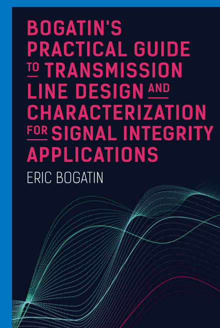
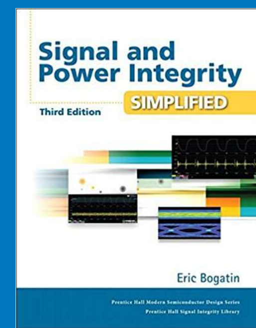
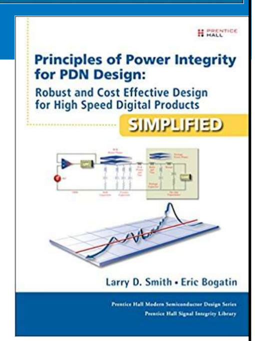
SI/PI Measurements on a Budget







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Free webinars

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Example of an Entry Level General Purpose Scope

WaveSurfer 4104HD:
4 channels
1 GHz BW
Upto 5 GS/s
25 Mpts buffer

https://teledynelecroy.com/oscilloscope/wavesurfer-4000hd-oscilloscopes

Four Essential Best Measurement Practices

- Rule #9:
  - anticipate what you expect to see before you do the measurement
- Always perform as many consistency tests as you can think of
- Situational awareness
  - Be aware of the condition and limitations of your measurement set up
  - Be aware of the features of your DUT
  - Be aware of how close are the limitations of your measurement system and your DUT
  - Be aware of potential measurement artifacts
  - Know the sample rate, BW, resolution, trigger,…
- Answer the “so what?” question
  - Data (measurements) → Information (figures of merit) → so what (design decisions, actions)

Best Measurement Practices for SI and PI applications (at no extra cost)

1. Get the highest BW from your 10x probe
2. Avoid probe to probe cross talk
3. Use your 10x probe as a near field emissions probe
4. Measuring switching noise: use a spare I/O as a quiet high or quiet low
5. When to use 50 Ohms or 1 Meg input?
6. Measuring a power rail with 10x probe

A Simple, Fast Pulse Source

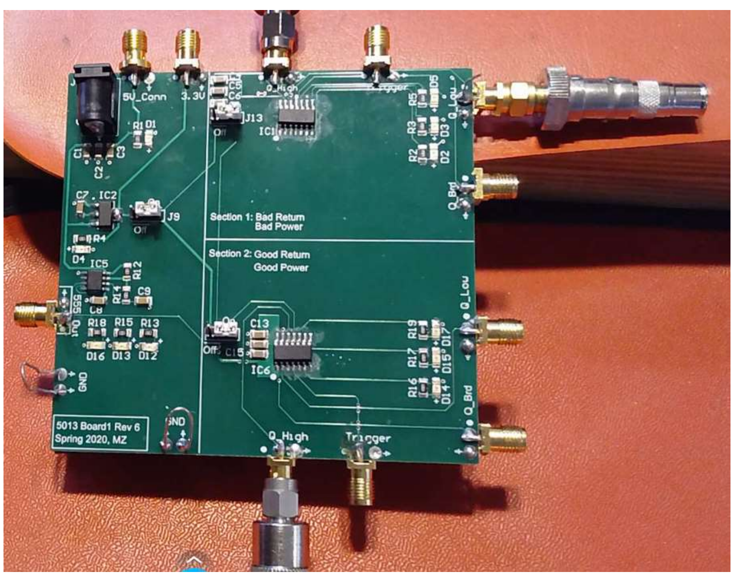
http://www.leobodnar.com/shop/index.php?main_page=product_info&cPath=124&products_id=295

~ 40 psec rise time
50 Ohm source
~ 1 V peak to peak, adjustable

BW and Probes

- Fast rise time source, 50 Ohm
  - Directly into the scope
  - Rise time and BW
  - Rise time affected by the scope BW
  - Impact on rise time from RG174 cables
  - Impact on rise time of having a large inductive loop
  - How we probe influences the BW, rise time
- The 10x probe
  - Compensation
  - Using highest BW adaptor: tip to BNC
  - Using long gnd lead
  - Using spring tip

Measuring Switching Noise (ground bounce and power rail collapse)



Trigger scope on an I/O switching

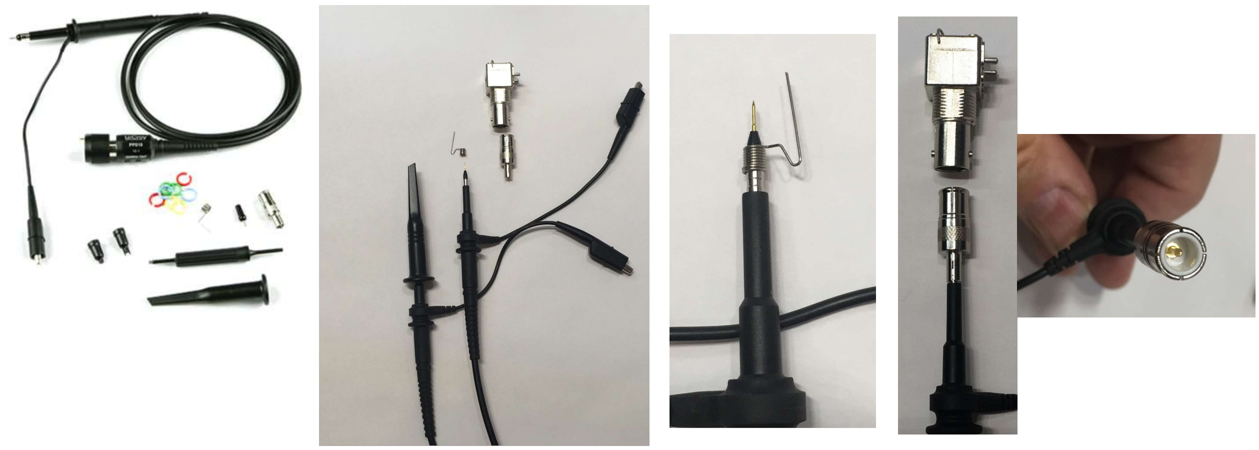
Measure an output set as a low (quiet low)

Measure an output set as a high (quiet high)

Compare with the on-board power rail

Be aware probing artifacts:
- Probe BW
- Probe to probe xtk
- Probe near field pick up
- Direct coax connections: 1 Meg input of 50 Ohms

The Classical 10x Passive Probe (PP023)



Three important tip options: mini-grabber clip, short return clip, coaxial BNC

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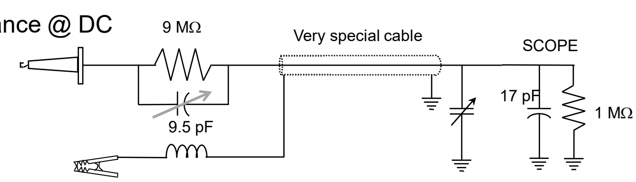
Inside the 10x Passive Probe

10 M Ohm input impedance @ DC



DC signal at scope is 1/10th DC signal at tip

3 problems with the 10x passive probe:

1. It's not a 10x probe, it's a 1/10th probe! (signal at scope is attenuated from the tip- lost 20 dB of the signal!)

2. If the parallel impedance is 1 Meg and scope as (17 pF capacitance + cable capacitance)…..

$$RC = 1\,\text{Meg} \times 100\ \text{pF} = 100\ \text{usec}$$

This is a bandwidth ~ 10 kHz!!! OMG! Unusable.

Enter: the equalization circuit

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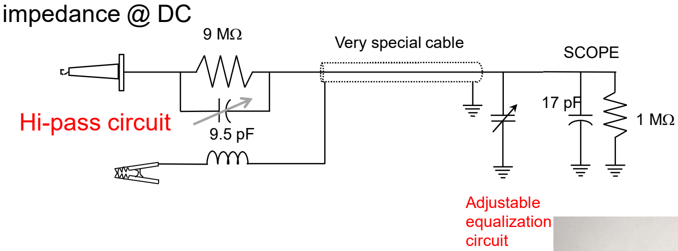
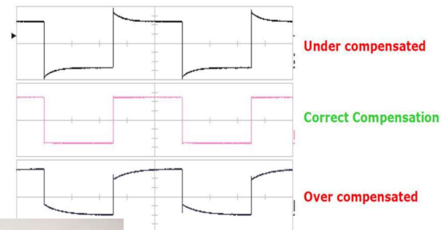
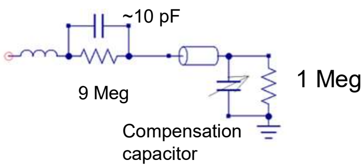
Equalization Circuit

- The probe is a low-pass filter
- Add a high-pass filter in parallel and match their pole frequencies

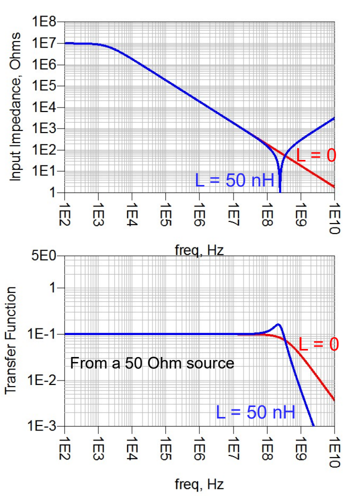
10 M Ohm input impedance @ DC

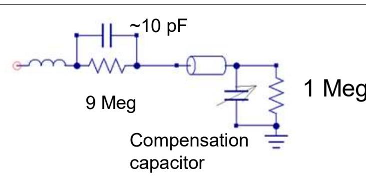






Performance of a Passive Probe





Input impedance is mostly capacitive (9.5 pF), can be as low as 100 Ohms at 100 MHz (can still load the circuit)

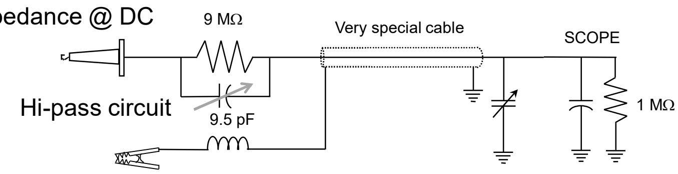
Match the two RC time constants to maintain a flat 10:1 transfer function up to BW

BW limited by when 9.5 pF gets close to ~ 3x source impedance, for 50 Ohm source, best case BW is ~ 100 MHz – 500 MHz

Loop inductance of tip further limits bandwidth and introduces ringing (why low inductance tip is a good habit)

Problem #3- what about reflections in the cable!!!

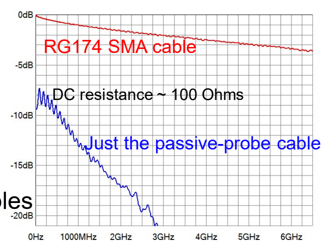
10 M Ohm input impedance @ DC



Adjustable equalization circuit

Very special cable:

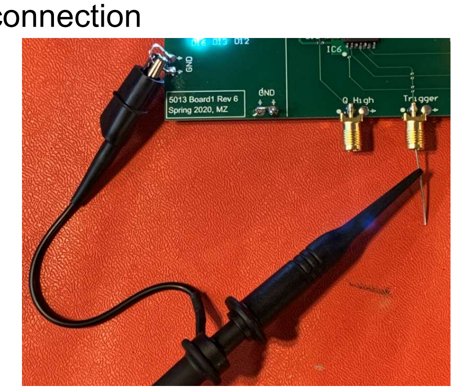
- Very tiny center conductor diameter
- NiCr wire ~ 50 Ohms/ft
- “Built-in” termination network
- High impedance, very lossy, no reflections



Measured S21 of 36 inch long cables

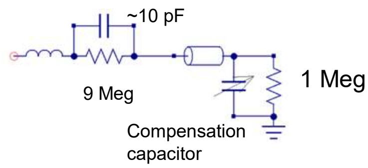
Best Measurement Practices with the 10x probe

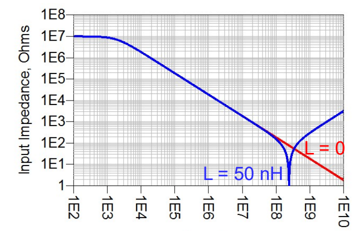
- Always compensate
- Three ways of probing the same signal:
  - Large loop inductance
  - Spring tip low loop inductance
  - Coax connection

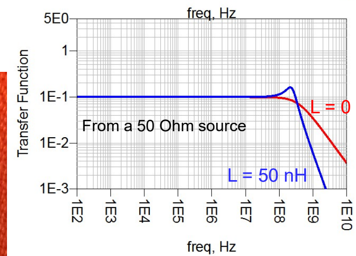


Watch out for rf pick up

- What is the input impedance of the 10x probe?
  - At 100 MHz, (3.5 nsec rise time) Zin = 100 Ohms
  - At 3.3 V, I = 3.3 V/100 Ohms = 33 mA!!
- Avoid rf pick up with small loop, PCB attach or coax connection



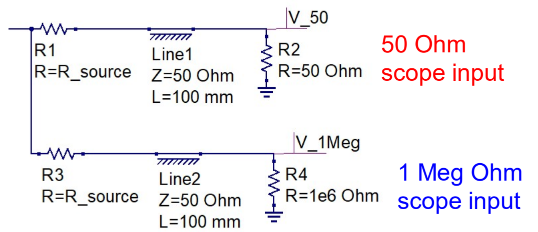


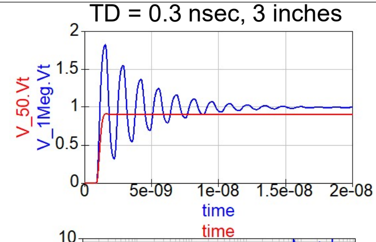


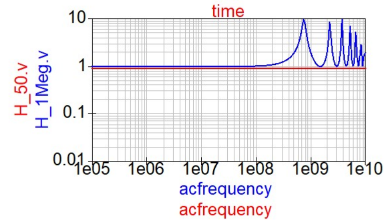
The 10x Probe for Probing Power Rails

- The good:
  - ✓ It's cheap
  - ✓ It's easy
  - ✓ Does not load the rail with DC current
- The bad:
  - You lose 20 dB SNR
  - Limited BW < ~ 100 MHz
  - Very sensitive to rf pick up
- Conclusion:
  - Use 10x probe if you:
    - ✓ Don't care about < 20 mV noise
    - ✓ Don't have much rf pick up
    - ✓ Don't have any signal components > 100 MHz
    - ✓ Filter BW to be < 100 MHz to avoid artifacts

Low Impedance Source, 50 Ohm or 1 Meg Scope Input







- Reflections in the cables
  - With low impedance source, 1 Meg scope, there will be reflections
  - Ringing frequency depends on cable length (4 x Time Delay (TD))
    - 3 ft cable, TD = 4.5 nsec, ringing period = 4 x 4.5 nsec = 18 nsec
  - Artifacts introduced at f > 50 MHz
- If you care about > 50 MHz, must use coax and 50 Ohm scope termination
  - But, a 50 Ohm scope impedance on a 5 V rail would draw 100 mA of current!

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4. Use a spare I/O as a quiet high or quiet low
5. When to use 50 Ohms or 1 Meg input?
6. Measuring a power rail with 10x probe or rail probe (20 dB SNR hit)

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