

The logo for Samtec, featuring the word "samtec" in a bold, lowercase, sans-serif font. The letters are white with a thick orange outline. The logo is positioned on the left side of the slide, separated from the other logo by a vertical line.

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The logo for gEEK® spEEK, featuring the word "gEEK" in a lowercase, sans-serif font with "g" in white and "EEK" in orange, followed by "spEEK" in a lowercase, sans-serif font with "sp" in white and "EEK" in blue. The logo is positioned on the right side of the slide, separated from the other logo by a vertical line.

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# 3 Tips to Reduce Cable-Braid Loop Error in Low-Impedance PDN Measurements

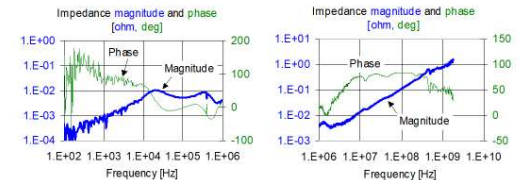
Istvan Novak | Samtec, Inc.

# Power Integrity, the Big Picture

- Paradigm Shift #1: late 1990s
  - Frequency domain design and verification became common
  - Increased power >> requirements to measure milliohms
  - Horizontal incremental impedance was relatively small
  - 3D interactions in PI measurements were small
  - **Solution: VNA with Two-port Shunt-through connection**
  - Frequency and time-domain verifications lined up
  
- Paradigm Shift #2: early 2020s
  - Requirements to measure microohms
  - 3D interactions in PI measurements become dominant
  - Horizontal incremental impedance becomes relatively high
  - Increasing gap between frequency and time-domain verification results (and mostly NOT because of nonlinearity)
  - **Solution: ???**

“3 Design Tips for Power Distribution Networks,” EDICON Online, October 4, 2023 and “Is Power Integrity the New Black Magic?,” Cadence Design Forum, April 2021  
 Cadence Live Boston, September 12, 2023, and “3D Connection Artifacts in PDN Measurements,” DesignCon 2023

## Measuring a Full PDN

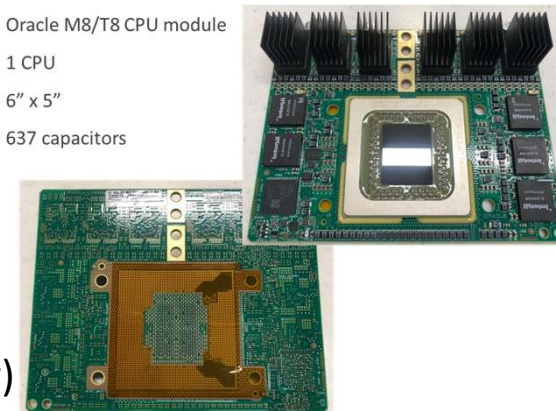


June 23, 2003

DesignCon East 2003 HP-TF1

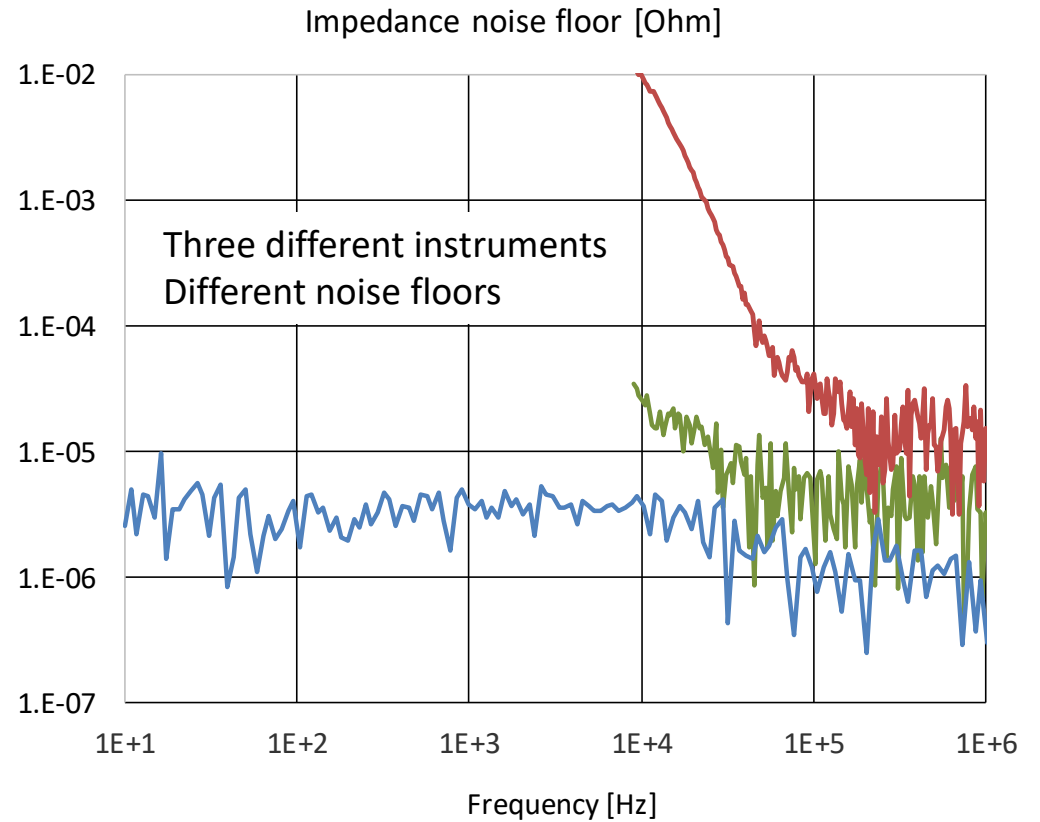
Istvan Novak 26

- Oracle M8/T8 CPU module
- 1 CPU
- 6" x 5"
- 637 capacitors



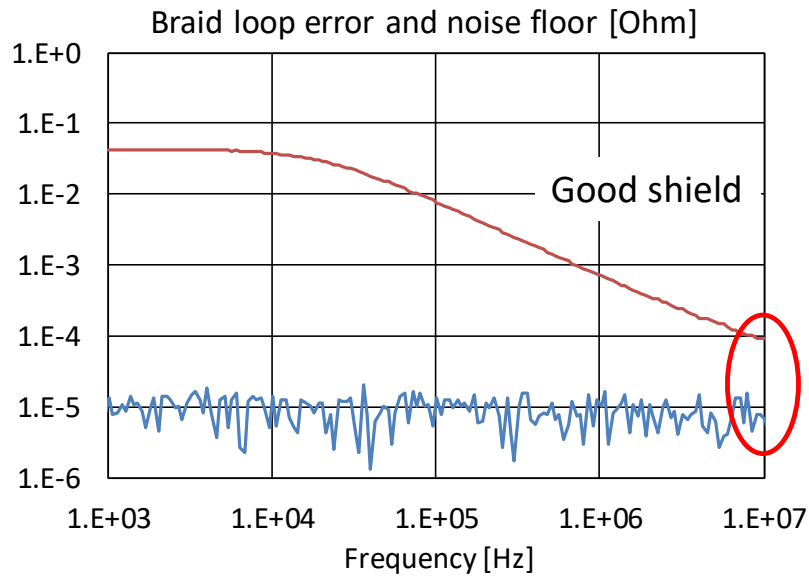
# Very Low Impedances; Be Aware

- Instrument trace noise may be the limit
- Always check before start measuring

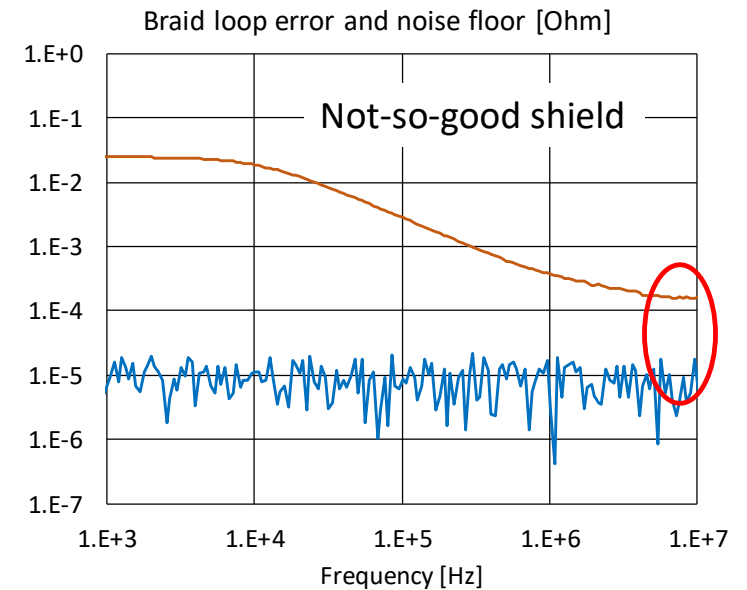
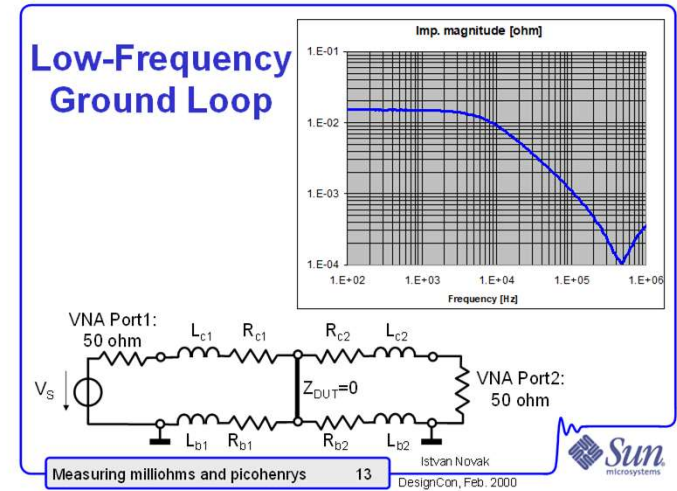


# The Cable Braid Error

- Braid loop error
- Shield leakage error



“Measuring Milliohms and Picohenrys,” DesignCon 2000  
 “How the Braid Impedance of Instrumentation Cables Impact PI and SI Measurements,” DesignCon 2019





The logo for Samtec, featuring the word "samtec" in a stylized, lowercase font with a white horizontal bar above the letters "a" and "t".

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## The Cable Braid Loop Error

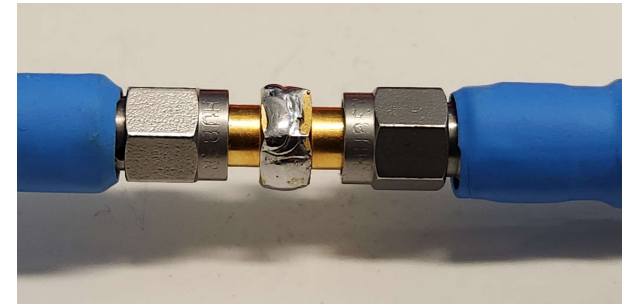
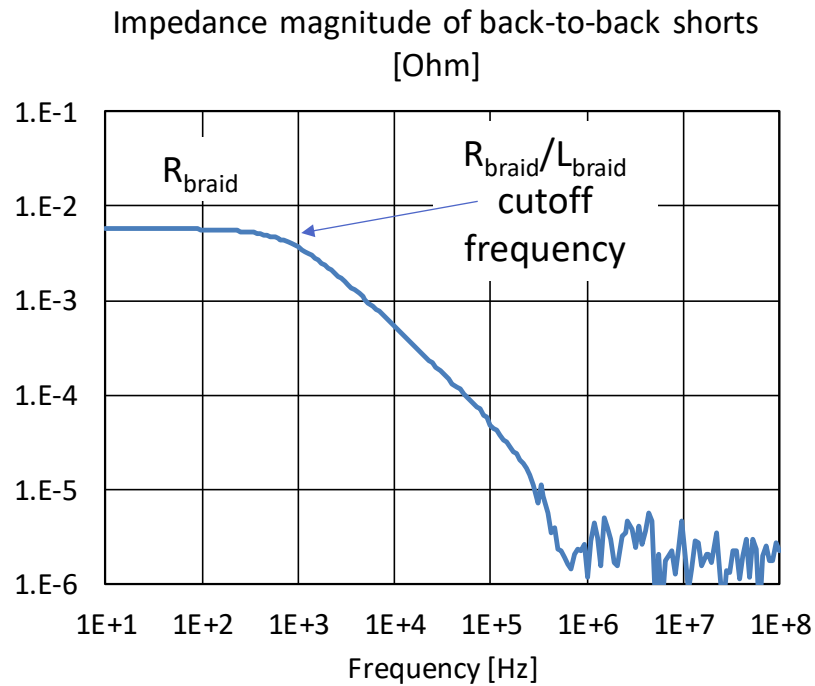
Can we calibrate it out? **NO**

- The cable braid error is caused by the return-path resistance
- Flexible coax braid resistance may change with flexing
- Connector shell contact resistance may change with re-torquing
- In general, it is not a good idea to try to calibrate out an error that is 40...60dB higher than the measured value

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## Tip 1: Reducing Cable Braid Error with Common-Mode Transformer



Goal: lower the braid cutoff frequency by increasing inductance more than resistance.

*Use common-mode transformer.*

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# Tip 1: Reducing Cable Braid Error with Common-Mode Transformer

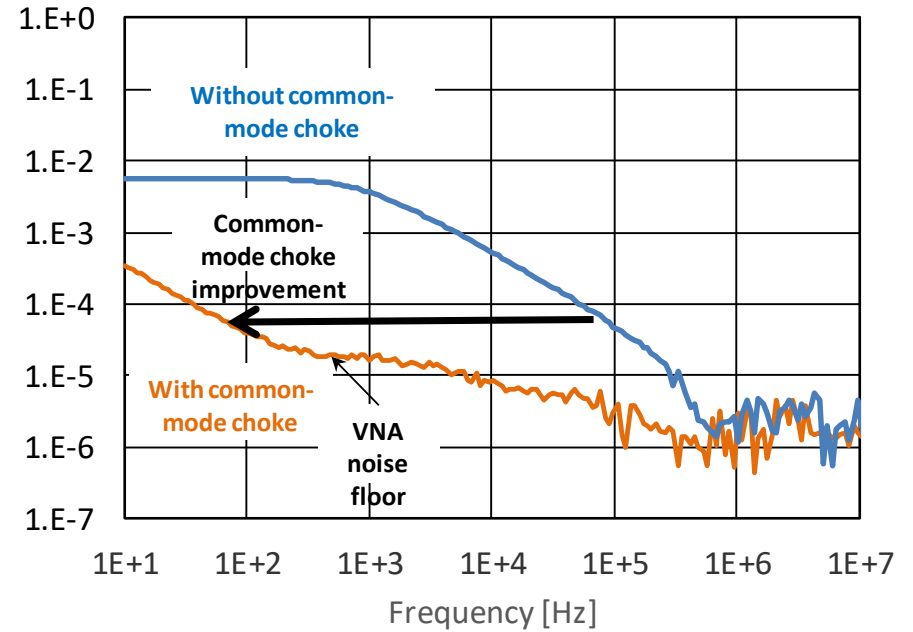


Picotest J2102B common-mode transformer



Home-made common-mode transformer

Impedance magnitude of back-to-back shorts [Ohm]



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## Tip 1: Reducing Cable Braid Error with Common-Mode Transformer

The good news: full two-port calibration still can be used

Be aware:

- DC (current) bias may alter the inductance of the common-mode transformer
  - Measuring passive components (capacitors) with DC bias
  - Measuring active DUT
- AC (current) bias may alter the inductance of the common-mode transformer
  - Measuring DUTs with high source power

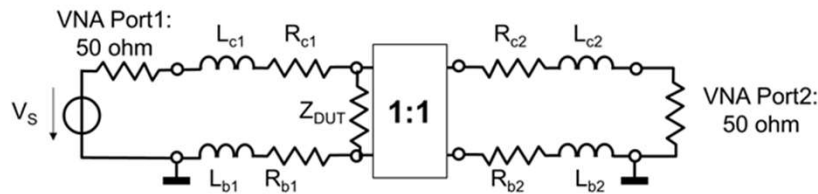


## Tip 2: Reducing Cable Braid Error with Amplifier

### Eliminating Ground Loop

Transformer

Differential amplifier



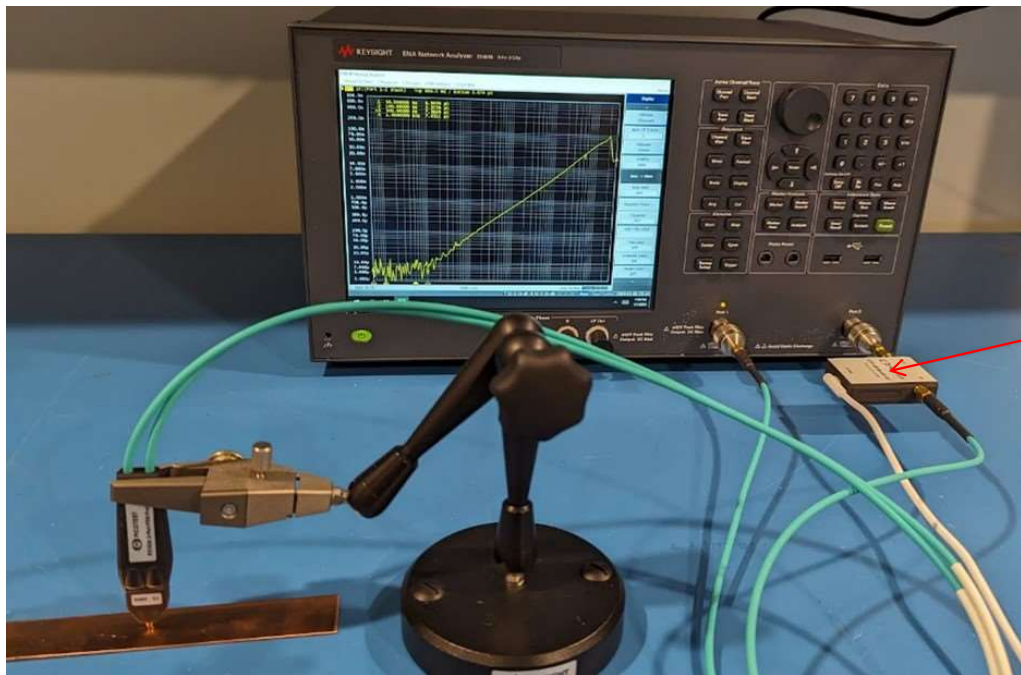
The ground loop can be opened up by

- Differentially sensing or transmitting the DUT voltage, or
- Boosting the test current at the DUT

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## Tip 2: Reducing Cable Braid Error with Amplifier



The large common-mode rejection ratio of the Picotest J2114A Prototype Isolator eliminates the DC potential lift

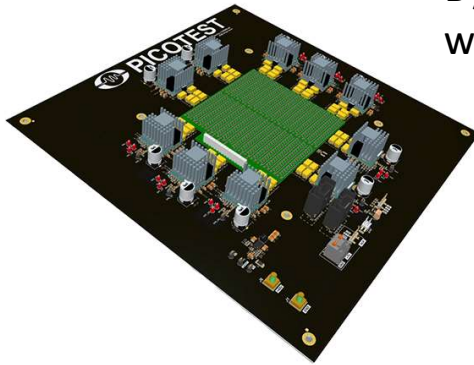
Figure 5 from "Extreme Measurements, Part 3," SignalIntegrity Journal, April 2024

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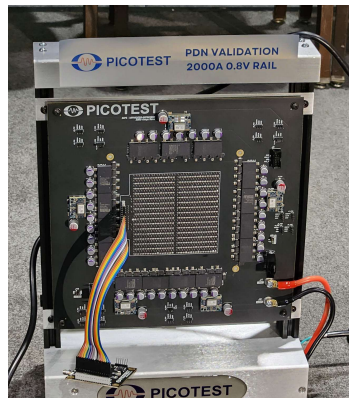
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## Tip 2: Reducing Cable Braid Error with Amplifier

By boosting the test current locally at the DUT, we can minimize the drive current

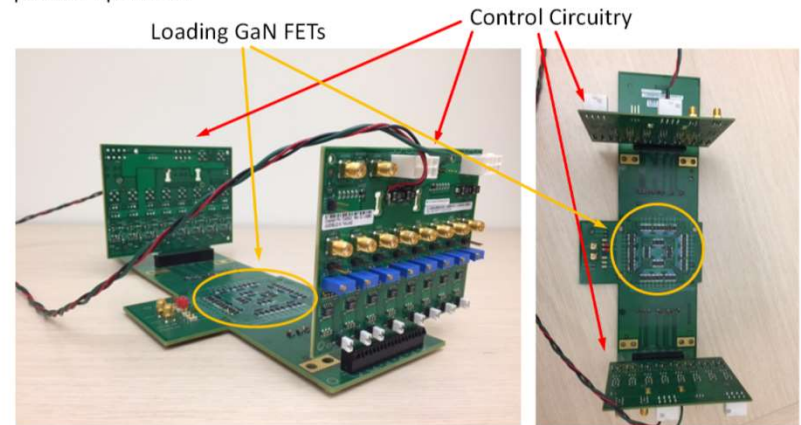


Load stepper visual from [https://www.picotest.com/products\\_transient-load-steppers.html](https://www.picotest.com/products_transient-load-steppers.html)



### TLT Full PCB Implementation

- Side and top views of 16 TLT circuits implemented in CPU BGA plug-in PCB for parallel operation



SEPTEMBER 11-13, 2017

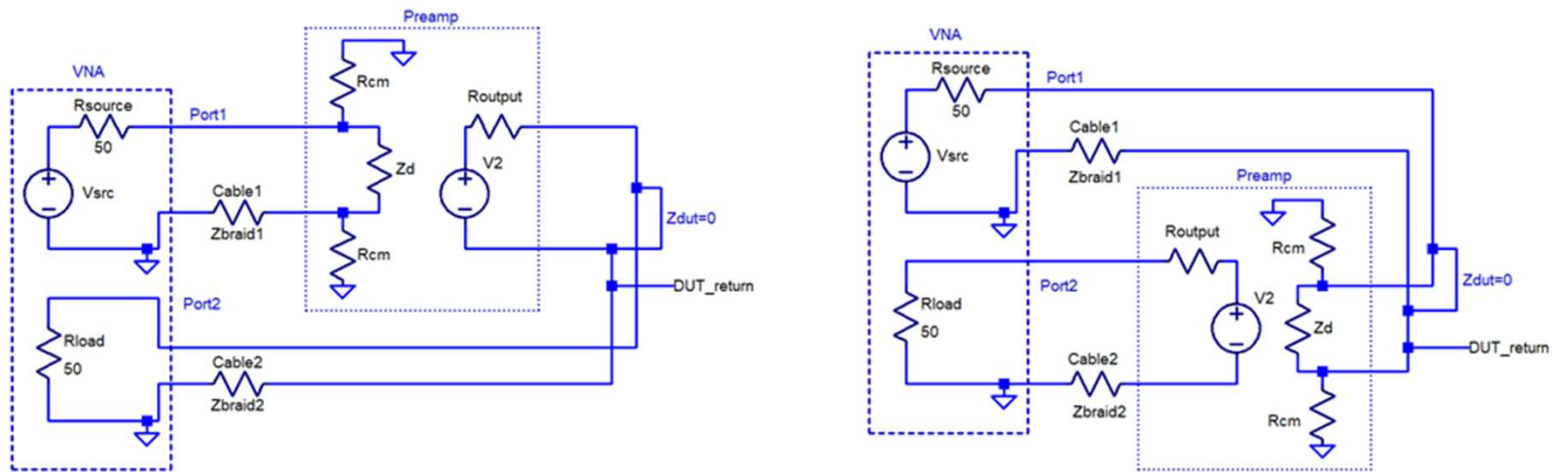
21

"Transient Load Tester for Time Domain PDN Analysis," EDICON 2017



# Tip 2: Reducing Cable Braid Error with Amplifier

## Connection options for small-signal amplifiers



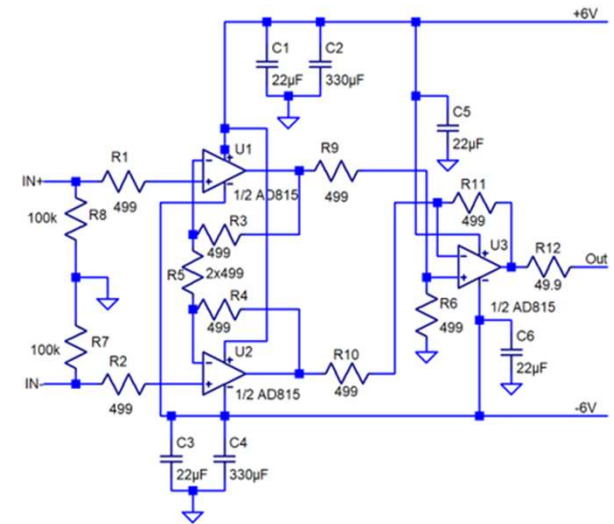
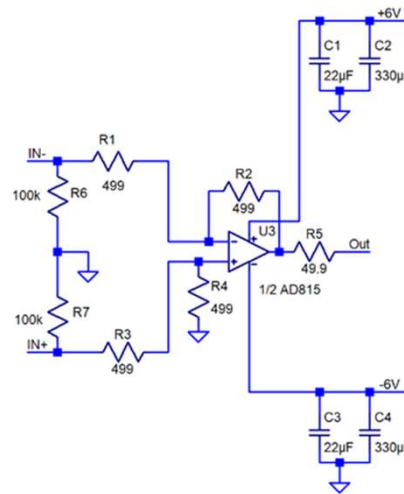
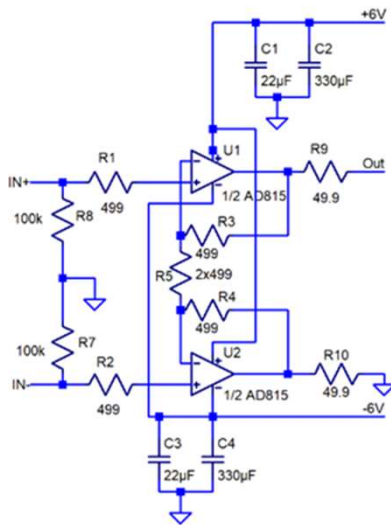
"Preamplifier Options for Reducing Cable-Braid Loop Error," [http://www.electrical-integrity.com/Quietpower\\_files/QuietPower-48.pdf](http://www.electrical-integrity.com/Quietpower_files/QuietPower-48.pdf)



# Tip 2: Reducing Cable Braid Error with Amplifier

Amplifier options for small-signal amplifiers

- High input impedance, no CMRR (left)
- High CMRR, low input impedance (middle)
- High CMRR, high input impedance (right)



“Pre-amplifier Options for Reducing Cable-Braid Loop Error,” [http://www.electrical-integrity.com/Quietpower\\_files/QuietPower-48.pdf](http://www.electrical-integrity.com/Quietpower_files/QuietPower-48.pdf)

## Tip 2: Reducing Cable Braid Error with Amplifier

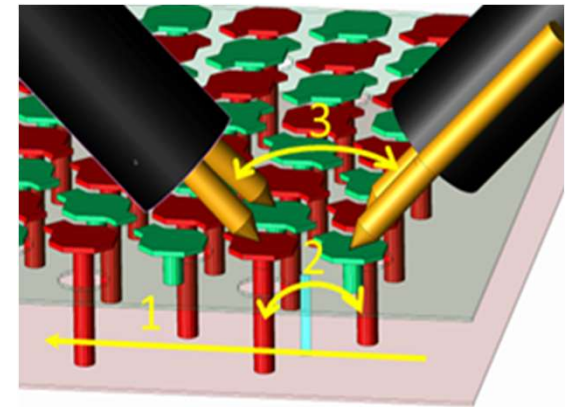
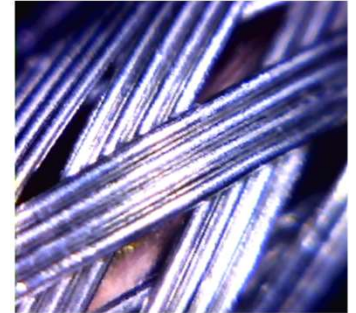
When using amplifiers, be aware

- High CMRR will suppress built-in bias (use on undriven port)
- Active DUT and built-in bias may drive the amplifier to saturation
- Opening up the cable braid loop may introduce mid- and high-frequency resonances

When using transient loads, be aware

- Large-area drive raises questions about where and how the response is obtained

Cable braid detail



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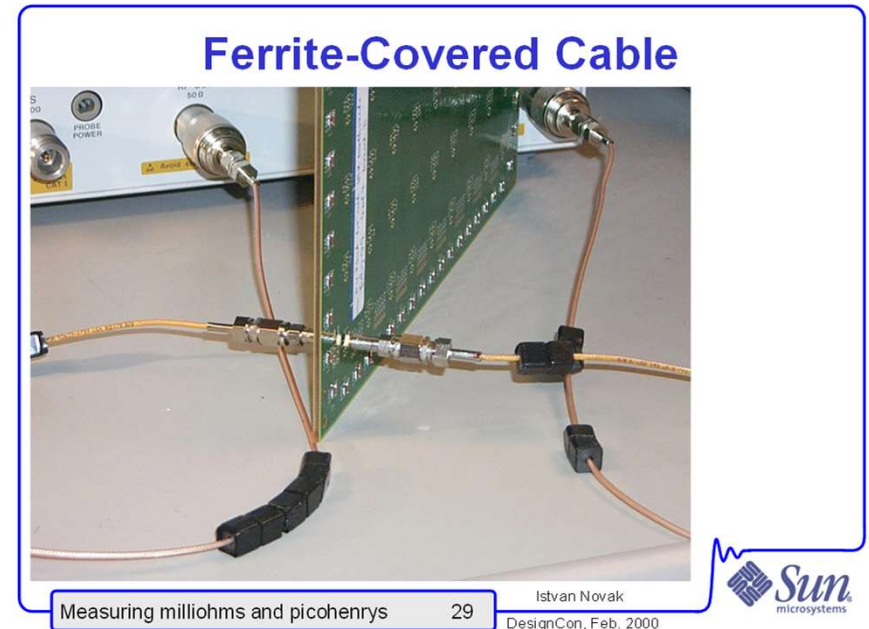
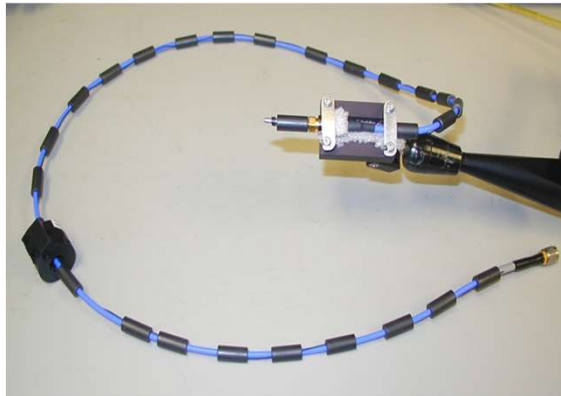
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## Tip 3: Reducing Cable Braid Error with Absorbers

At medium and high frequencies

- finite surface transfer impedance and direct shield leakage
  - shield resonances
- will become the limit

Use ferrite absorbers to address both



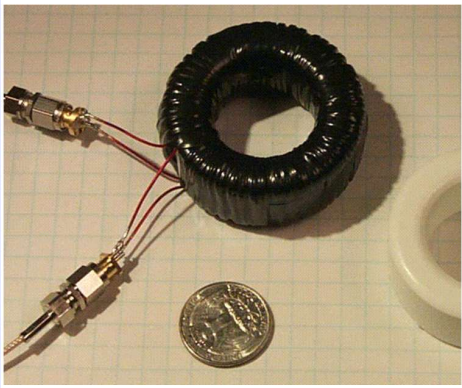
“Measuring Milliohms and PicoHenrys in Power Distribution Networks,”  
DesignCon 2000

“Overview of Frequency-Domain Power-Distribution Measurements,”  
DesignCon East 2003



# Reducing Cable Braid Error; Further Options

### Transformer



- Phillips core:  
TX51/32/19-3F3
- Diameter: 52mm
- 2x50 turns
- AWG 20
- bifilar
- SMA female

Istvan Novak  
DesignCon, Feb. 2000

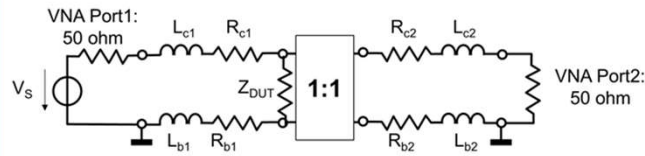
Measuring milliohms and picohenrys 16

- Works well with passive DUTs
- Be careful with
  - DC bias
  - Active DUTs

“Measuring Milliohms and Picohenrys,” DesignCon 2000

### Eliminating Ground Loop

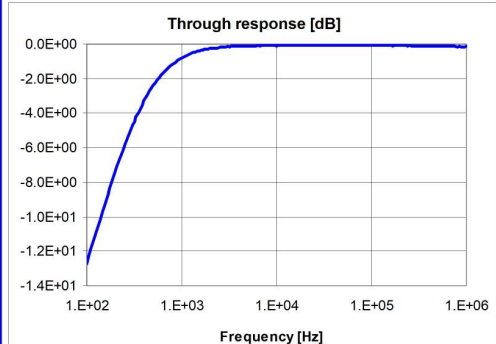
Transformer  
Differential amplifier



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DesignCon, Feb. 2000

Measuring milliohms and picohenrys 15

### Transformer Response (1)



Frequency [Hz]	Through response [dB]
1.E+02	-1.4E+01
1.E+03	-2.0E+00
1.E+04	-0.5E+00
1.E+05	0.0E+00
1.E+06	0.0E+00

- 1:1 transformer
- HP4395B
- 50 ohms terminations

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DesignCon, Feb. 2000

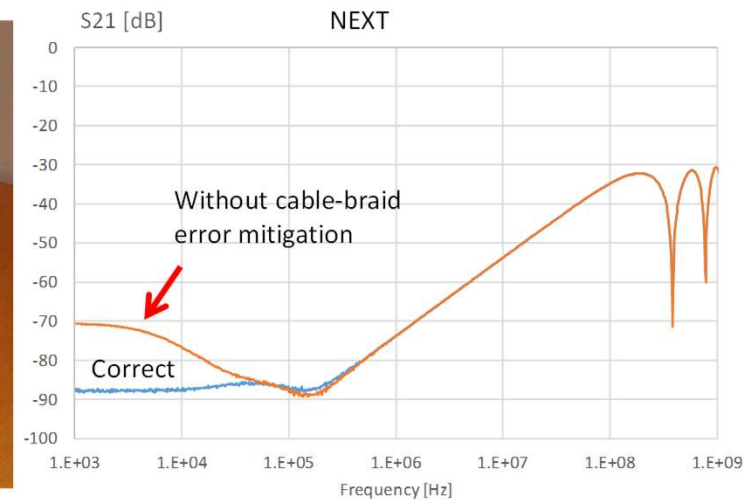
Measuring milliohms and picohenrys 18



# Happens in SI, Too

## Introduction

- Illustration of cable braid error in SI measurements
- All crosstalk measurements are prone to this error
- DUT: coupled microstrip traces



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## Summary

Cable-braid error becomes more important as we need to measure sub-milliohm impedance

Cable-braid error can be mitigated by

- Differential amplifiers
- Locally amplifying the test signal
- Common-mode transformers
- Ferrite absorbers

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