POWER INTEGRITY AND HOW IT AFFECTS SIGNAL INTEGRITY

Pasi Suhonen
Application Engineer Oscilloscopes

ROHDE&SCHWARZ

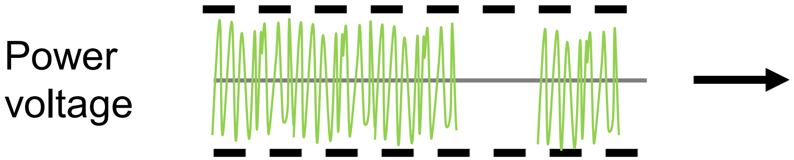
Make ideas real

AGENDA

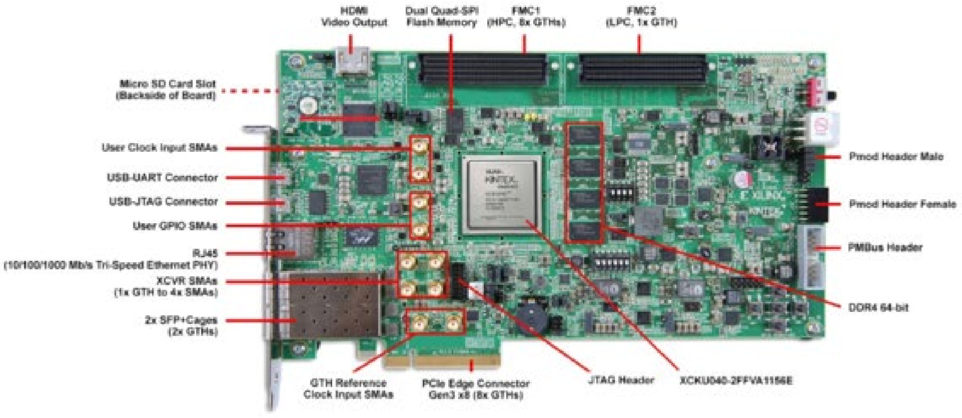
- Introduction to typical analysis and hurdles in Signal and Power Integrity
- How are Signal and Power Integrity linked together?
- How to hunt down Power Integrity issues in Jitter separation.
- Practical demo

WHAT IS POWER INTEGRITY?

- IC suppliers specify # of power rails, voltage for each, and tolerance for each.
  - FPGAs, ASICs, CPUs, DDR memory…
- Measurements: sequencing, noise / ripple, drift, load/step response, EMI

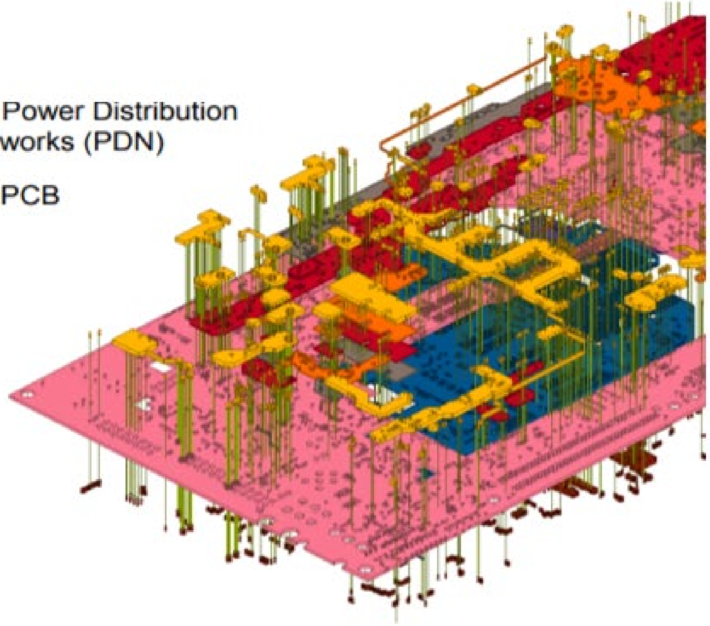


POWER DISTRIBUTION NETWORK (PDN) EXAMPLE

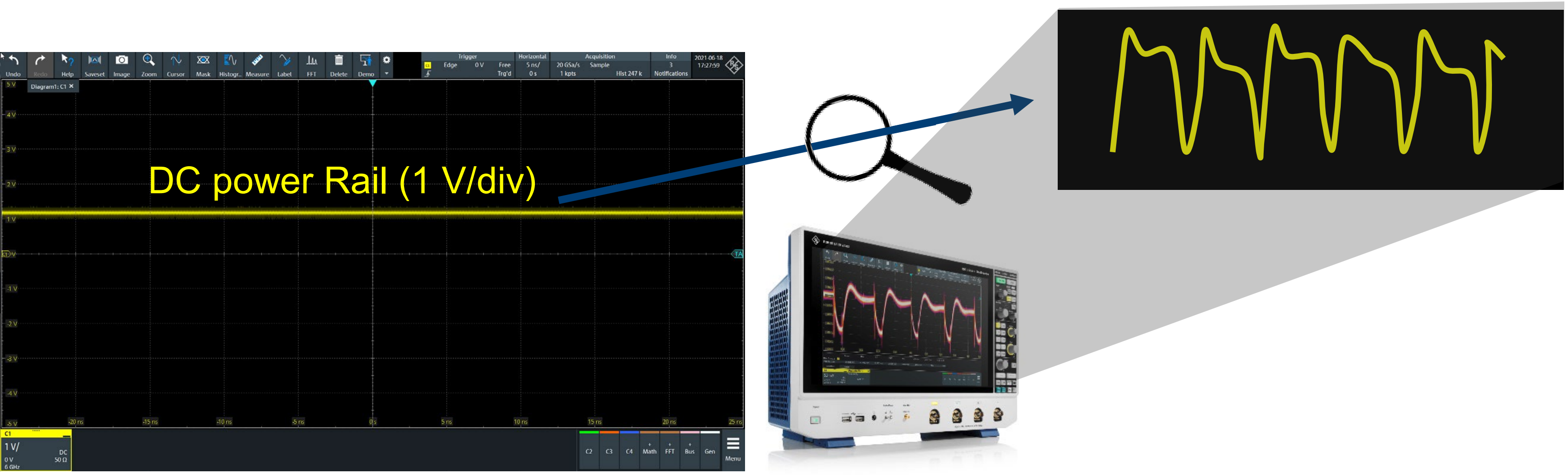


15 Major Power Distribution Networks (PDN)

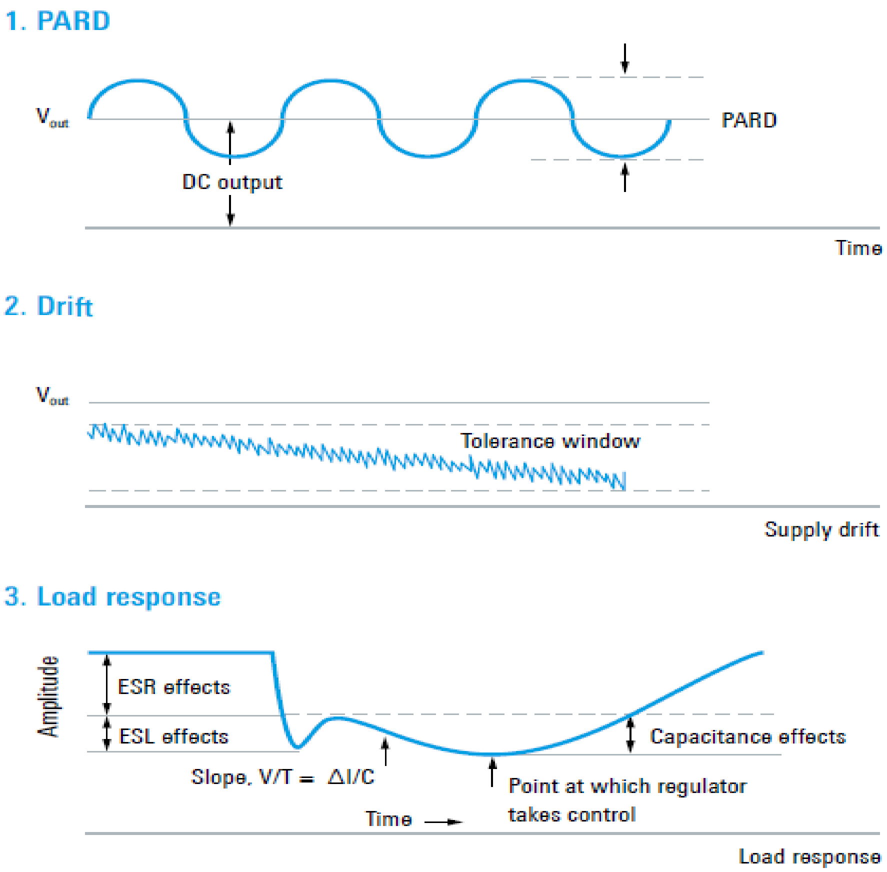
16 Layer PCB



OSCILLOSCOPE PRIMARY TOOL FOR POWER RAIL ANALYSIS



COMMON POWER RAIL MEASUREMENTS



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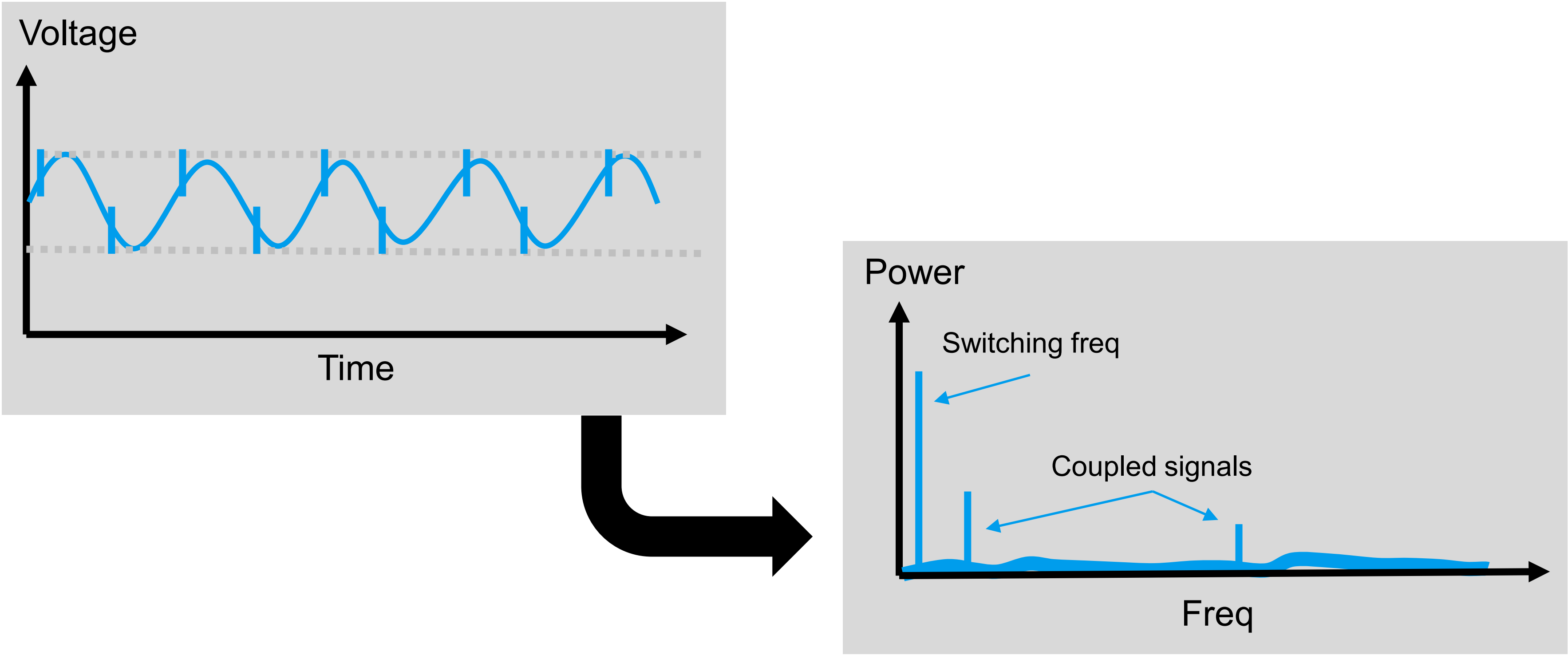
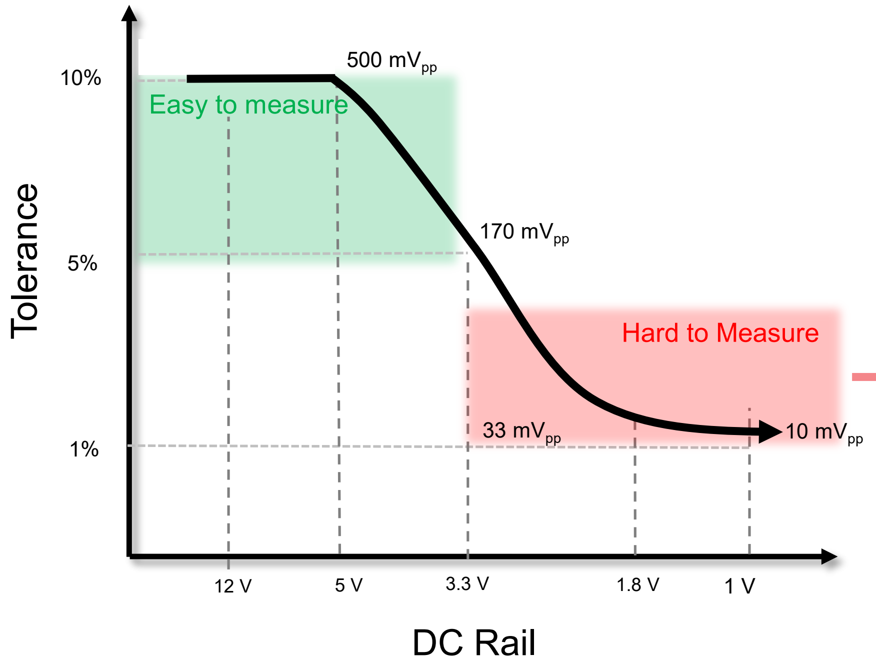


POWER RAIL MEASUREMENT CHALLENGES



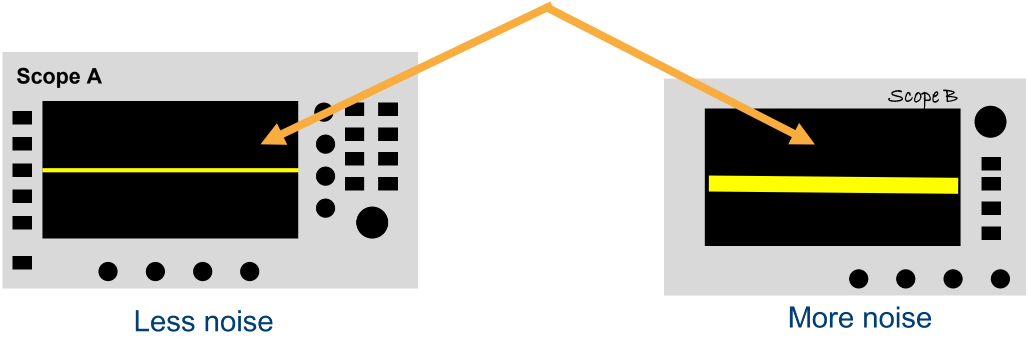
Examples

Rail Value	Tolerance	Need to measure
3.3 V	1%	33 mV_{pp}
1.8 V	2 %	36 mV_{pp}
1.2 V	2 %	24 mV_{pp}
1 V	1 %	10 mV_{pp}

Scope measurement noise can approach or exceed needed signal measurement values

POWER RAIL MEASUREMENT CHALLENGES

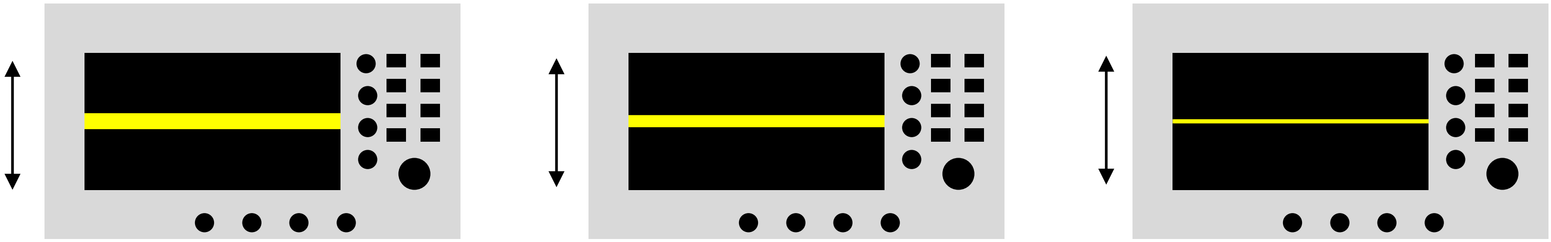
Differentiation in time domain become a tough task for signals that are smaller than the intrinsic noise of the scope.



Intrinsic measurement noise with all input signals disconnected.

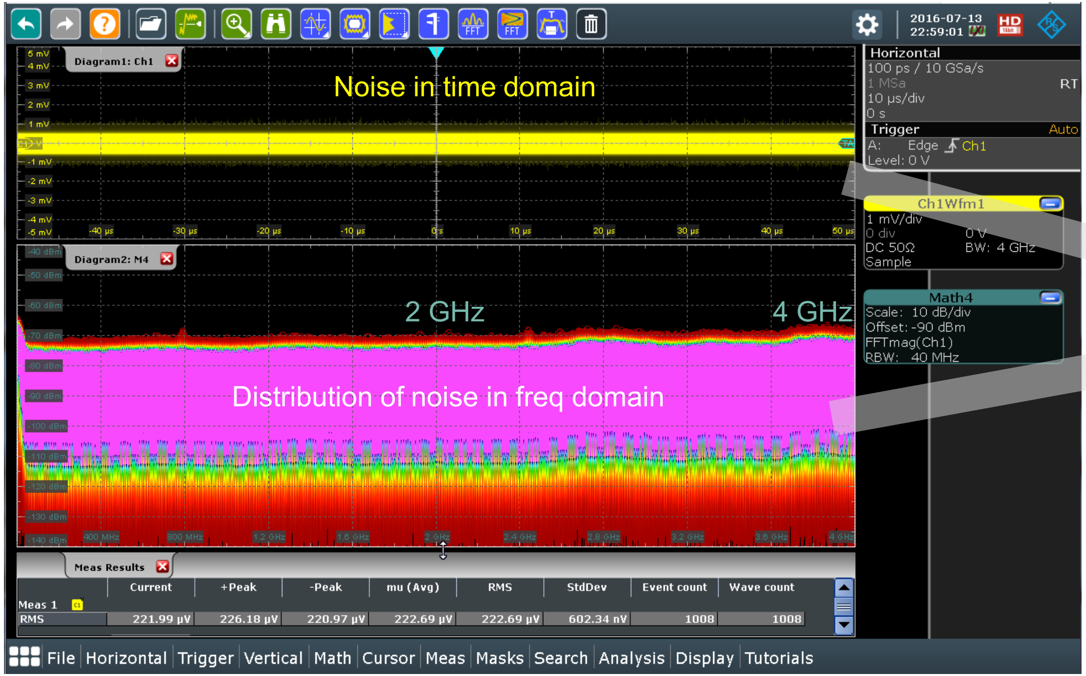
POWER RAIL MEASUREMENT CHALLENGES

10 mV full screen | 100 mV full screen | 5 V full screen



Least noise | More noise | Even more noise

POWER RAIL MEASUREMENT CHALLENGES



Noise in time domain

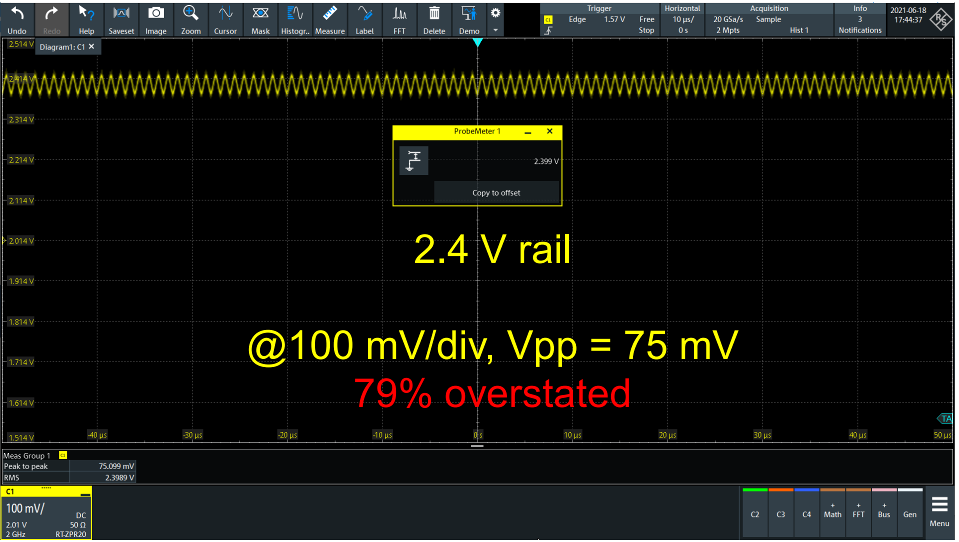
=

$\int$ freq domain form 0 to BW

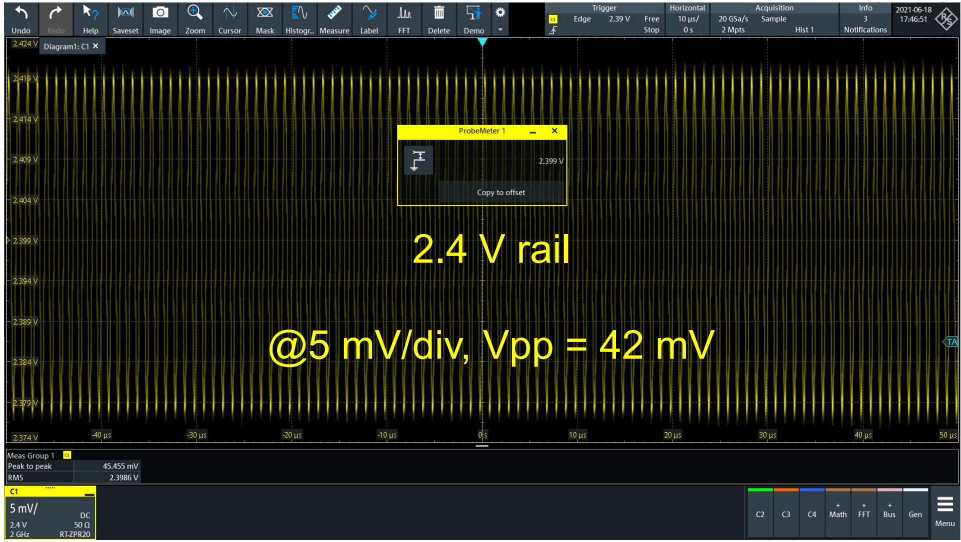
More measurement bandwidth = more measurement noise

POWER RAIL MEASUREMENT CHALLENGES

Using max built-in scope offset

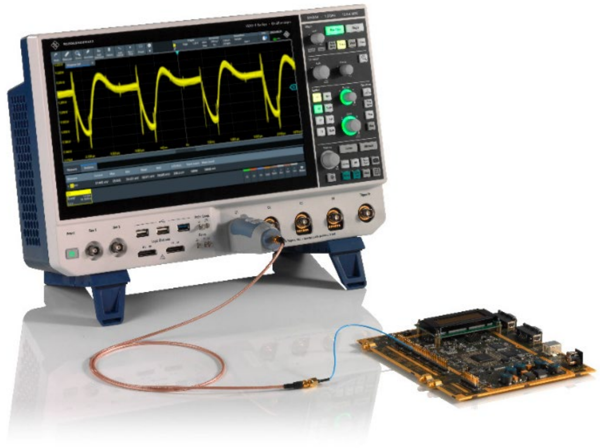


Using built-in probe offset



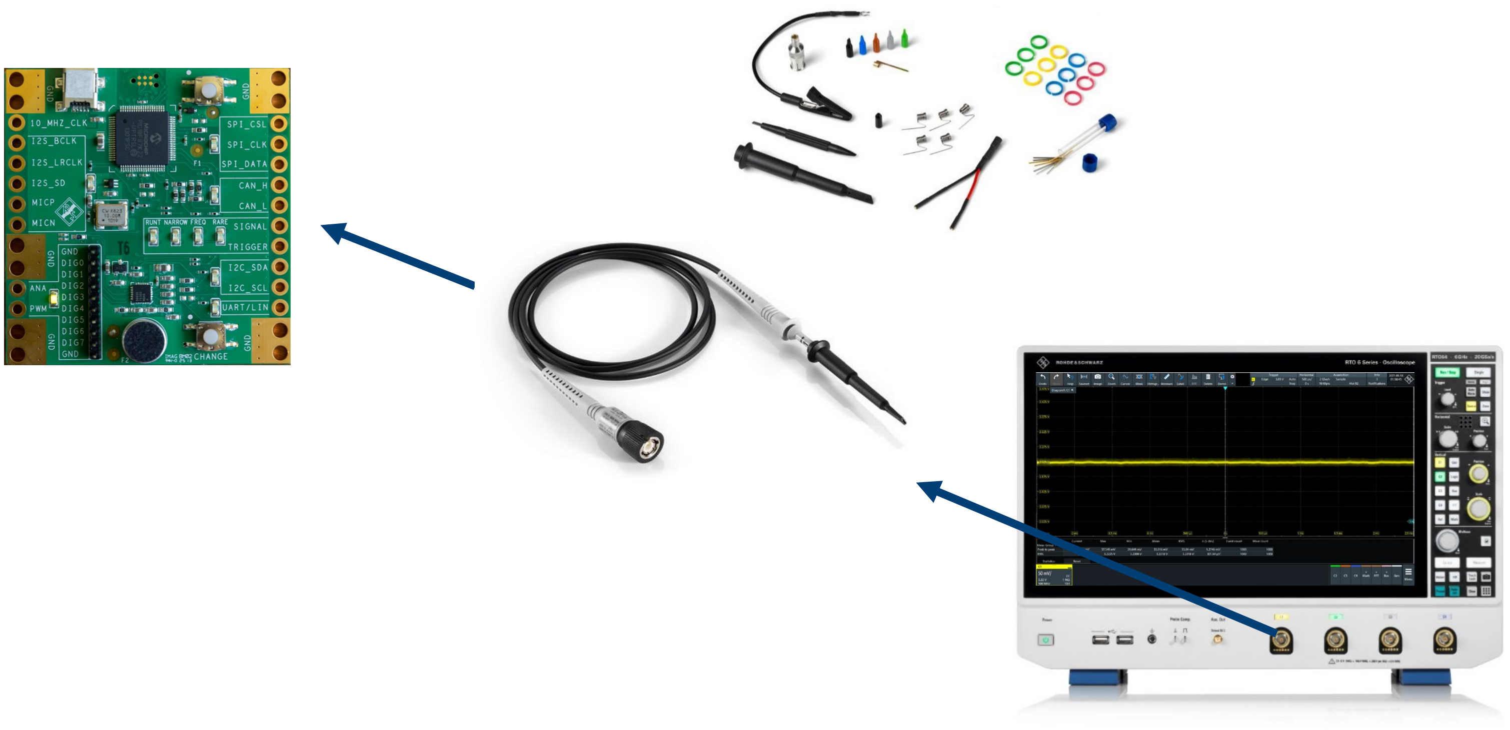
POWER RAIL MEASUREMENT CHALLENGES

MXO4 Oscilloscope



18-bit resolutions and fast acquisitions makes result correlation faster and precise

POWER RAIL MEASUREMENT CHALLENGES



PROBING METHODS
10:1 PASSIVE PROBE

Advantages

- Comes standard with most scopes
  - no extra expense
- 10 MΩ loading at DC
  - Preserves expected DC value
- Easy to connect using browser tip
  - Multiple ground alternatives

Disadvantages

- Significant noise
  - 10:1 attenuation
  - Minimum vertical setting of 10 mV/div
- Long grounds
- BW limited (500 MHz for ZP-10)
- No solder-in alternative

PROBING METHODS
1:1 PASSIVE PROBE

Advantages

- Low cost
- Excellent 1 MΩ loading at DC
  - preserves expected DC value
- Ability to scale to 1 mV/div
- Easy to connect using browser tip
  - Ground spring ground alternative

Disadvantages

- Limited BW
  - 38 MHz for ZP-1X
  - under reports V_{pp} measurements
  - masks high freq signal coupling
- Limited offset – may require AC coupling
- No solder-in alternative

PROBING METHODS
50Ω PATH

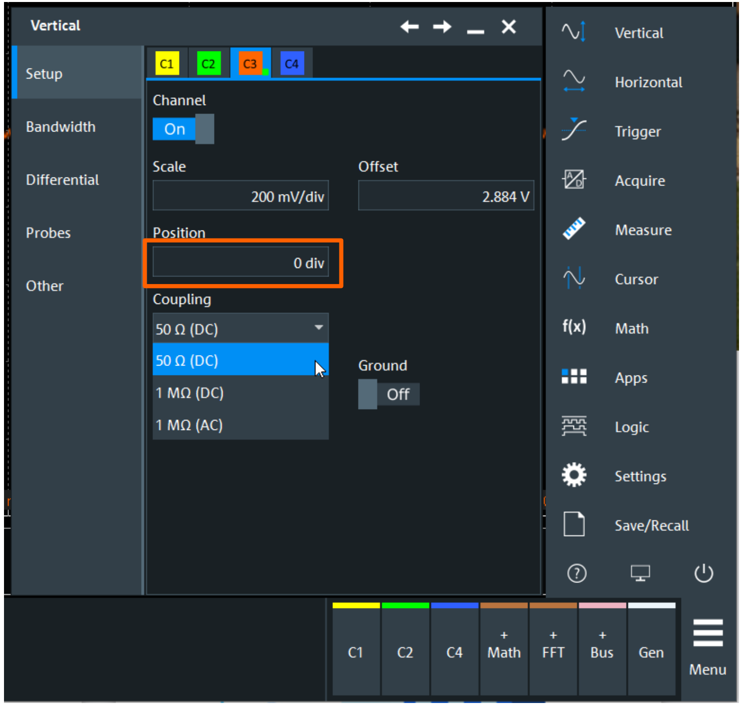
Advantages

- 50 Ω scope path typically has less noise than 1M Ω scope path
- SMA connector or solder-in pigtail allows for measurement consistency and ease of access

Disadvantages

- 50 Ω loading at DC reduces power rail voltage
- Insufficient offset (requires blocking cap or AC coupling)
  - Masks DC drift
  - Eliminates ability to see true DC voltage

PROBING METHODS
AC COUPLING



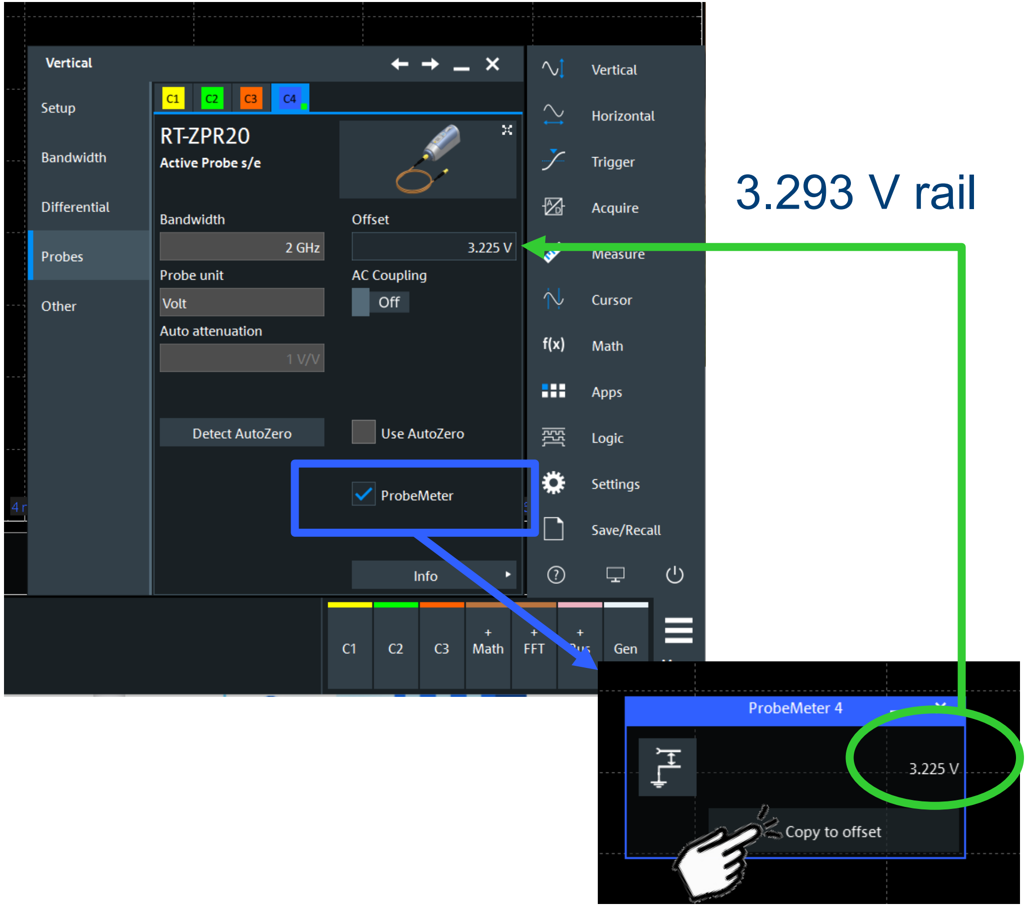
- Set to 50Ω path (channels setup)
- Attenuation to 1:1 (probe setup)
- 50Ω path (limited offset may require AC coupling)

PROBING METHODS
RT-ZPR POWER RAIL PROBE

- Designed uniquely for measuring small perturbations on power rails
- Active, single-ended probe
- Low noise with 1:1 attenuation
- Offset compensation capability
- Built-in DC meter

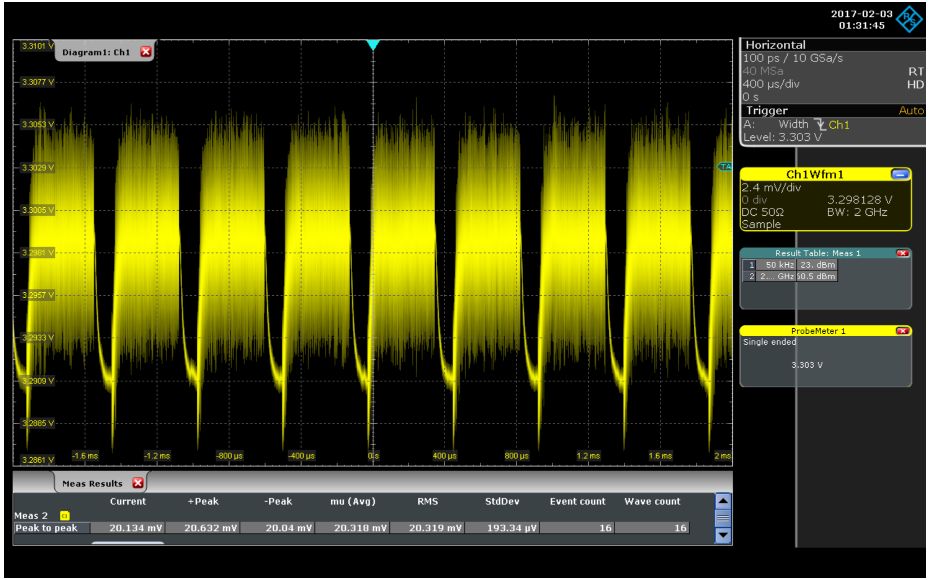
Key Specifications	
Attenuation	**1:1**
BW	**2 GHz or 4 GHz**
Browser BW	350 MHz
Dynamic Range	±850 mV
Offset Range	**> ±60 V**
Probe Noise Scope standalone Scope + Probe (at 1 GHz, 1mV/div)	 107 µV AC_{rms} **120 µV AC_{rms}**
Input Resistance	**50 kΩ** @ DC
R&S ProbeMeter	Integrated
Coupling	DC or AC

INTEGRATED VOLT METER



HOW MUCH BANDWIDTH DO YOU NEED?

How much is needed here?



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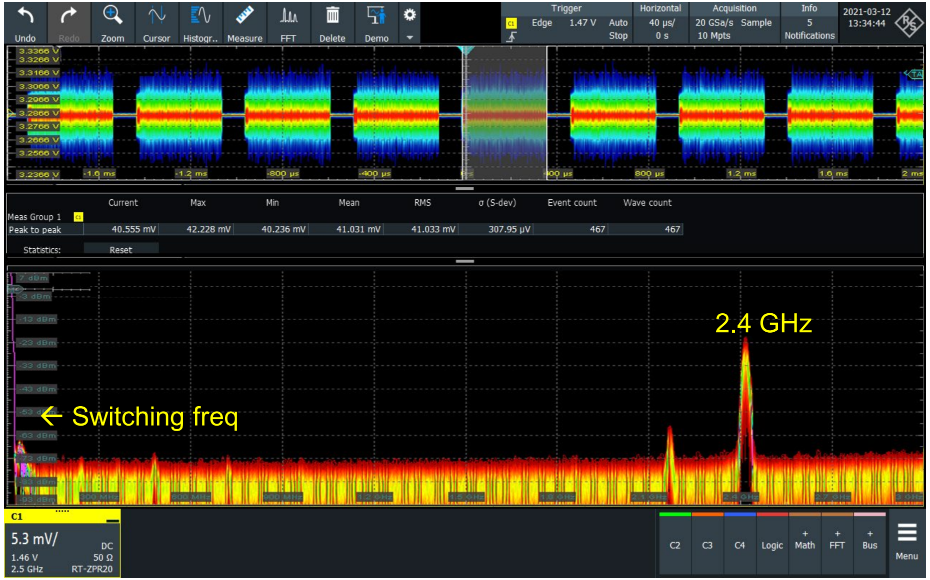
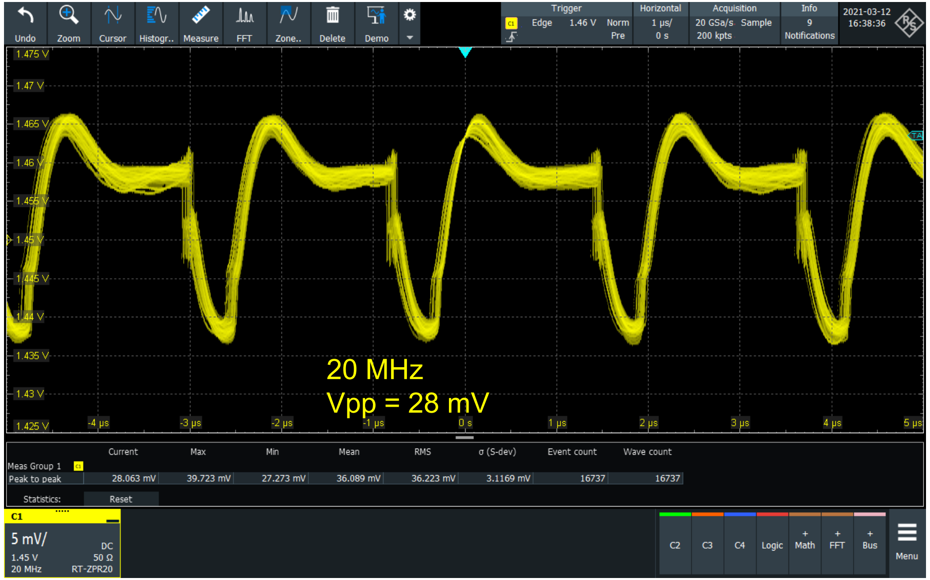
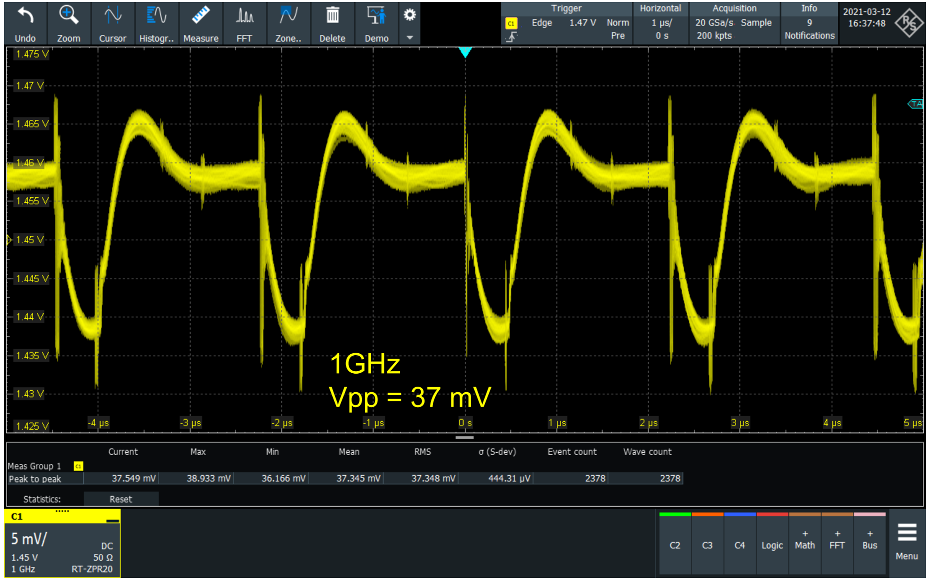


HOW MUCH BANDWIDTH DO YOU NEED?

20MHz



1GHz



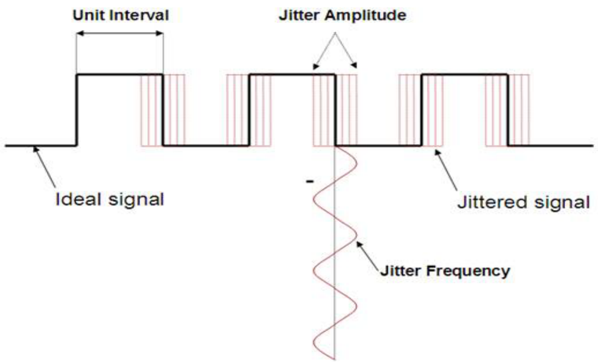
SIGNAL AND POWER INTEGRITY ISSUES CAN CAUSE JITTER

► Jitter is the short-term time-domain variations in clock or data signal timing

► Jitter includes instability in signal period, frequency, phase, duty cycle or some other timing characteristic

► Jitter is of interest from cycle to cycle, over many consecutive cycle, or as a longer term variation

► **Jitter is equivalent to Phase Noise in the frequency domain**

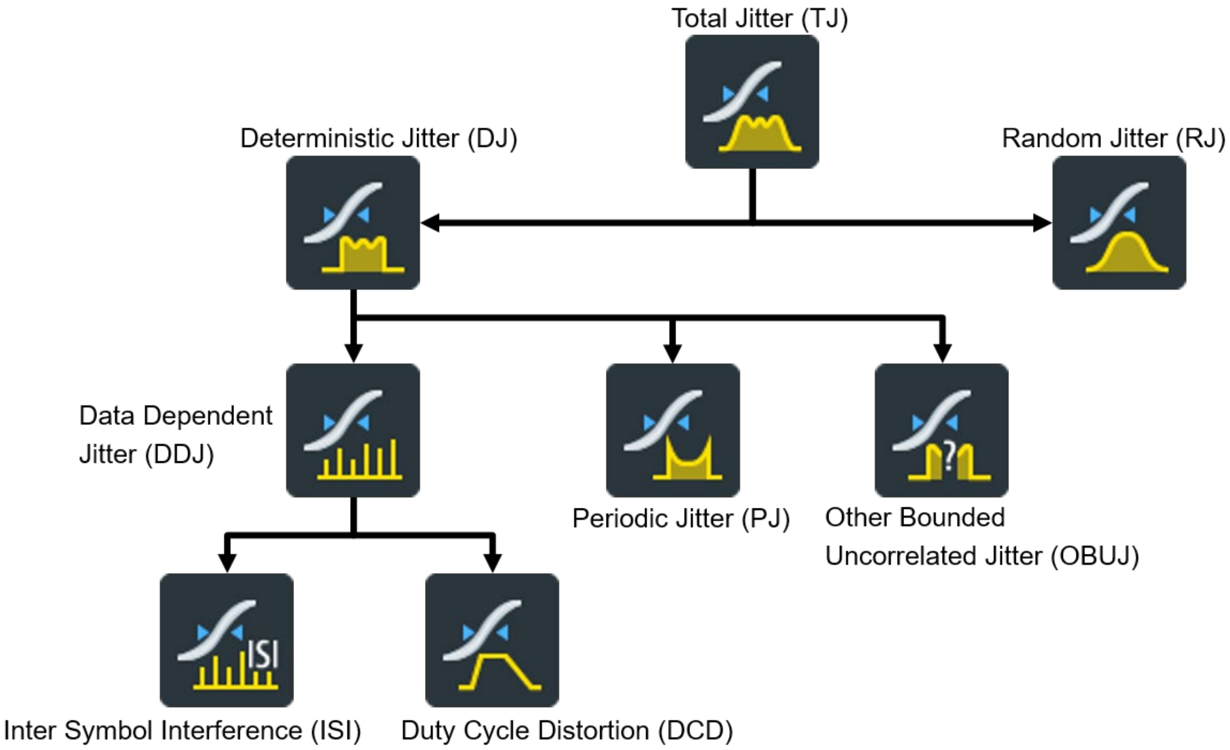


JITTER COMPONENTS

Total Jitter is composed out of several jitter contributions:

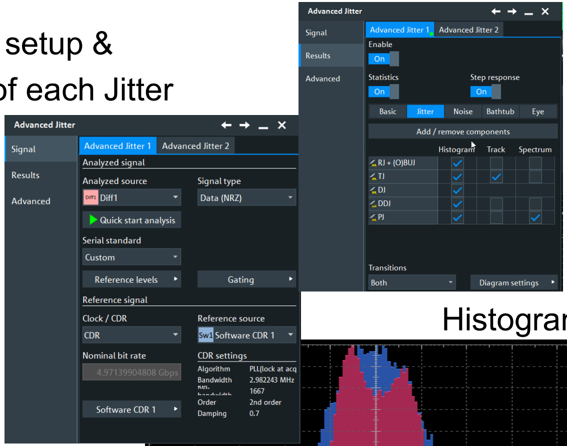
– Random Jitter: “unbounded”

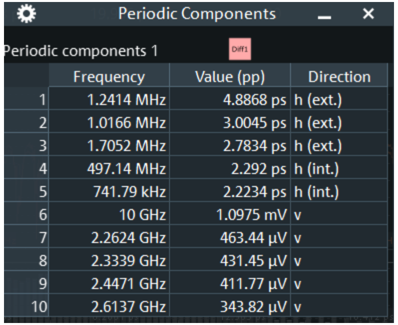
– Deterministic Jitter: usually “bounded”



VARIOUS JITTER MEASUREMENTS AND JITTER COMPONENT SPECIFIC RESULTS

Quick 3 step setup & explanation of each Jitter componenet





Periodic Components

Periodic components 1

	Frequency	Value (pp)	Direction
1	1.2414 MHz	4.8868 ps	h (ext.)
2	1.0166 MHz	3.0045 ps	h (ext.)
3	1.7052 MHz	2.7834 ps	h (ext.)
4	497.14 MHz	2.292 ps	h (int.)
5	741.79 kHz	2.2234 ps	h (int.)
6	10 GHz	1.0975 mV	v
7	2.2624 GHz	463.44 µV	v
8	2.3339 GHz	431.45 µV	v
9	2.4471 GHz	411.77 µV	v
10	2.6137 GHz	343.82 µV	v

Various jitter results:

- ▶ Standard deviation and peak-peak values
- ▶ Total Jitter@BER
- ▶ Duty Cycle Distortion (DCD)
- ▶ Inter Symbol Interference (ISI)
- ▶ DJ dual dirac

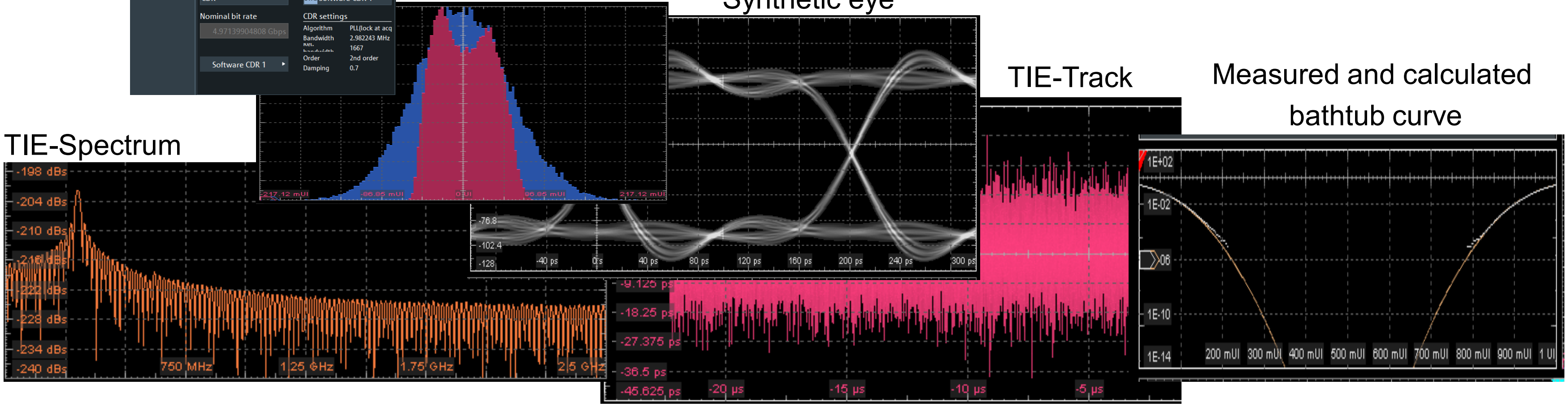
Histograms

Synthetic eye

TIE-Track

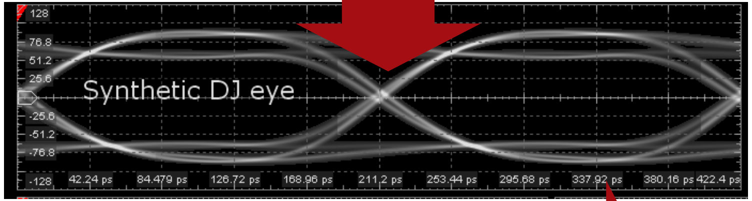
Measured and calculated bathtub curve

TIE-Spectrum



NEW INSIGHTS

Synthetic eye



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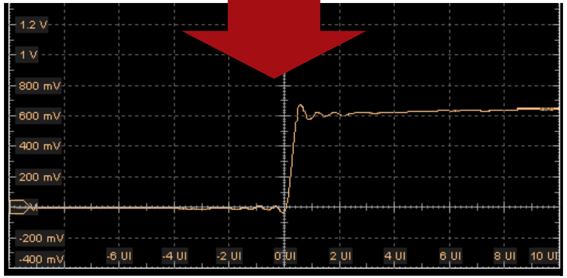
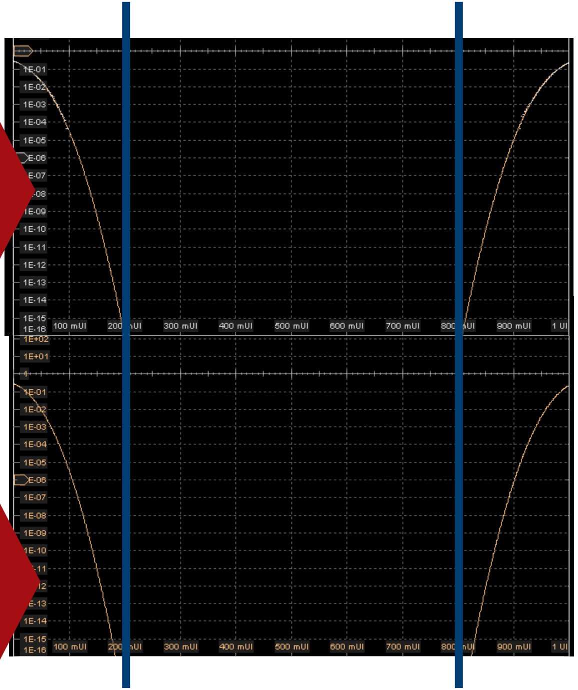
Step response



Bathtub
Total Jitter

What-if Bathtub
DDJ+RJ only
assuming no
periodic jitter



SUMMARY

How important is measurement accuracy?

1. Learn & use scope settings that impact accuracy
2. Investment in low-noise scope with needed BW for your power rail needs
3. Investment in specialized power rail probes