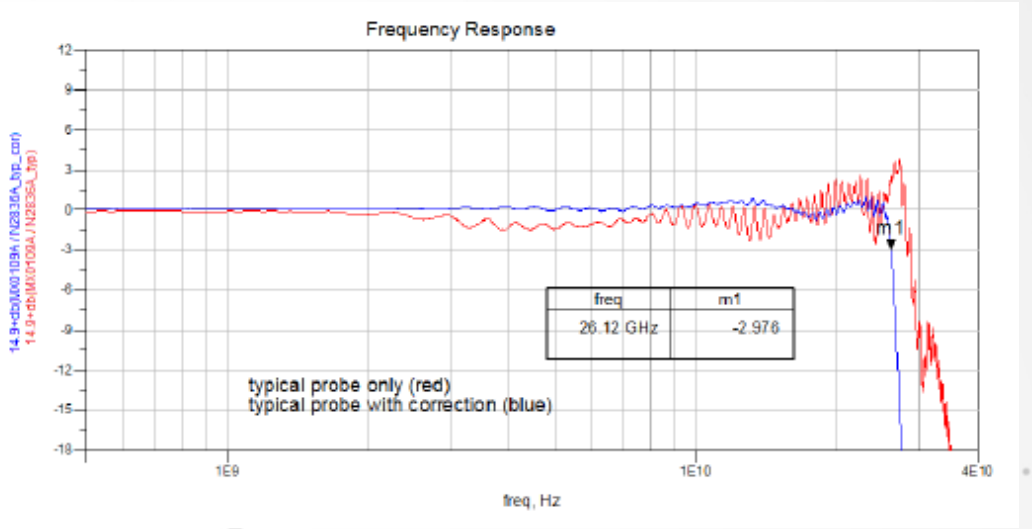
Enhanced probe response with DSP correction

- To address the need for better performance and increased accuracy, high performance probes started utilizing measured response of the probe system to DSP correct and enhance the hardware response.

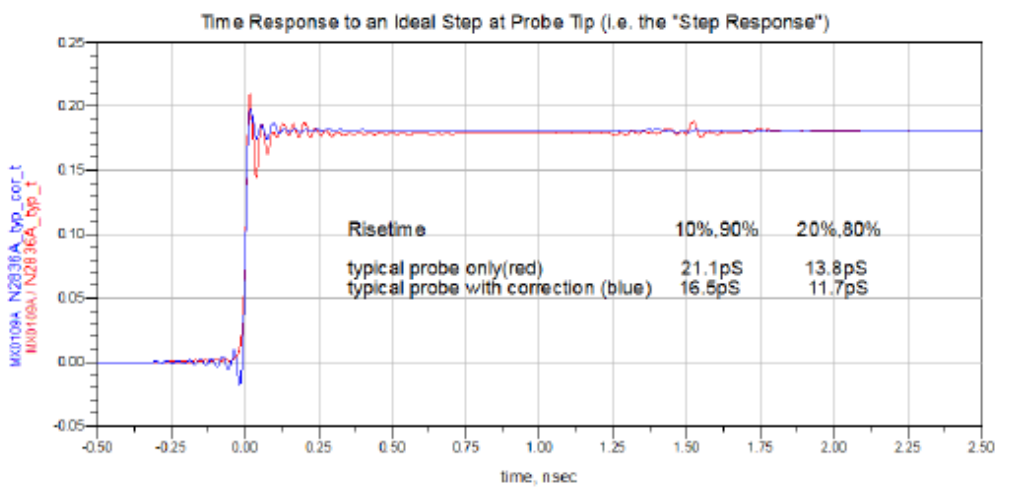
- Currently, Keysight InfiniiMax II, III and III+ probe systems use S parameter for correcting probe responses. No correction for InfiniiMax I.

- On the probe menu of the Infiniium software, you can choose the S parameter of a probe head in the probe head selection menu. It is combined with the S parameter of the probe amp to correct the response of the whole probe system.





Red = before correction
Blue = after correction



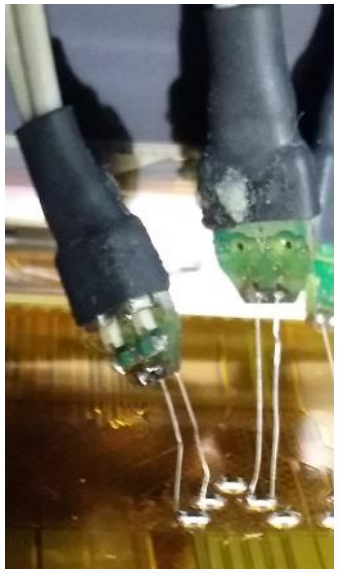
Important variation factor to keep in mind..

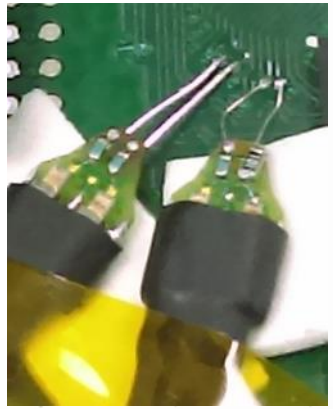
Keysight provides S parameter correction filters for all these components based on standard tip configuration.

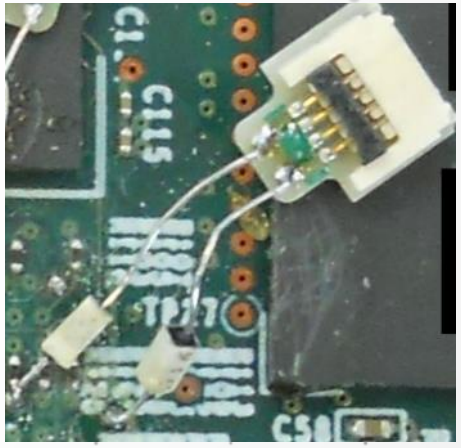
However, other factors such as the variation in probe tip configuration such as

- tip length,
- tip span,
- arrangement of wires,
- partial damage, and
- probe orientation to DUT

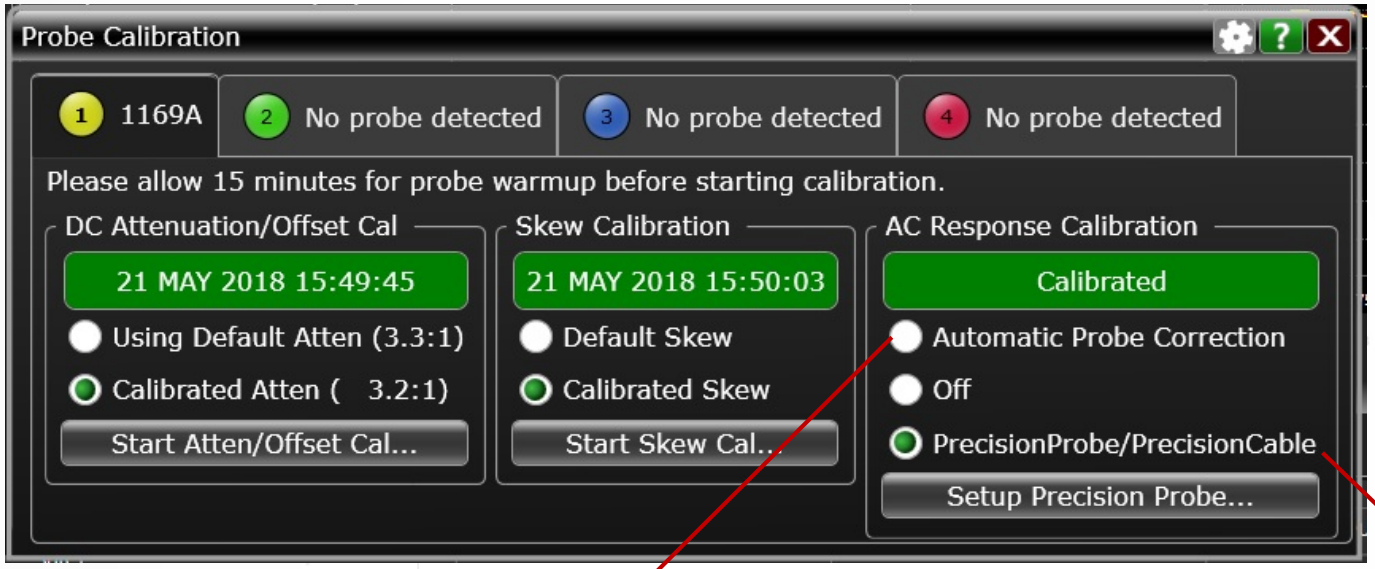
can still affect probe response.







AC response calibration options

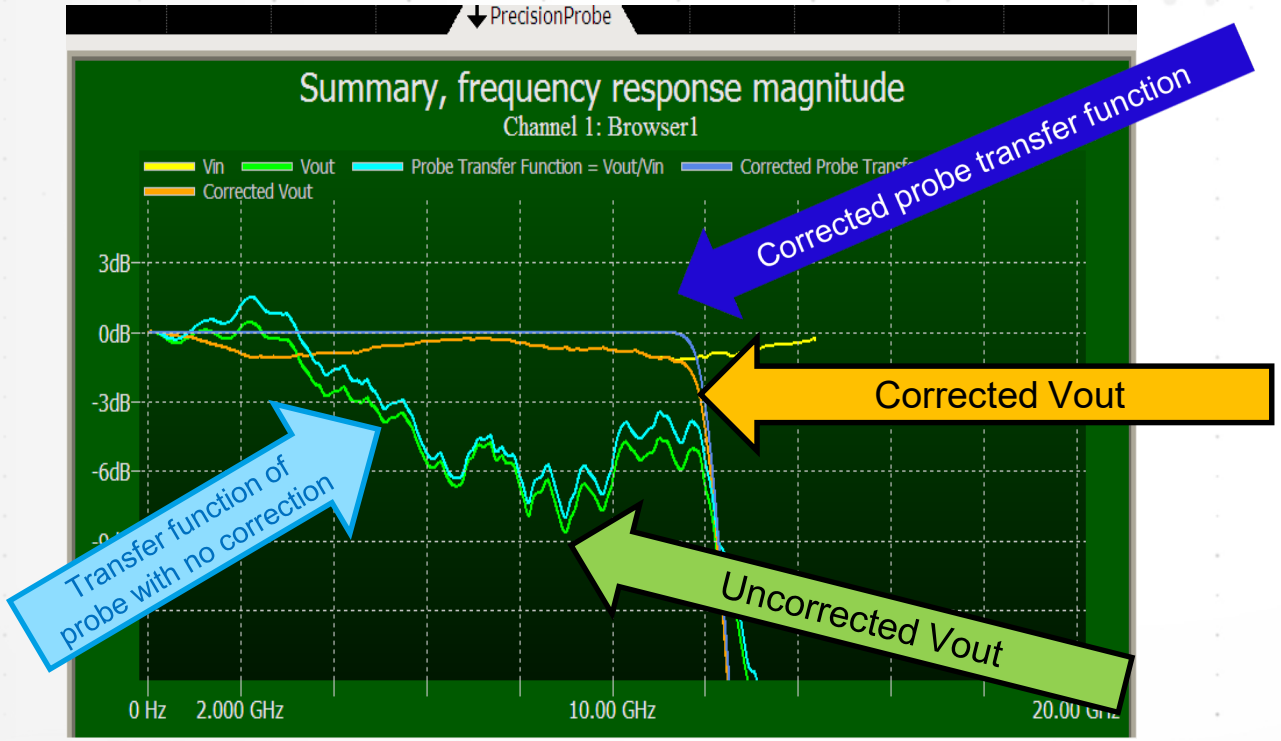


Automatic Probe Correction: uses factory generated S parameters for InfiniiMax probe amp and head. It is important to choose the right probe head and accessories in the probe head menu to get appropriate probe head correction.

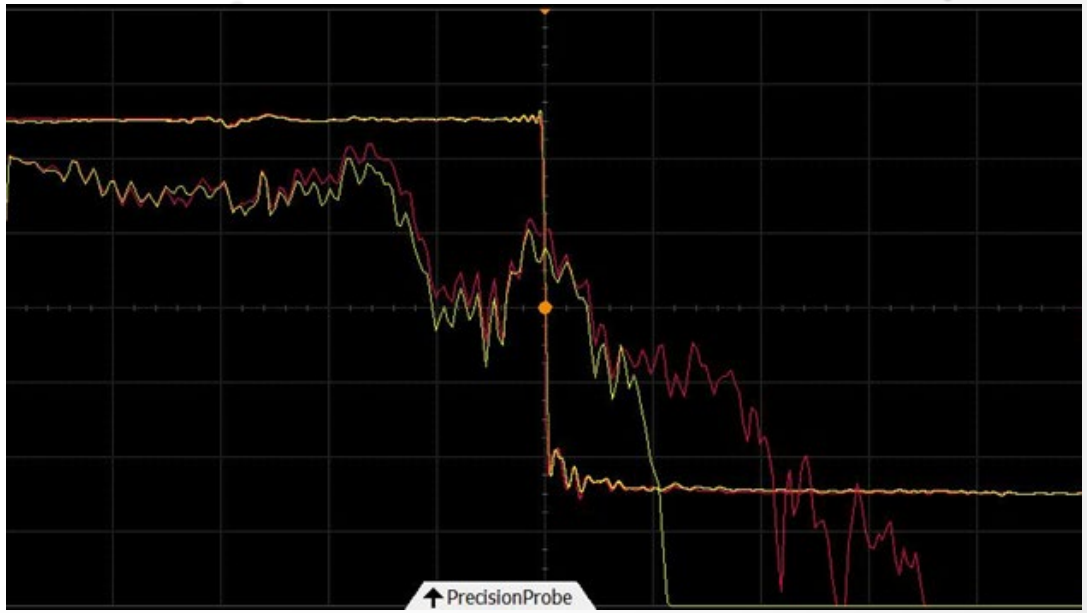
PrecisionProbe/PrecisionCable: uses the measured probe/cable response obtained from the PrecisionProbe cal. PP cal takes care of AC correction from the probe amp to the tip end.

Advanced probe correction method using PrecisionProbe

- The ideal way to ensure the best accuracy for a probe is to perform a calibration of its response ***in the configuration that it will be used*** before critical measurements are made.
- The PrecisionProbe application uses the fast calibration step signal and a high quality probe fixture with cables to accurately measure and correct for the response of any probe.

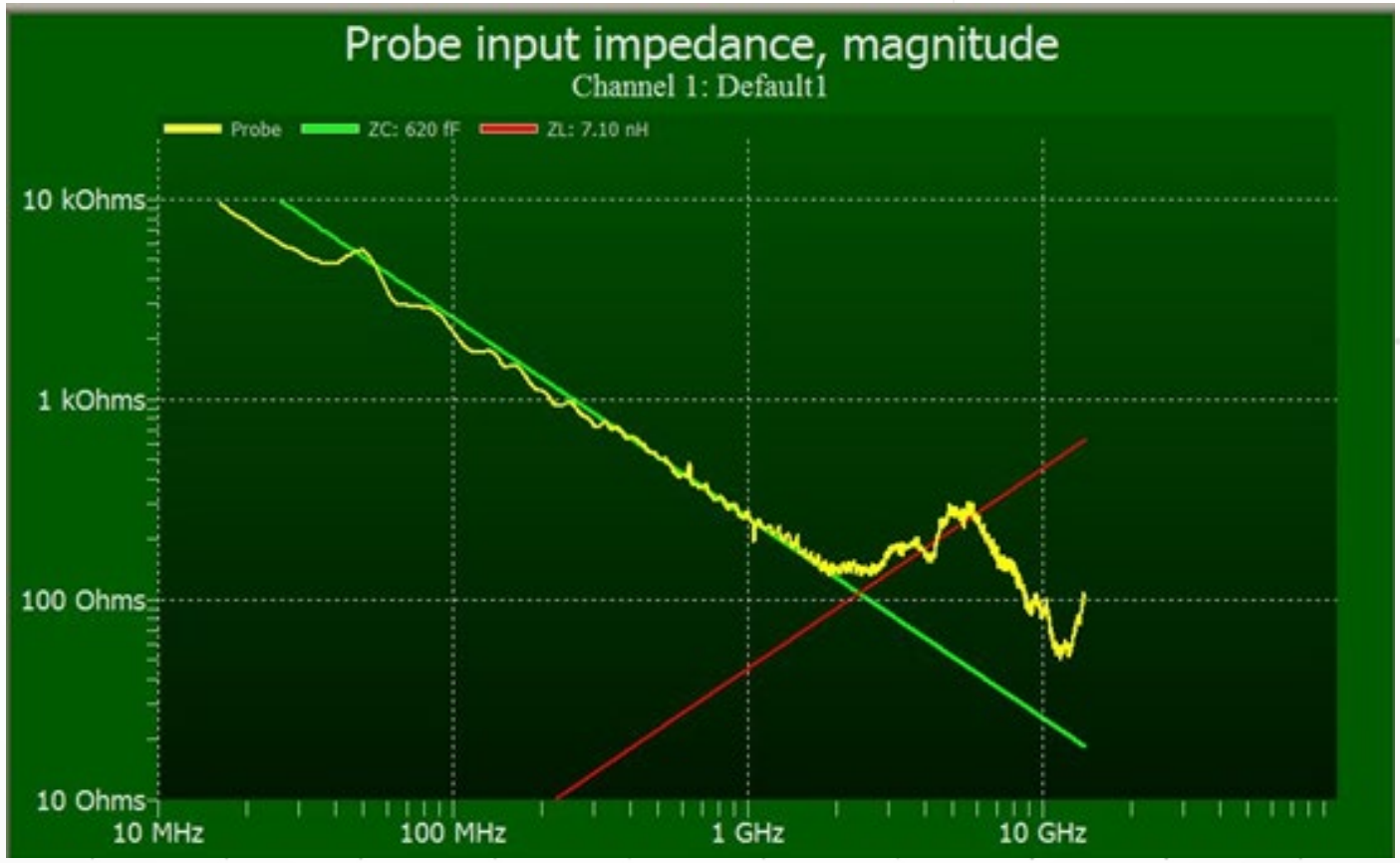


E2675B 6 GHz browser- Precision Probe corrected to 12 GHz without increasing noise excessively.



Capacitive and inductive loading plot

- Another very useful result furnished by the Precision Probe application is a plot of the measured input impedance of the probe and adjustable measurement lines to determine the **capacitive and inductive loading of the probe.**
- Note that the PrecisionProbe may be able to show you the signal the way you want, but probe loading is still there impacting the target signals. **Always!**

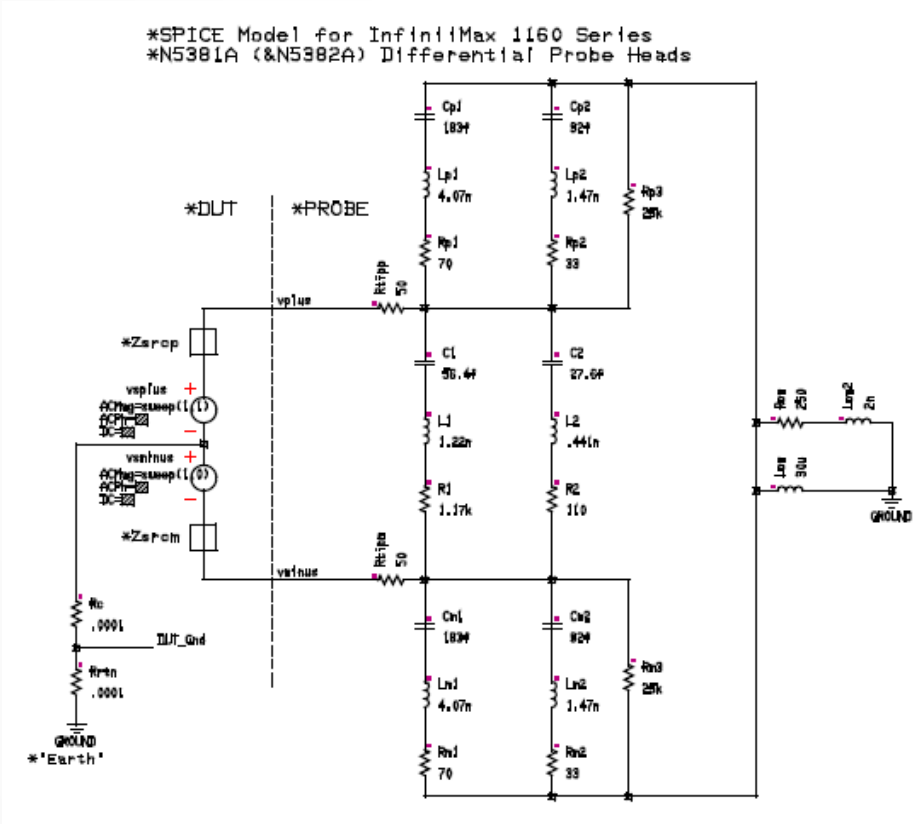


PrecisionProbe vs InfiniiSim

	PrecisionProbe	InfiniiSim
What it does	Characterize cable or probe quickly/easily and remove unwanted cable loss or probe loading with a scope	De-embedding and waveform transformation toolset providing means to render waveform anywhere in the system link
Use model	For simple characterization and correction without need of a VNA or a complex simulation SW	Very broad- Remove unwanted channel effect or insert channel effect, view waveforms in physically unprobable location, remove probe loading effect etc
When to use	For quick and easy Vout/Vin or Vout/Vsrc correction and probe input impedance measurement	When you have a s-parameter file or a measurement expertise and want full 4-port modeling
Limitation	* Only for S21 insertion loss removal of cable or probe • No return loss • Limited bandwidth boost due to elevated noise floor	• Takes extra equipment (VNA, TDR) • Takes effort and time

Spice models for probe loading effect simulations

- Spice models for all InfiniiMax probe heads/amps are supplied in the InfiniiMax user's manuals.
- Only ***input impedance models*** are supplied for modeling probe loading
- Cut/paste the spice deck into a regular txt file and import into programs like Pspice.



SPICE Deck

```
C2   %44 %40   27.6f
Cm2   %41 %38   92f
Cp2   %43 %36   92f
Cp1   %43 %34   183f
Cm1   %41 %31   183f
C1   %44 %28   56.4f
vsminus   %16 %vminus ACMag=sweep(1,0)
vsplus   %vplus %16 ACMag=sweep(1,1)
Lom2   %47 %0   2n
Lom   %43 %0   30u
L2   %40 %39   .441n
Lm2   %38 %37   1.47n
Lp2   %36 %35   1.47n
Lp1   %34 %33   4.07n
Lm1   %31 %30   4.07n
L1   %28 %32   1.22n
Rm3   %41 %43   25k
Rp3   %43 %44   25k
Rom   %43 %47   250
R2   %39 %41   110
Rm2   %37 %43   33
Rp2   %35 %44   33
Rp1   %33 %44   70
Rm1   %30 %43   70
R1   %32 %41   1.17k
Rtipm   %vminus %41   50
Rtipp   %vplus %44   50
Rrtn   %15 %0   .0001
```

Summary – Probe response correction

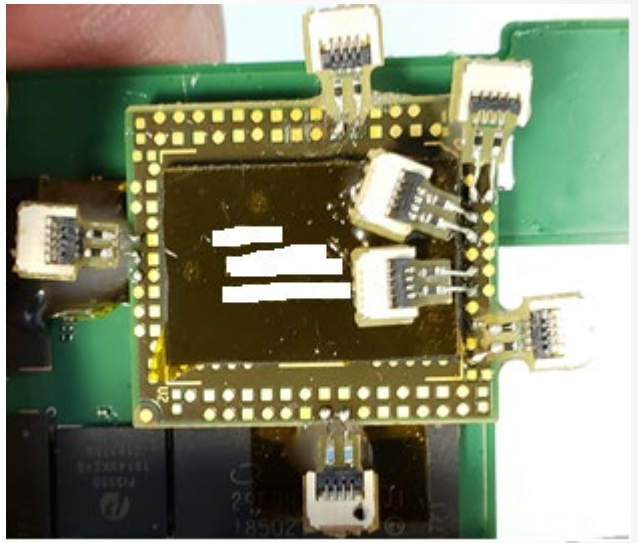
- Keysight provides S parameter correction filters for InfiniiMax probe amps and heads based on standard tip configuration.
- Other factors such as the variation in probe tip configuration can still affect the probe response.
- PrecisionProbe application accurately measures and corrects for the response of any probe in the configuration it will be used.
- PrecisionProbe may be able to show you the signal the way you want, but probe loading is still there impacting the target signals. Always!

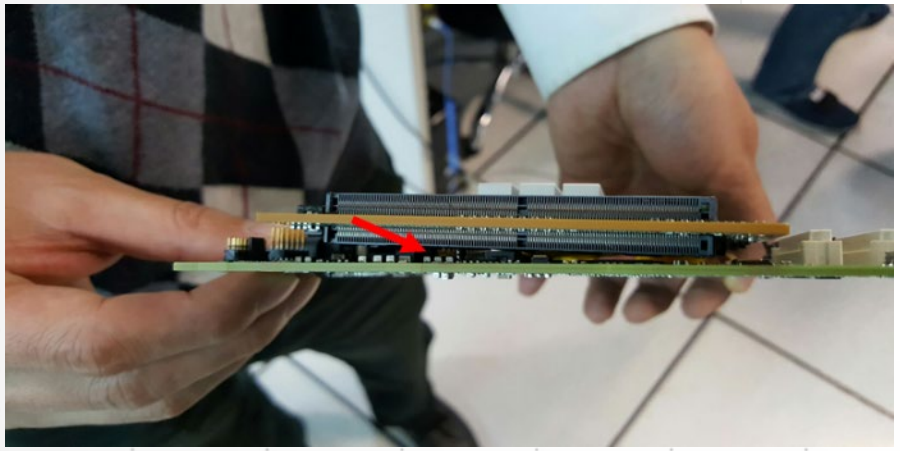
Probing in Extreme Conditions

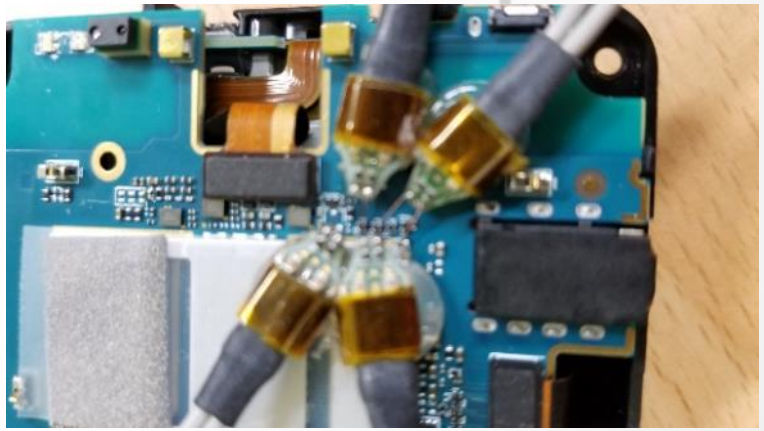
Small Geometry Probing – Key Drivers

Target devices (connection pads, SMD, vias, interposers etc.) are ever getting

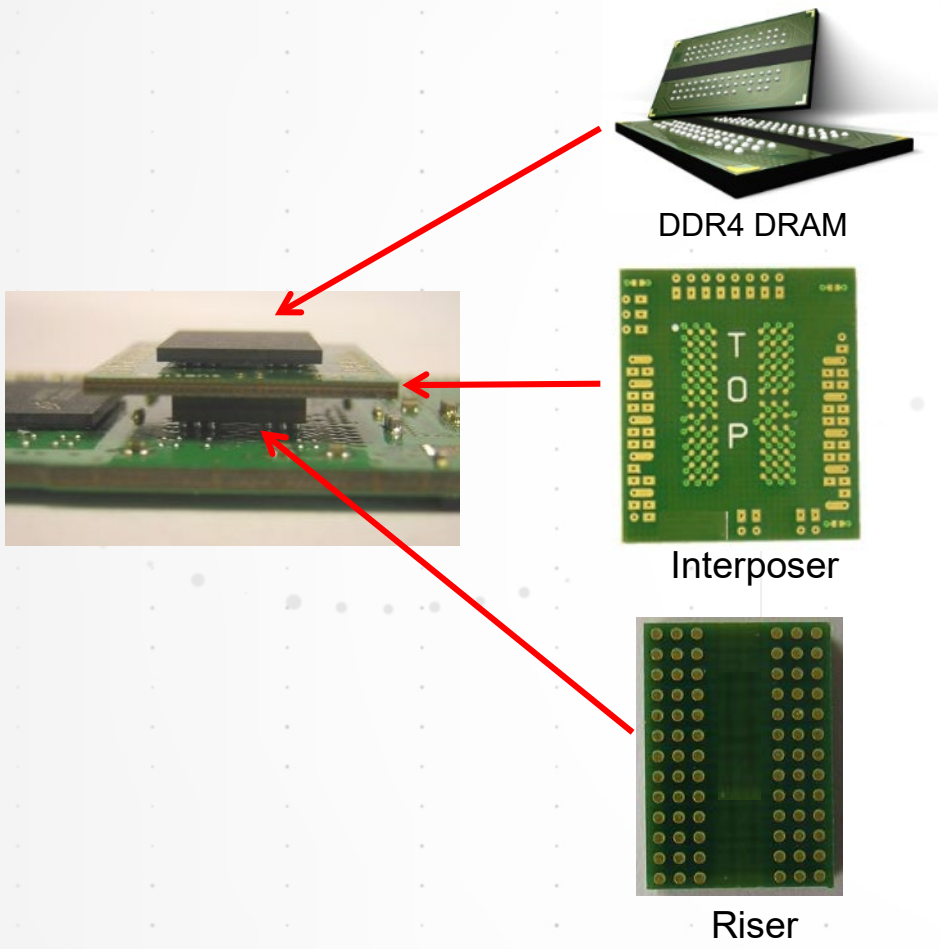
- Smaller
- Denser with lots of signal to look at in tight space
- More challenging with narrow spacing between PCAs

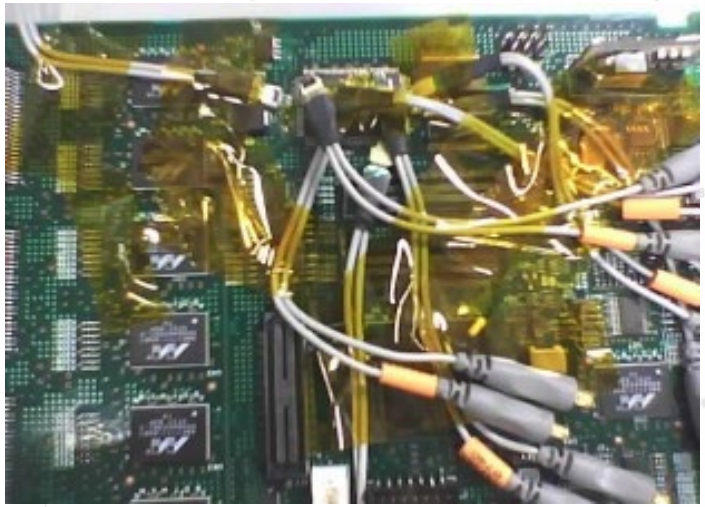


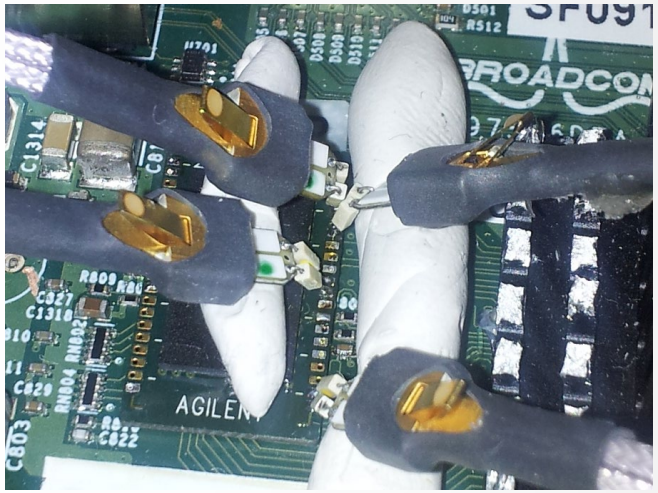




Small Geometry Probing Challenges







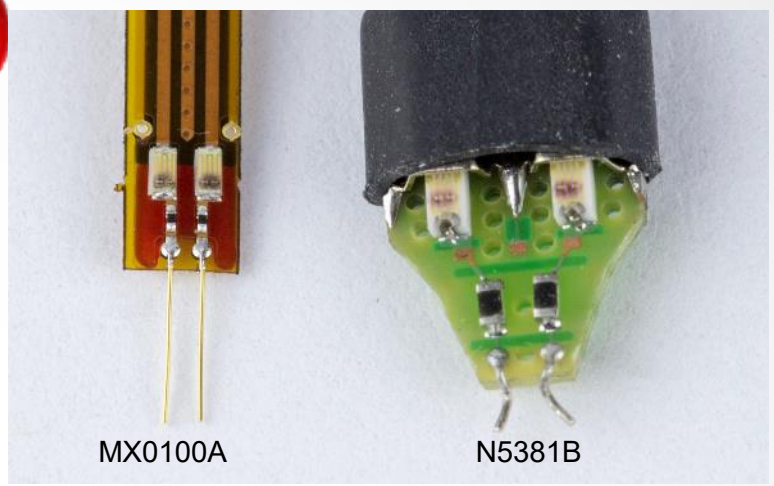
- DDR memory probing – lots of signals to look at in very tight space!
- DUT size gets smaller and smaller, resulting in smaller pads and narrower pitch spacing that make probing job ever more challenging.

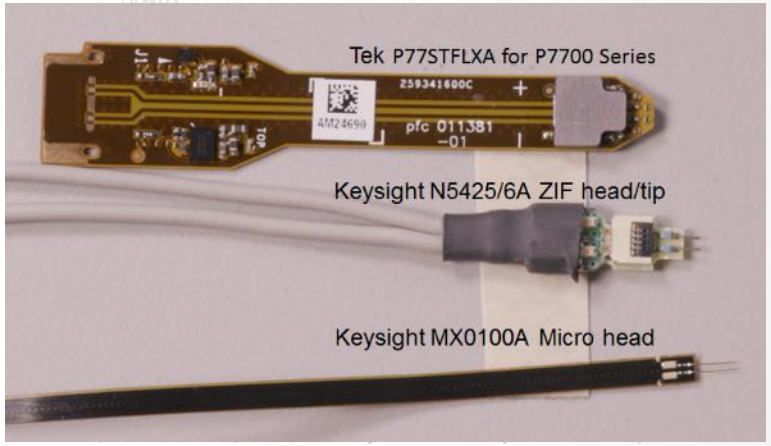
New MX0100A micro probe head

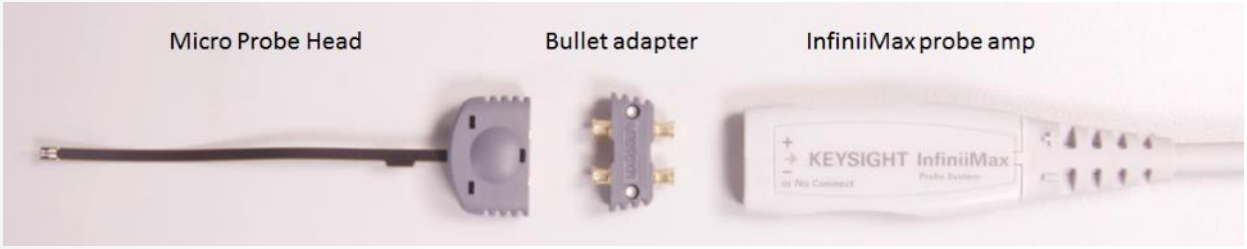
NEW

Uncompromised access to your fine pitch devices

- < Half the size of existing solder-in probe heads
- **Small, flat and flexible** (using flex printed circuit)
- Full probe amp bandwidth (>12GHz with 1169B)
- **Excellent probe loading (0.17 pF)**
- Compatible with "RC" probe amps (InfiniiMax I/II and next generation RC probes)
- **Reusable**
- **Wider operating temp range : -55 to +150 degC**
  (per JEDEC JESD22-A104 revision E spec)
- Half the price of existing solder-in heads







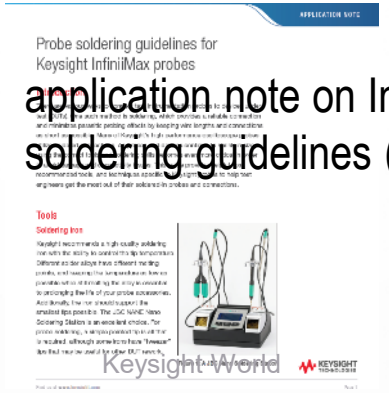
New MX0100A micro probe head – how to use

The life span of the head is highly dependent on how you use it!

- Microscope is a MUST have tool.

- Highly recommend **low temp solder** such as SAC (Tin-Silver-Copper with 220 degC melting point), or tin-bismuth with 138 degC melting point with the temperature-controlled **solder iron with the tip temp set as low as possible**.

- Use a small solder tip (<1mm tip).
- Don't apply heat on the probe lead for long time. Use <2 sec of dwell time on the joint.



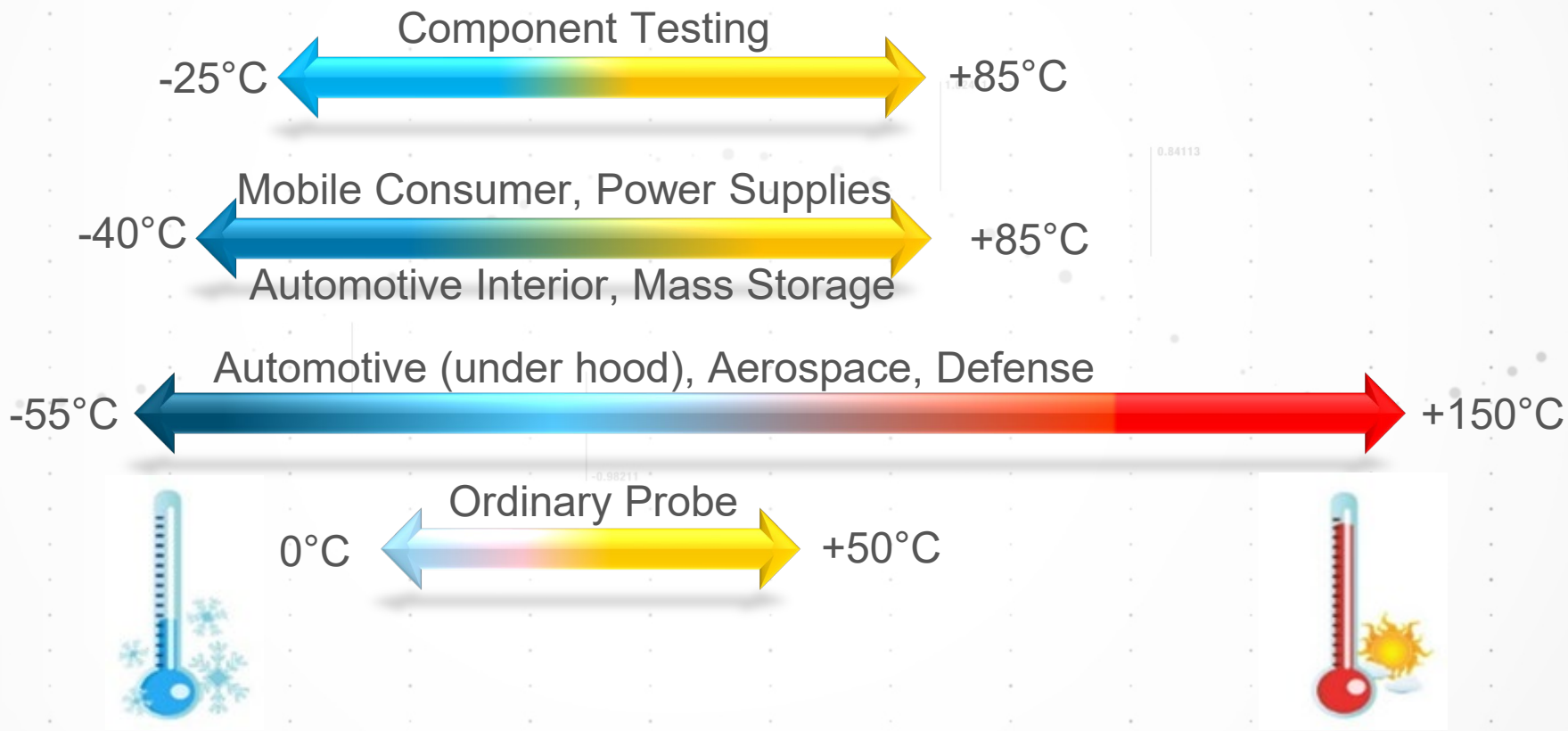
application note on InfiniiMax probe soldering guidelines (5992-3350EN)

- Strain relieve the head and amp if possible. Use Kepton tape, putty, low temp glue etc.

- Apply flux at the DUT and solder head tip for easier solder flow.

Oscilloscope Probing in Extreme Temperature

Temperature test ranges and applications



Extended Temperature Probing with InfiniiMax Probes, as wide as -55 to +155 degC

MX0100A : 12 GHz Micro Solder-in Probe Head (RC)

- < Half the size of existing solder-in probe heads
- Small, flat and flexible (using flex printed circuit)
- Compatible with any InfiniiMax I/II RC probe amps
- Operating temp range: -55 - +150°C

MX0109A : 26 GHz Solder-in Probe Head

- 26 GHz bandwidth
- Same performance as N2836A
- Compatible with InfiniiMax III/III+ RCRC probe amps
- Operating temp range: -55 - +150°C

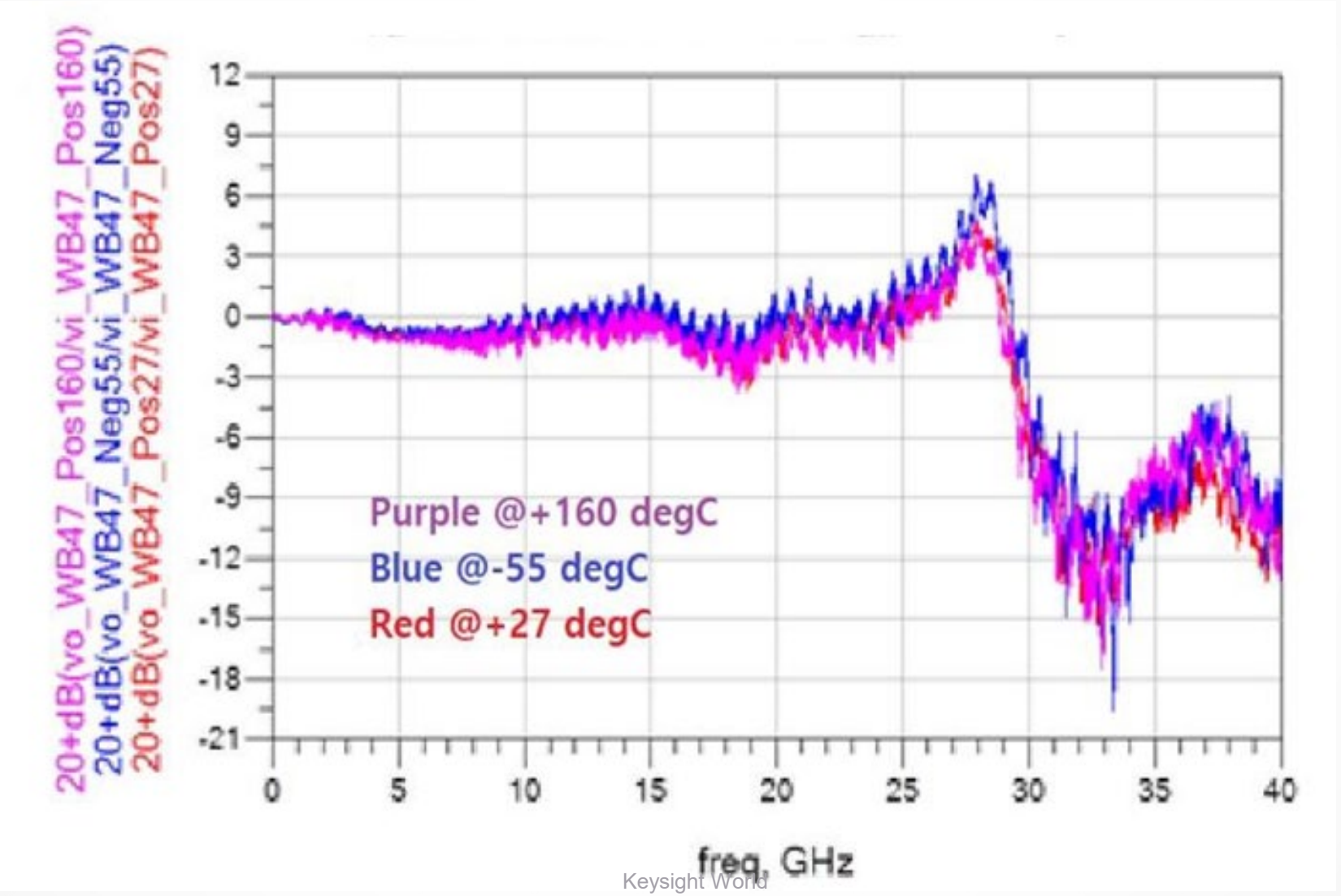
New probe heads are designed to withstand

- -55°C dwell, >1000 hours
- +150°C dwell, >1000 hours
- -55 °C to 150 °C cycles, 1000 cycles minimum per JEDEC JESD22-A104 revision E

N5450B extreme temperature extension cable

MX0109A frequency response variations over temp

Vout/Vin variation over +160 to -55 degC temperature is fairly small



InfiniiMax probe heads – operating temperature ranges

Probe head	Description	Max bandwidth	Temp range	Allowed Test cycles
MX0109A	InfiniiMax III Solder-in head	26 GHz	-55 to +150 degC	750+
N2836A	InfiniiMax III Solder-in head	26 GHz	-40 to +85 degC	1000+
MX0100A	InfiniiMax II Solder-in head	12 GHz	-50 to +150 degC	1000+
N5381B	InfiniiMax II Solder-in head	12 GHz	-40 to +85 degC	1000+
N5425B + N5426A	InfiniiMax II ZIF head/tip	12 GHz	-40 to +85 degC	500+
E2677B	InfiniiMax I Solder-in head	12 GHz	-25 to +85 degC	
E2678B	InfiniiMax I Socketed head	12 GHz	-25 to +85 degC	

Keysight's Extreme Temperature Probing Solution

N7007A
Single-ended Passive
400 MHz
10MΩ input R
2 m long cable
-40 to +85 °C

N7013A
Probing kit for differential probe
70 MHz
Compatible with N2790A, N2791A, N2792A, and N2818A
70 cm long cable
-40 to +85 °C

N2797A
Single-ended Active
1.5 GHz
1MΩ input R
2 m long cable
-40 to +85 °C

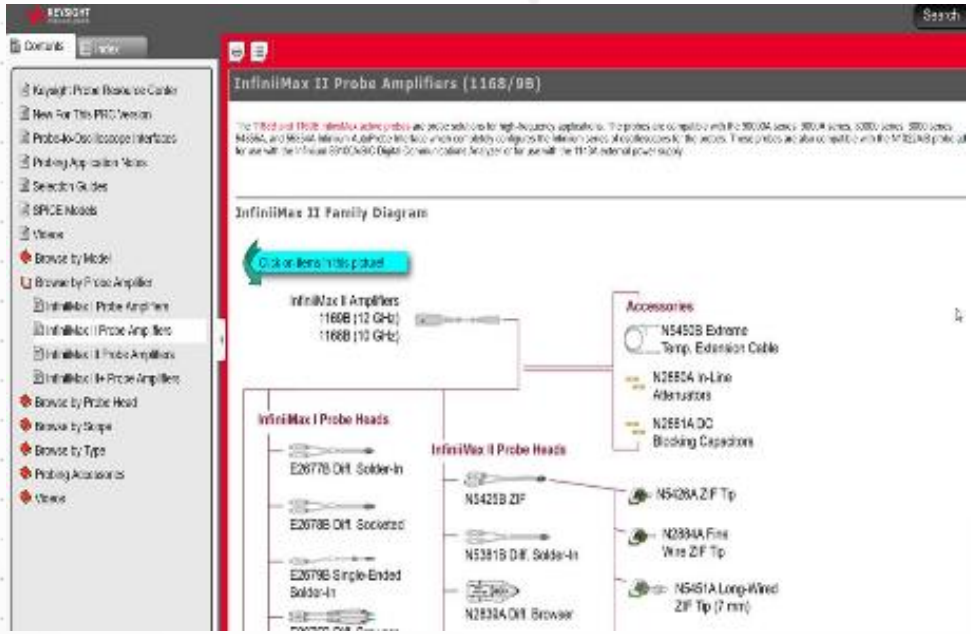
InfiniiMax + N5450B extension cable + probe head
Differential & SE Active
1.5 GHz – 26 GHz
50 kΩ input R
-55 to +150 °C

N2820A/21A High-sensitivity current probe
Current
3 MHz
1.5 GΩ input R
-55 to +150 °C

Keysight offers the broadest selection of extreme-temperature oscilloscope probing solutions. www.keysight.com/find/extreme

Probe Resource Center (PRC) available on a new HTML platform

- Probe Resource Center (PRC) has been a free Adobe AIR-based application that contains Keysight scope probe information and allows customers to efficiently browse or search for probing information in one easy-to-access location.
- Updated to a new web based HTML5 format which is suitable for Windows, Mac, Android, or iOS devices and can also be downloaded for offline references.



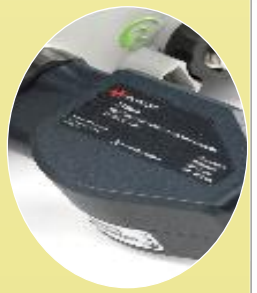
http://prc.keysight.com

Keysight Oscilloscope Probes and Accessories

Wide selections from 50 MHz to 33 GHz

InfiniiMax Diff/SE probe

- Up to 30 GHz
- Probe amp/ head topology
- Variety of connections – browser, solder-in, socketed, SMA, ZIF tip, QuickTip
- S parameter correction
- 1130B-34B, 1168/69B, N2800A-03A, N2830A-32A, N7000A-03A

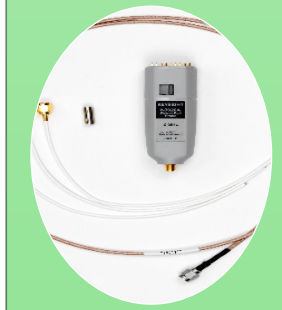


Optical

* 33 GHz O/E converter for covering up to 28 Gbps optical signal
* Optical measurement software built into Infiniium
* For reference receiver testing or characterizing raw response of an optical transmitter
* N7004A

InfiniiMode Diff/SE/CM probe

- 1.5-6GHz
- Making diff, SE and CM measurement with a single probe
- Multi-function scope control
- Includes solder-in, browser and socketed tips
- N2750A/51A/52A

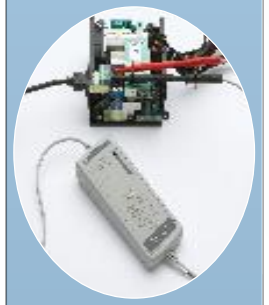


Power rail

* Up to 6 GHz
* For making power integrity measurement
* Low noise
* Large offset range
* Low DC loading
* N7020A/**24A**

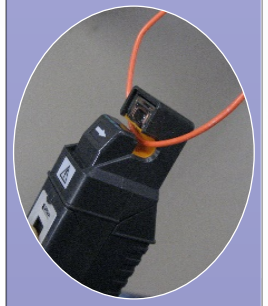
Single-ended Active

- Up to 2 GHz
- High Input R & low C for low loading
- For high speed , ground referenced signal measurement
- N2795/96/97A



High-voltage Differential

- Up to 800 MHz
- Up to 7 kV
- Ideal for power measurement
- High common mode rejection
- N2790A-93A, N2891A, N2818A/19A, N2804A/05A



AC/DC Current Probes

- DC to 100MHz
- Clamp-on or high sensitivity
- 50uA to 500A
- 1146B, 1147B, N2780-83B, N2893A, N2820A/21A, **N7026A, N7040A/41A/42A**

Passive

- Low cost, rugged design
- Variety of accessories
- Up to 6 GHz
- N2870-76A, 1007x, N2862B/63B/89A/90A,54006A, 10076C, N7007A+13A
- **N2140A/42A**

Accessories

InfiniiMax probe heads + **accessories**

- Compliance test fixtures (**type C**)
- TekProbe ® adapter
- BGA probe adapters
- Probe positioners
- Wedge adpters

www.keysight.com/find/probes


KEYSIGHT
WORLD 2019

Competition & E-Survey

Want to be the owner of a Galaxy Tab A (10.1”) With S Pen

Take part in our Keysight World Survey.
Many more fantastic prizes waiting to be won.

E-Survey

Steps to win:
1) Go to https://www.surveymonkey.com/r/KW2019BKK or scan the below QR code:

2) Complete the survey form.
3) Answer 3 simple quiz questions.
4) Submit.

*Winners will be determined via a draw by end of the day.
To qualify for the draw, contestants need to provide at least one correct answer from the Quiz found in the Survey Form.

Outsmart your competitors and walk away with a *JBL T450BT Headset.*

We have 3 sets waiting to be won during the Kahoot session at the end of the day.

Kahoot | Pick and Win

Steps to win:
1) Go to www.kahoot.it or scan the below QR code

2) Key in the Game PIN shown on the projection screen.
3) Once game starts, questions will pop up on the projection screen with multiple choice answers.
4) Answer via your mobile phone by choosing the corresponding colour/shape on the projection screen.
5) At the end of the game, the top 3 winners’ names will be flashed on the screen.

*Winners will be determined via speed and accuracy of the answers given.