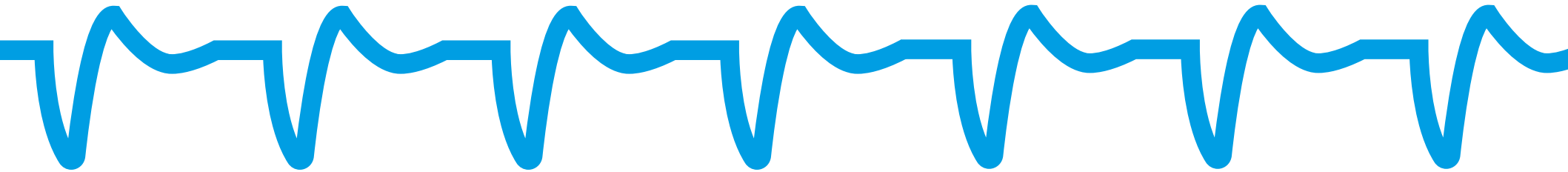


# POWER INTEGRITY

Important considerations to make  
in order to achieve the most accurate  
power integrity measurements



eGuide | Version 02.00

**ROHDE & SCHWARZ**

Make ideas real



Clean and stable power rail voltages are the basis for proper performance of any electronic design. The continuing demand for higher performance, higher level of integration and lower power consumption drives supply voltages down, making voltage tolerances tighter and power rail qualification a challenging task.

Therefore, making accurate power integrity measurements remains an ever-increasing challenge, and for precise results, it is important to use the right tools regardless of whether it is an oscilloscope, a probe or a vector network analyzer. This pocket guide evaluates important considerations you should take into account in order to achieve the most accurate power integrity measurements.

A digital copy of the Power Integrity Pocket Guide and other power integrity resources are available at:

[www.rohde-schwarz.com/electronic-design/power-integrity-test](http://www.rohde-schwarz.com/electronic-design/power-integrity-test)

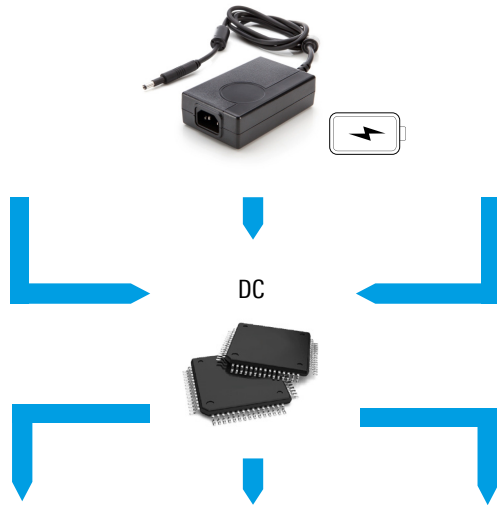
# CONTENTS

Overview	4	Rohde & Schwarz oscilloscope portfolio	28
Measurement techniques	8	Choosing between 50 $\Omega$ and 1 M $\Omega$	29
Why impedance is a critical metric	18	What to look for in a probe	31
Impedance tells us about	19	What should you look for in a PI solution from a probe?	31
Impedance measurements have an unlimited frequency range	20	Probing methods	32
Interpreting impedance results	21	Choosing the right probe	34
How to fix poor impedance	21	R&S®RT-ZPR20/RT-ZPR40 power rail probe	35
Oscilloscopes: the primary tool for power rail analysis	22	Check to see connection options	36
What should you look for in a PI solution from an oscilloscope?	22	Power rail browser	36
50 $\Omega$ check at 1 mV/div	23	R&S®RTE/RTO/RTP oscilloscopes and power rail probe	37
Characterizing your oscilloscope's $V_{pp}$ noise in five minutes	24	Impedance measurements using a vector network analyzer	37
Choose an oscilloscope with low noise	25	One-port VNA measurements	38
Use the most sensitive vertical setting possible	25	Two-port VNA measurements	39
Noise comparison: time domain versus spectral content	26	Rohde & Schwarz vector network analyzers	40
Reduce noise with BWL filters	26	References	42
How much bandwidth do you need?	27		

# OVERVIEW

## What is power integrity?

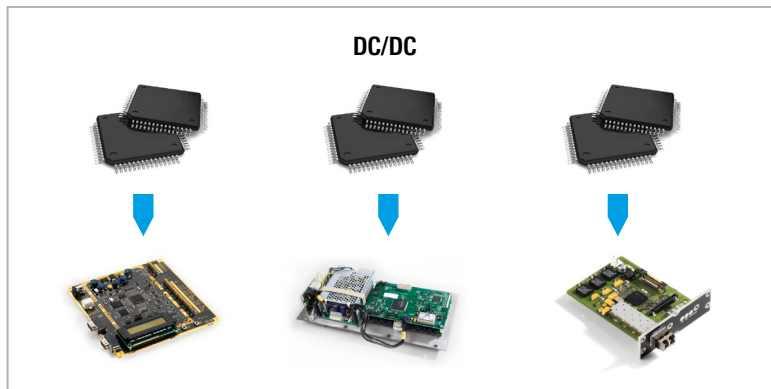
Power integrity is the analysis of DC power rails to determine the quality of DC power from the output of the DC converter to the ICs.



Clean and stable power rail voltages are the basis for proper performance of any electronic design. The continuing demand for higher performance, higher level of integration and lower power consumption drives supply voltages down, making voltage tolerances tighter and power rail qualification a challenging task.

Rail value	Tolerance	Need to measure
3.3 V	1%	33 mV ( $V_{pp}$ )
1.8 V	2%	36 mV ( $V_{pp}$ )
1.2 V	2%	24 mV ( $V_{pp}$ )
1 V	1%	10 mV ( $V_{pp}$ )

## Printed circuit boards



Ripple, noise and load-step response measurements on integrated circuits such as CPUs, DDR memories and FPGAs require very low noise and broadband probing solutions that can measure in the single-digit millivolt range. Qualifying the power supply for sensitive analog receiver circuits means measuring very small disturbances at relatively high DC offset levels.



### What do power integrity issues cause and where do they come from?

- ▶ ICs have sporadic anomalies
  - Examples: FPGAs, ASICs, ADCs, DACs, MCUs, DDR memories
  - IC suppliers therefore specify the number of power rails and the voltage and tolerance for each rail
  - PI is a common support issue for FPGA users
- ▶ PI issues can cause increased jitter (can cause design to not work)
- ▶ PI issues can be caused by crosstalk and EMI: coupling of other sources on power rails (display, clock, RF signal, etc.)

Relatively new effects such as crosstalk between power rails and high speed data lines and significant RF signal coupling easily exceed 2 GHz and put the entire system performance at risk – to the point of complete device failure.

## Power rail measurement challenges

### Lower voltage rails and smaller tolerances

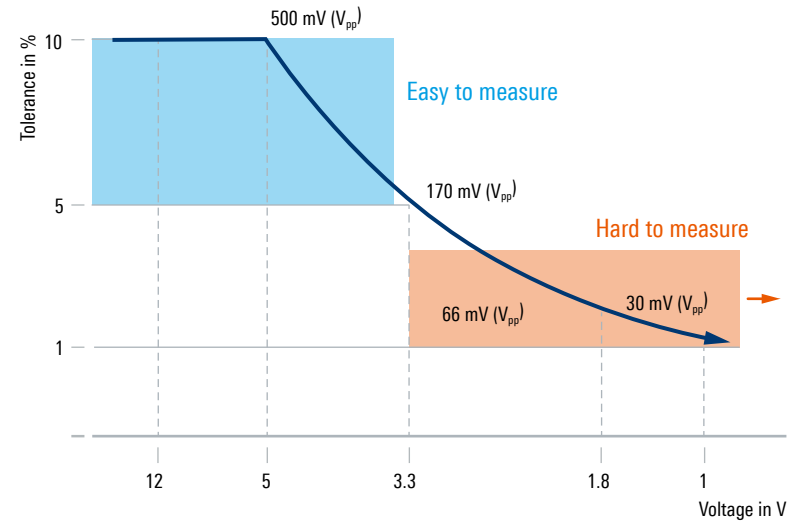
Lower rail voltages and smaller tolerances make it more difficult to make accurate power rail measurements.

As rails get smaller, so does the tolerance associated with these rails. Even older standards such as 5 V and 3.3 V rails may now have tighter tolerances than a few years back.

Rail value	Tolerance	Need to measure
3.3 V	1%	33 mV ( $V_{pp}$ )
1.8 V	2%	36 mV ( $V_{pp}$ )
1.2 V	2%	24 mV ( $V_{pp}$ )
1 V	1%	10 mV ( $V_{pp}$ )

Measuring 10% tolerance on 5 V is 500 mV; this is simple to do on any oscilloscope.

Measuring 1% tolerance on a 1 V signal is 10 mV; this is very difficult to do on most oscilloscopes. At these levels, oscilloscope noise may impact the measurement.



Not easy  
to measure

### What should be kept in mind?

With the tighter tolerances and lower voltages, accurately measuring the periodic and random disturbances and the drift is significantly more difficult.

1. Limited oscilloscope offset makes it difficult to zoom in on the waveform sufficiently.

2. Noise from the oscilloscope eats into the tolerance margin.

3. Noise from the probing system eats into the tolerance margin.

4. Oscilloscope and probe may not have enough bandwidth to see coupling sources.

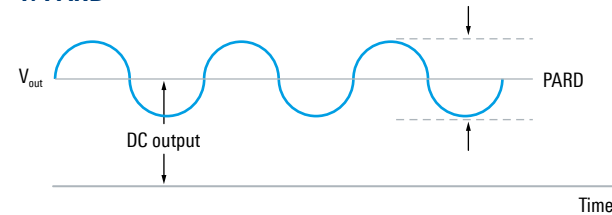
5. Capturing enough waveforms to make sure you see potential outliers can be difficult.

6. Viewing coupling sources in the frequency domain can be problematic.

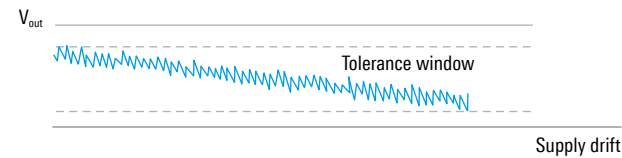
### Common power integrity measurements

Common power integrity measurements include periodic and random disturbances (PARD)

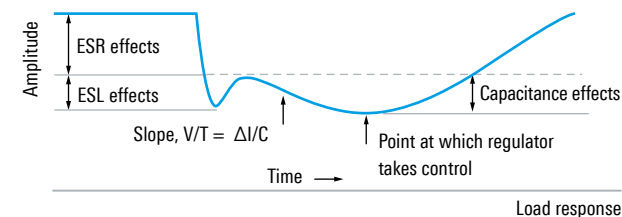
#### 1. PARD



#### 2. Drift



#### 3. Load response



# MEASUREMENT TECHNIQUES

## Waveform intensity

Let us start by talking about a few simple techniques to give you additional visual information about each power rail. The waveform intensity does not affect measurement accuracy, but rather makes it easier and faster to gain insight visually. Normally, an oscilloscope's default intensity is set so that users can see various signal intensity levels.

For power integrity measurements, the major concern is to find worst-case violations, not how frequently the signals occur. Increasing the waveform intensity can give you a better view of worst-case violations that happen less frequently.

## Default – 50%



## Adjusted to 90%





## Improving the display

There are several more techniques that give you additional visual information about each power rail. Improving the display does not affect measurement accuracy, but rather makes it faster and easier to gain insight visually.



## Infinite persistence

Turning on infinite persistence provides a good view of power rails and the amount of total noise on them. Looking at a  $V_{pp}$  measurement with stats will show ripple and noise.

Measurement results will be the same whether infinite persistence is on or not. It is simply a way of visually seeing how much of the  $V_{pp}$  contribution is due to noise.



## Color grading

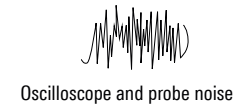
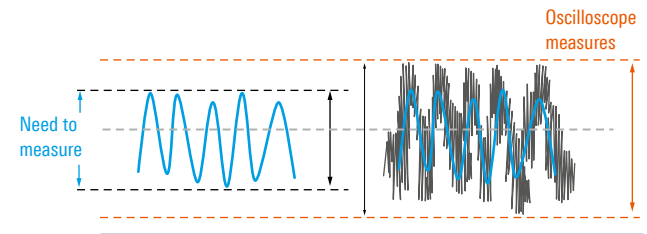
Another way to get additional visual information about each power rail is to turn on color grading. In this example, it is much easier to see transients when color grading is turned on:

- ▶ Pixels that are hit less frequently can be identified more easily
- ▶ You can see how often anomalies occur



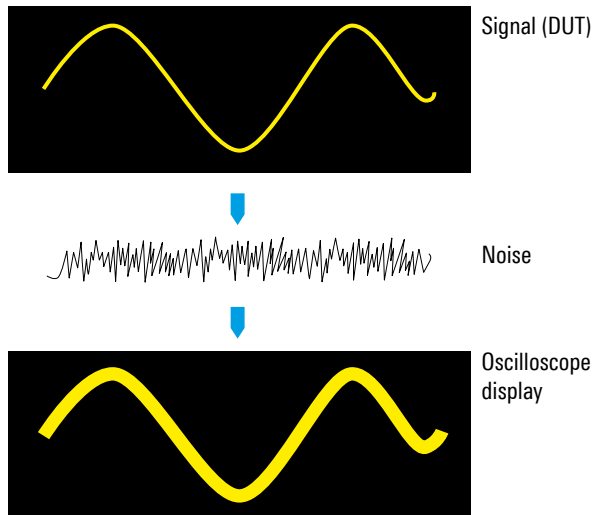
## Oscilloscope noise can make it difficult to measure small signals

What is so hard about making power rail measurements with oscilloscopes? For example, noise inherent to the oscilloscope and the probe used is problematic and results in overstated measurements



### Noise limits power rail $V_{pp}$ measurement accuracy

Noise from the oscilloscope and the probe is an enemy to measurement accuracy. When a signal enters an oscilloscope, frontend noise gets added to the signal before the ADC. Each stored sample point now includes the value of the original signal plus the noise that was present when the sample was acquired. On your oscilloscope, you will see this manifest with a thick wave-shape – not to be confused with fast update rate.



### Consequences

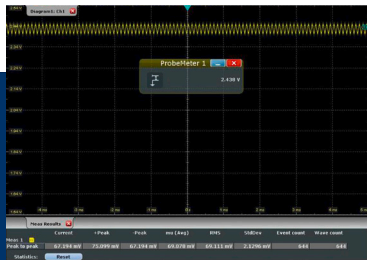
- ▶ Large measurement deviation:  
On your oscilloscope, you will see this manifest with a thick wavelshape
- ▶ Measured  $V_{pp}$  >> Actual  $V_{pp}$ :  
 $V_{pp}$  ripple measurement will be greater than the displayed voltage levels
- ▶ Can mask/hide anomalies:  
You will never be able to measure signals that are smaller than the noise on your oscilloscope

### Using more sensitive vertical setting

No oscilloscope has enough offset to address common power rails for today's products – ranging from under a volt to 12 V. In the case of the R&S®RTO, the oscilloscope natively has 1 V built-in offset compensation at 20 mV/div for example. This results in two negative factors:

- ▶ The oscilloscope is only using a fraction of its ADC vertical resolution
- ▶ Noise is a function of full screen vertical voltage. The oscilloscope is using a bigger vertical scale than is needed, resulting in additional noise

### 79% overstated



Using maximum built-in oscilloscope offset  
(3.0 V rail at 200 mV/div,  $V_{pp} = 79$  mV)



Using built-in probe offset  
(3.0 V rail at 2 mV/div,  $V_{pp} = 14$  mV)

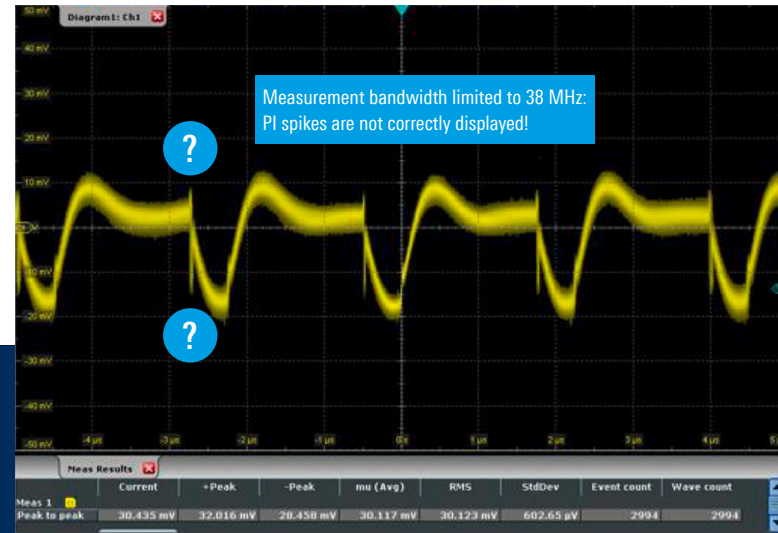
### Bandwidth versus noise tradeoff

Having sufficient probe bandwidth ensures measurement accuracy. The following example shows a very low-noise measurement from a 1:1 passive probe with 38 MHz of bandwidth.



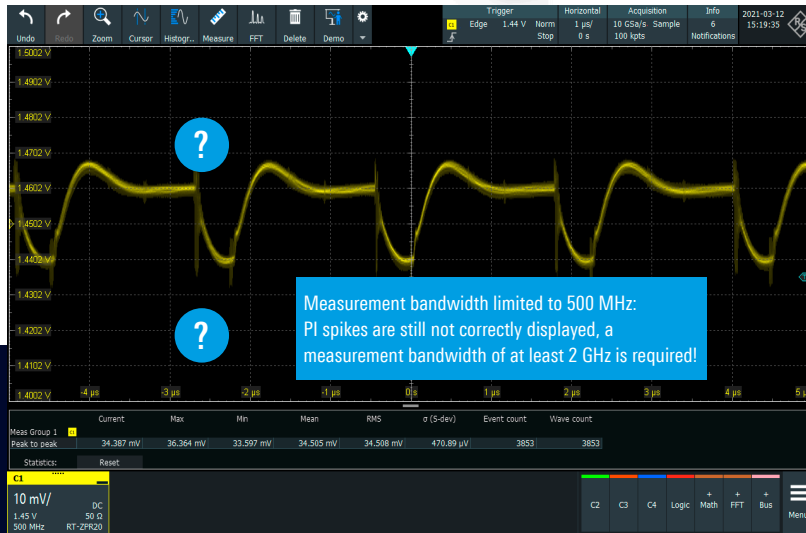
R&S®RT-ZP1X: 38 MHz,  
1:1 probes

### 16% underreported



R&S®RT-ZP1X: 1:1 passive probe  
38 MHz bandwidth ( $V_{pp} = 32$  mV)

But the 38 MHz bandwidth misses high frequency transients that are required for a precise measurement captured by a probe with 2 GHz bandwidth. While the 1:1 passive 38 MHz probe delivers low-noise measurements, it misses high frequency transients and therefore underreports  $V_{pp}$  measurements.



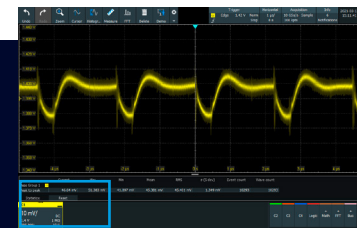
R&S®RT-ZPR20: 1:1 active 2 GHz bandwidth, captures high frequency transients ( $V_{pp} = 36.3$  mV; using 500 MHz BWL filter)

### Noise due to probe attenuation ratio

The choice of a probe is crucial for measurement accuracy. Attenuation is a critical factor for low noise. Here is a comparison of a 10:1 probe versus a 1:1 probe using 500 MHz bandwidth limit on each. Note the thickness of the trace using the 10:1 probe. This is noise and will cause overstated  $V_{pp}$  measurements.



34% overstated



### Challenges with insufficient oscilloscope offset

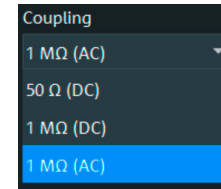
Oscilloscopes do not have enough offset to address common power rails – ranging from under a volt to 40 V. This results in two negative factors:

- ▶ The oscilloscope is only using a fraction of its ADC vertical resolution
- ▶ Noise is a function of full screen vertical voltage. The oscilloscope is using a bigger vertical scale than is needed, resulting in additional noise



Oscilloscope shows 1.5 V

Using a blocking cap or, if offered, AC coupling mode on the oscilloscope eliminates DC offsets. This enables the oscilloscope to see power rails, even if it does not have sufficient offset. However, these approaches limit the ability to see DC values.

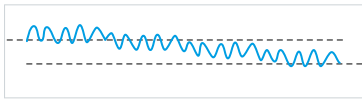


DC block

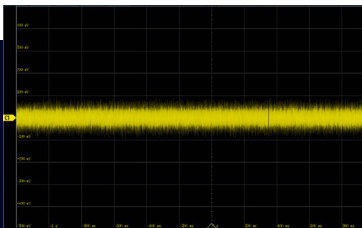
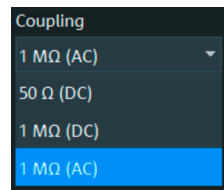


Oscilloscope shows 0 V

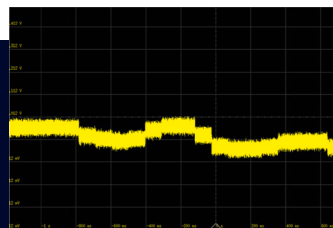
Worse, if there is any low frequency DC drift, AC coupling and blocking caps eliminate the ability to see this drift.



DC drift



DC blocks, eliminate visibility of low frequency effects



With the R&S®RT-ZPR40, low frequency effects can be detected

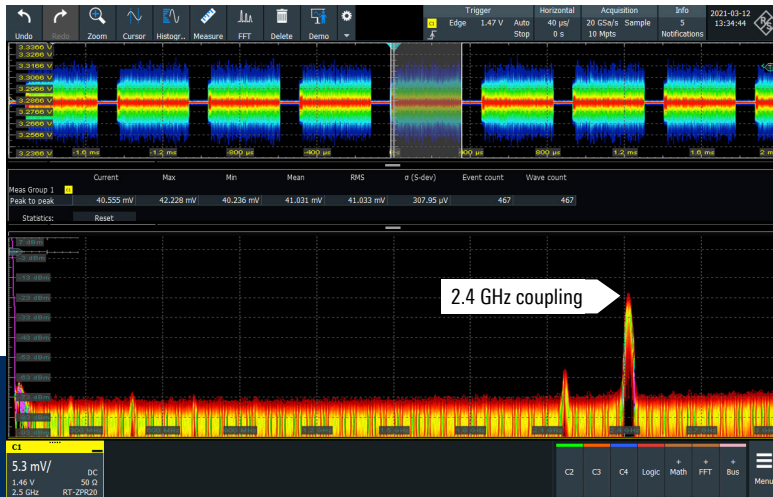
## Frequency domain view

Characterizing power rails typically involves ensuring there are no unwanted signals coupled onto the power rail. In addition, users sometimes need to look at switching harmonics. These are impossible to determine by looking at time domain waveforms, but are easy to see in the frequency domain using an oscilloscope's FFT.



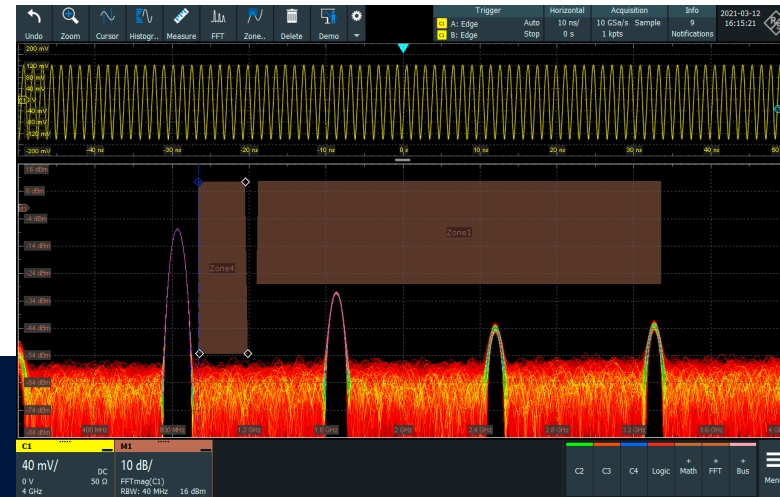
## Finding coupled signals

How much bandwidth is needed for frequency domain views? This depends on the potential signals including clocks and fast edge harmonics that may be coupled onto the power rail. Looking at the power rail in the time domain provides critical insight into  $V_{pp}$ . However, to find and isolate coupled signals on the power rail, such as this 2.4 GHz Wi-Fi signal, a frequency domain view is required.



## Zone triggering in frequency domain

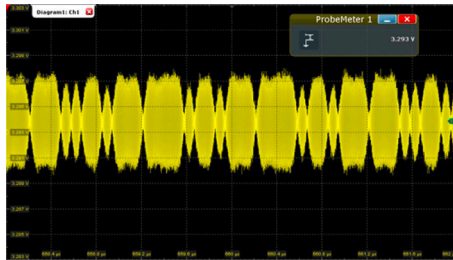
Zone triggering is an application that allows users to set up a geometric shape at a certain power level and frequency span. If the oscilloscope finds a power rail signal that enters this zone, the oscilloscope will trigger on this event.



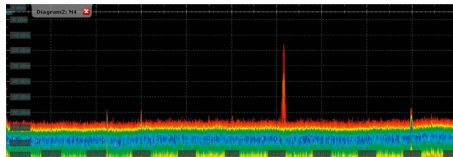


### Faster update rates

To be able to see certain types of signals, a fast update rate is needed. Oscilloscopes with slower update rates may have difficulty showing modulated signals. Here is an example of a power rail measurement in the time domain. If you can see the modulation, you know to look in the frequency domain.



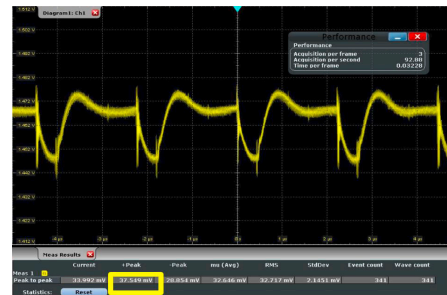
Fast update rate shows a modulated signal on a power rail. Such a signal is difficult to see on oscilloscopes with a slower update rate.



This indicates that a frequency domain view is needed.

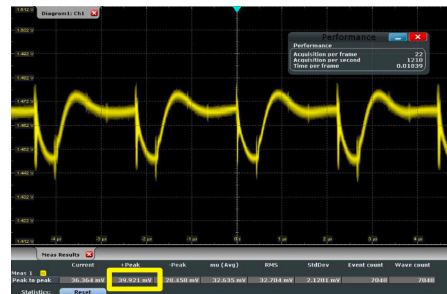
### Find worst-case violations faster

Finding these violations requires a fast update rate (how quickly the oscilloscope triggers, processes the information and plots it to the display). Slow update rates require 10 to 1000 times longer to capture the same amount of information.



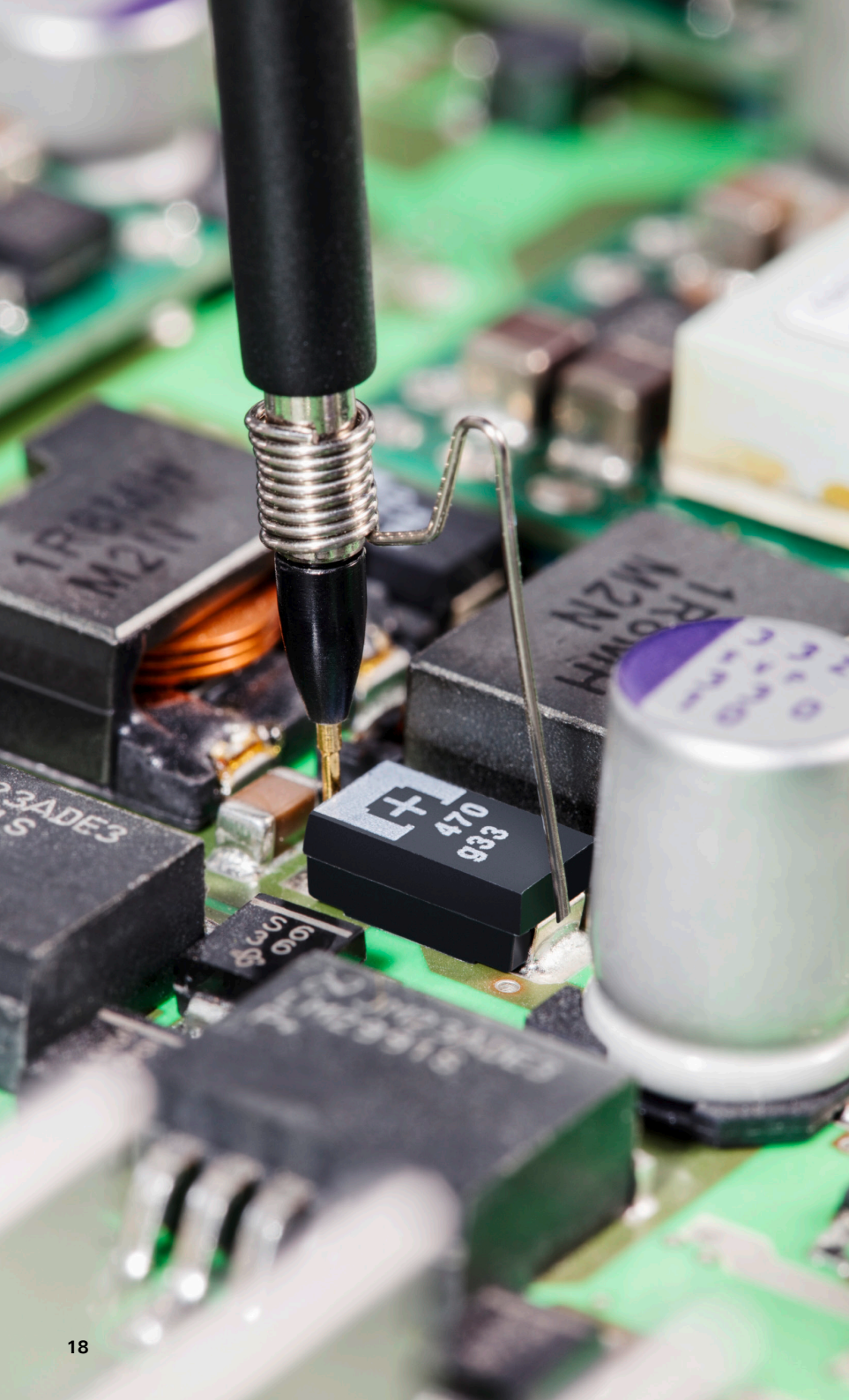
$$V_{pp} = 37 \text{ mV}$$

The worst-case  $V_{pp}$  measurement is understated due to slow update rate. You would need to let the oscilloscope run 10 times longer to see the actual worst-case  $V_{pp}$ .



$$V_{pp} = 39 \text{ mV}$$

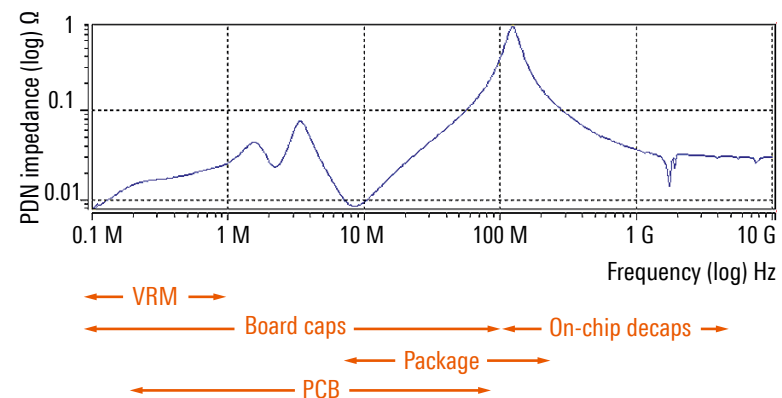
The worst-case  $V_{pp}$  measurement is more accurate due to fast update rate. This was achieved 10 times faster than a slower update rate would provide.



# WHY IMPEDANCE IS A CRITICAL METRIC

One of the biggest challenges in power integrity debugging is to identify the root cause of the problem. Impedance measurements provide valuable insights. They help to identify resonances, which are often responsible for power integrity as well as EMI problems.

Typical PDN impedance profile

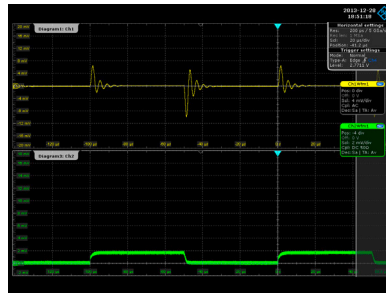
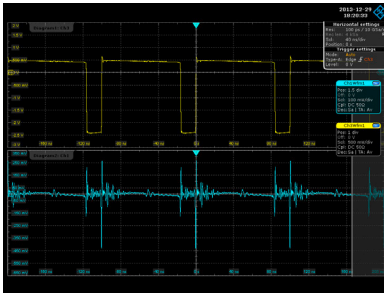


- ▶ Impedance profile formed by the interaction of various PDN components
- ▶ Impedance peak at package/chip resonance
- ▶ Peak impedance dependent on package, PCB, and on-chip parameters
- ▶ Typical impedance in the range of tens of milliohms

# IMPEDANCE TELLS US ABOUT

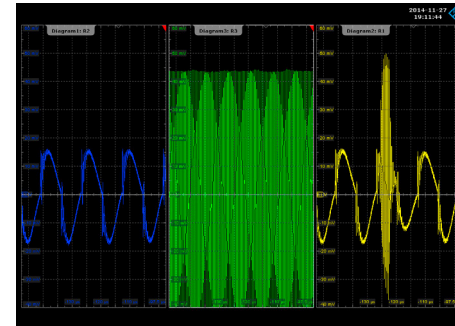
## High speed transients

While power integrity is mainly related to high speed systems, it stretches over a wide power range. Many difficult power integrity problems also occur below 50 mW. For example, a high speed logic driver, single gate logic, with about 40 mA and 250 ps edges, is a tough challenge. The high-speed switching causes strong transients on the power rail. It is not high current, but it is fast.



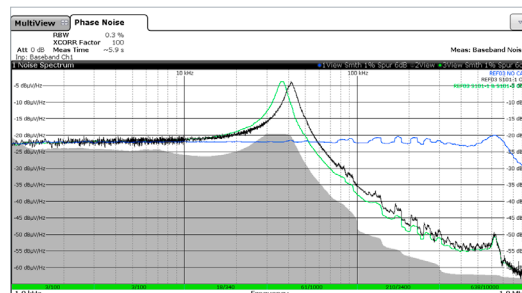
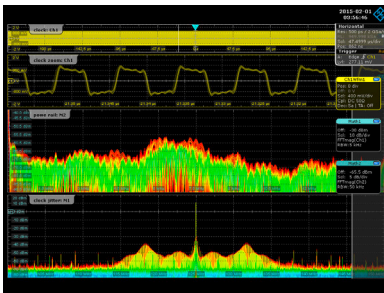
## Rogue waves

A rogue wave occurs when the circuit has more than one resonance, and those are excited at the same time and phased in such a way that one gets stacked right on top of the other.



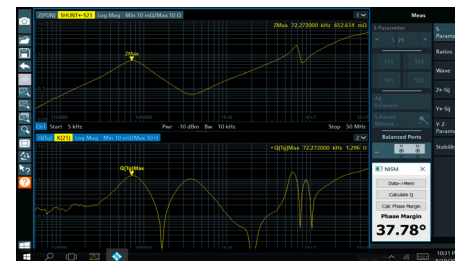
## EMI, jitter and LNA noise

EMI, jitter and low-noise amplifier (LNA) noise are caused by power supply noise. This noise can almost always be correlated to impedance.



## Control loop stability

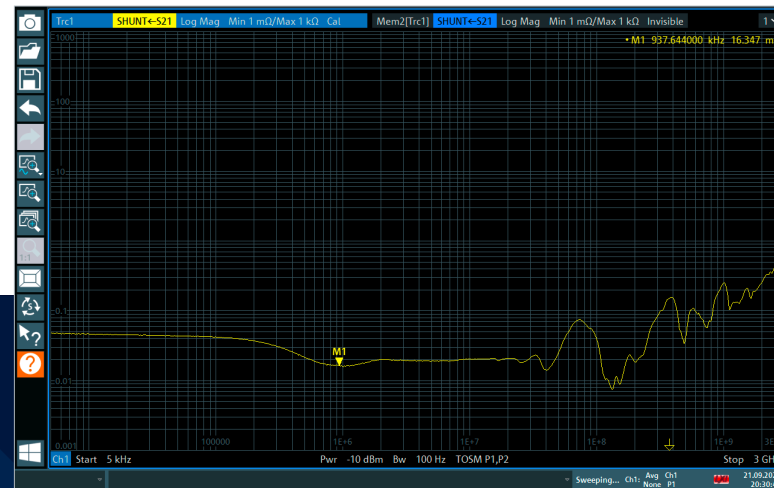
Determining control loop stability is becoming a challenge, because many voltage regulators do not allow access to the control loop. So directly measuring a Bode plot is not possible, as this would require inserting a small resistor into the control loop where a disturbance signal can be injected. Even if they do have access, they might have nested control loops. They may be seen on the outside of the package, but it is difficult to know anything about the ones that are inside the package. For this reason, a method of measuring stability from impedance was created.



Impedance measurement, showing control loop stability with 38° phase margin

# IMPEDANCE MEASUREMENTS HAVE AN UNLIMITED FREQUENCY RANGE

An impedance measurement is also beneficial because it can be performed on a broad bandwidth. For example, if a device design includes a gigahertz ADC and uses a front-end amplifier, there is a need to be able to measure stability at 1 GHz. If you are building a power supply and need to measure PDN bursts to the speed of your transceivers, that could easily be several GHz. This test method makes it possible to measure impedance to GHz frequencies using a vector network analyzer.



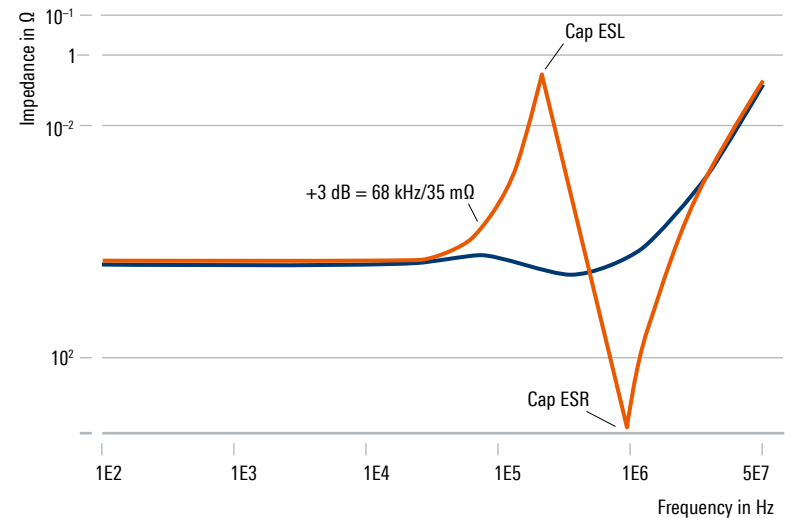
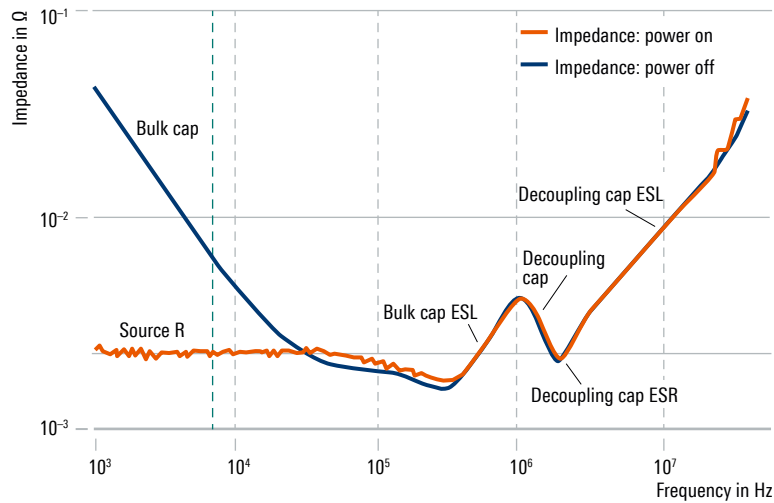
# INTERPRETING IMPEDANCE RESULTS

# HOW TO FIX POOR IMPEDANCE

Minimize L and maximize R.

1. Determine L from resonance or 3 dB point
2. Determine R from below resonant frequency
3. Set  $C = L/R^2$
4. Set Cap ESR = R

Undersized output capacitor reveals the inductance resulting from the internal pole and slope compensation

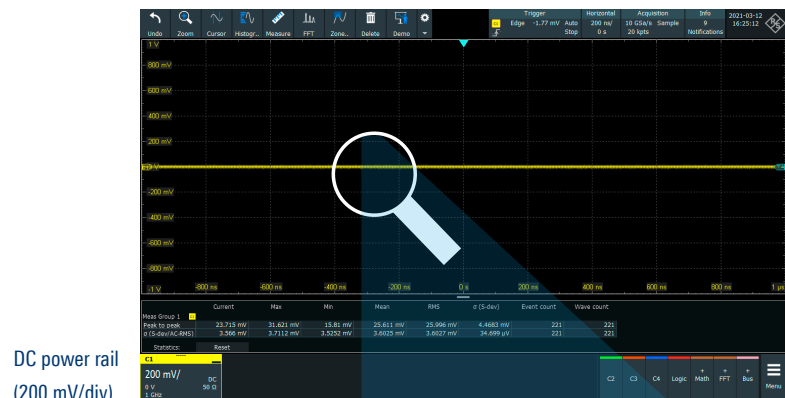


Motherboard measurements: Power on (red), power off (blue)

Flat = resistor | Rising = inductor | Falling = capacitor

# OSCILLOSCOPES: THE PRIMARY TOOL FOR POWER RAIL ANALYSIS

Oscilloscopes are a primary tool for measuring AC attributes of DC signals including ripple and PARD.



# WHAT SHOULD YOU LOOK FOR IN A PI SOLUTION FROM AN OSCILLOSCOPE?

- ▶ Low noise to minimize measurement system impact on tolerance testing
- ▶ 2 GHz to 4 GHz of bandwidth to capture high frequency coupling
- ▶ Fast update rate to quickly capture worst-case outliers
- ▶ Excellent frequency domain capability to view both time and frequency content easily
- ▶ Deep acquisition memory to capture long time periods at high sample rates



# 50 Ω CHECK AT 1 mV/div

The best approach is to measure with an oscilloscope that has low noise. It is possible to measure its noise by removing all of its inputs and to measure the peak-to-peak curve at 1 mV/div..

Oscilloscope vendors characterize  $V$  (RMS) in data sheets, but not  $V_{pp}$   
For power integrity measurements, a  $V_{pp}$  AC (RMS) measurement will be lower and more impressive, but a  $V_{pp}$  amplitude measurement is what you will care about.



R&S®RT06: 100 μV (RMS) at 1 GHz bandwidth, 1 mV/div



R&S®RT06: max. 988 μV ( $V_{pp}$ ) at 1 GHz bandwidth, 1 mV/div

# CHARACTERIZING YOUR OSCILLOSCOPE'S $V_{pp}$ NOISE IN FIVE MINUTES

Noise is directly related to full screen vertical scale. So, at each larger vertical scale, the oscilloscope will have more overall noise. You can quickly check each vertical setting that you will be using for power integrity measurements.

$V_{pp}$  (max.) = ?



1. Disconnect all inputs (can be performed with probe attached)
2. Set sample rate (e.g. 10 Gsample/s), memory depth, (e.g. 1 Mpoint), path and bandwidth to mirror your requirements
3. Turn on  $V_{pp}$  measurement with statistics for channel 1
4. Adjust vertical setting to cover the smallest vertical setting you will use
5. Record  $V_{pp}$  value
6. Repeat for all other vertical scales that you may use
7. Repeat for all channels that may be used (will vary from channel to channel)

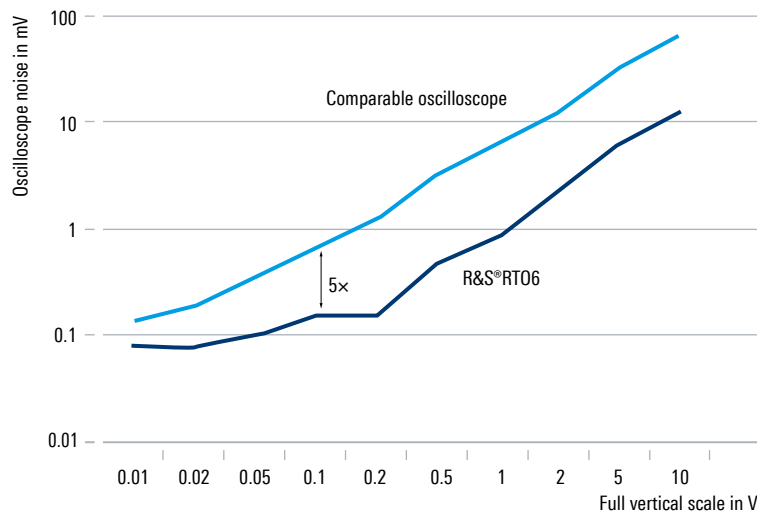


# CHOOSE AN OSCILLOSCOPE WITH LOW NOISE

# USE THE MOST SENSITIVE VERTICAL SETTING POSSIBLE

Oscilloscopes will have less noise on smaller vertical settings. Here is an example at 20 mV/div and 2 mV/div, where noise is almost three times lower.

1 GHz noise comparison between two oscilloscopes with equivalent bandwidth



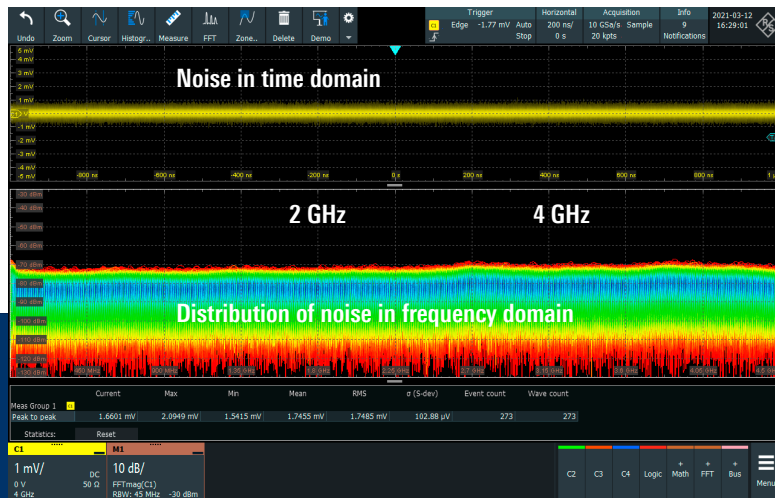
20 mV/div (noise  $V_{pp} = 3.16$  mV)



2 mV/div (noise  $V_{pp} = 870$   $\mu$ V)

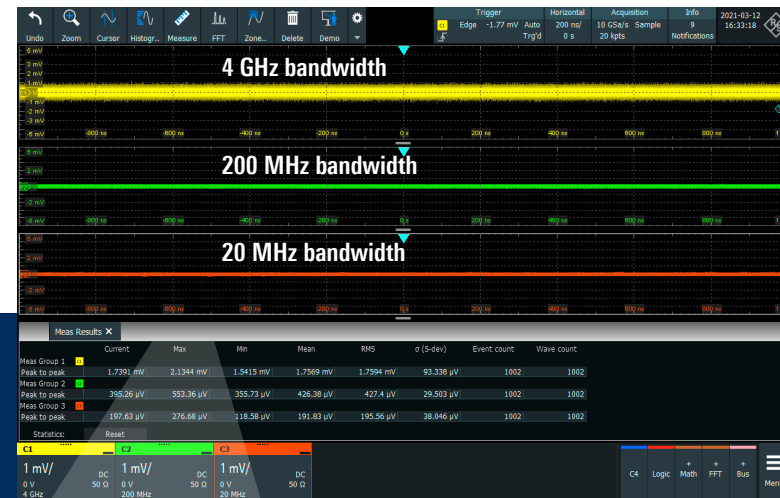
# NOISE COMPARISON: TIME DOMAIN VERSUS SPECTRAL CONTENT

Another technique to make more accurate measurements is to get rid of broadband noise. Here is an FFT of the oscilloscope's trace – with no signals connected to the input. The oscilloscope has a Gaussian noise distribution. If all of the noise is integrated in the frequency domain, the result will provide the same value as the noise measurements in the time domain.



# REDUCE NOISE WITH BWL FILTERS

By turning on a BWL filter, the overall system noise is reduced. The more filtering, the lower the noise. In this example, there is 10 times less noise with 20 MHz versus full system bandwidth of 4 GHz



All other settings are identical

4 GHz	$V_{pp} = 2.13 \text{ mV}$	Highest noise
200 MHz	$V_{pp} = 0.553 \text{ mV}$	
20 MHz	$V_{pp} = 0.277 \text{ mV}$	Lowest noise

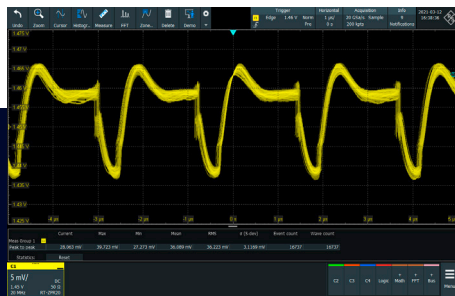
# HOW MUCH BANDWIDTH DO YOU NEED?

Measurement bandwidth will also impact measurement accuracy. You can get very low-noise measurements from a 1:1 probe with 20 MHz of bandwidth, but the probe misses high frequency transients that are required for a precise measurement that can be seen with a 1 GHz bandwidth.

Measurement bandwidth will also impact measurement accuracy. You can get very low-noise measurements from a 1:1 probe with 20 MHz of bandwidth, but the probe misses high frequency transients that are required for a precise measurement that can be seen with a 1 GHz bandwidth.

This depends on your power rails and it is impossible to tell in the time domain. A rule of thumb is: bandwidth =  $0.35/\text{rise time}$  if you know what edge speed is needed. However, it is not known which coupled signals may be present. One way to determine this is to look at the oscilloscope's FFT without any signals connected, then connect to a power rail and see which upper frequencies have content that differs.

Bandwidth = 20 MHz



$V_{pp} = 30 \text{ mV}$

Bandwidth = 1 GHz



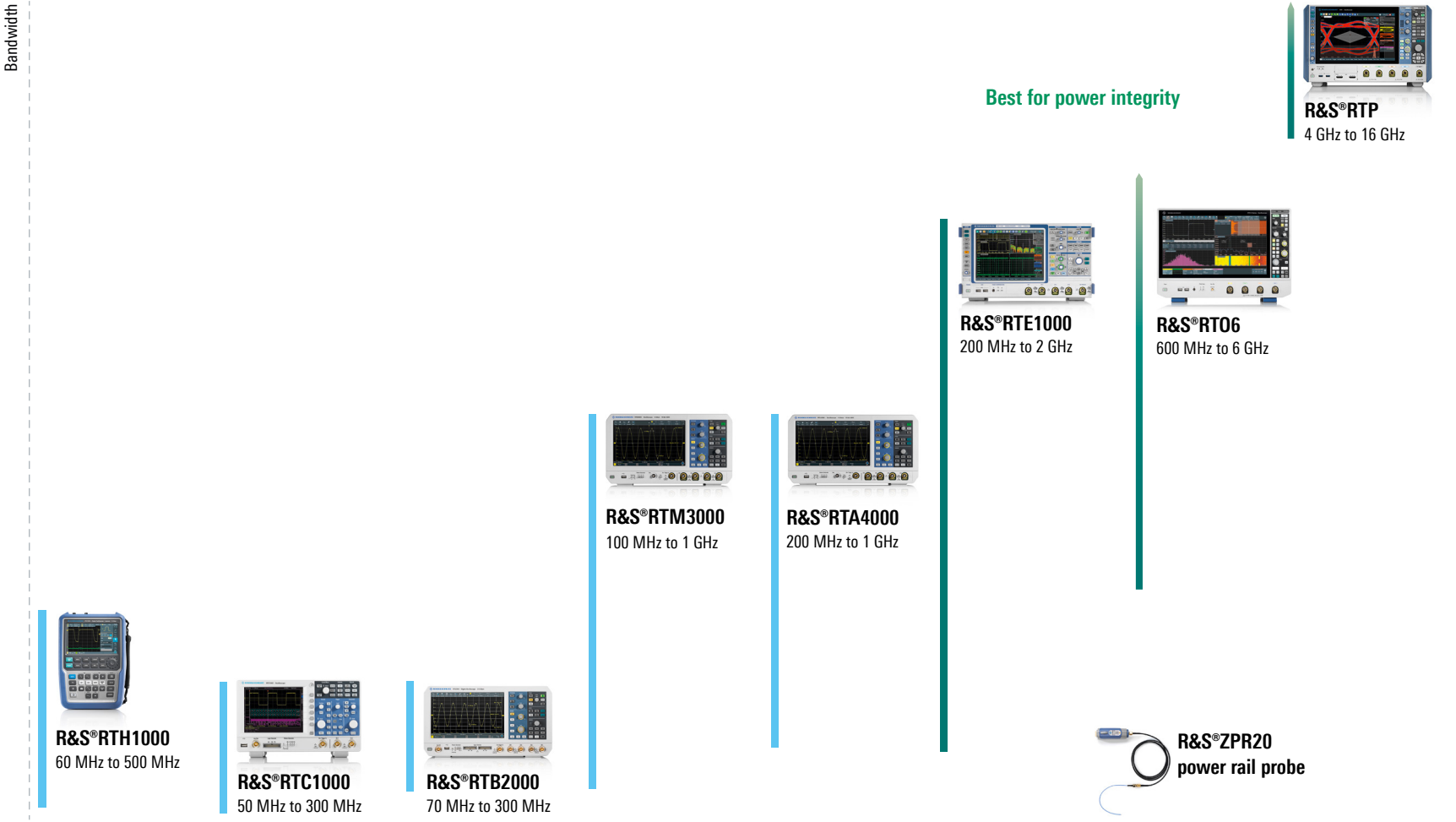
$V_{pp} = 39 \text{ mV}$

How much is needed here?



# ROHDE & SCHWARZ OSCILLOSCOPE PORTFOLIO

Most oscilloscope manufacturers will have a certain class of oscilloscopes that are better suited for power integrity measurements. These oscilloscopes generally have sufficient bandwidth, the lowest noise in the portfolio, deep memory, bandwidth limit filters and other attributes that make for better PI measurements. The same holds true for Rohde&Schwarz. In the Rohde&Schwarz oscilloscope portfolio, two families, the R&S®RTO and R&S®RTE, are best suited for PI measurements.



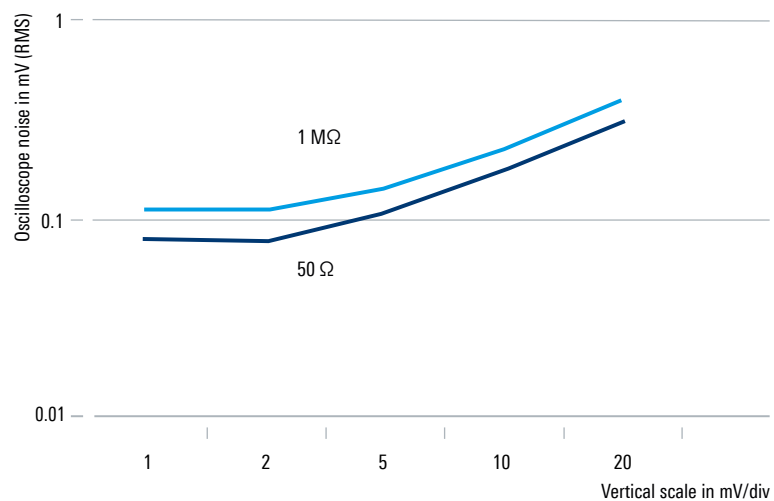
Performance class/segment

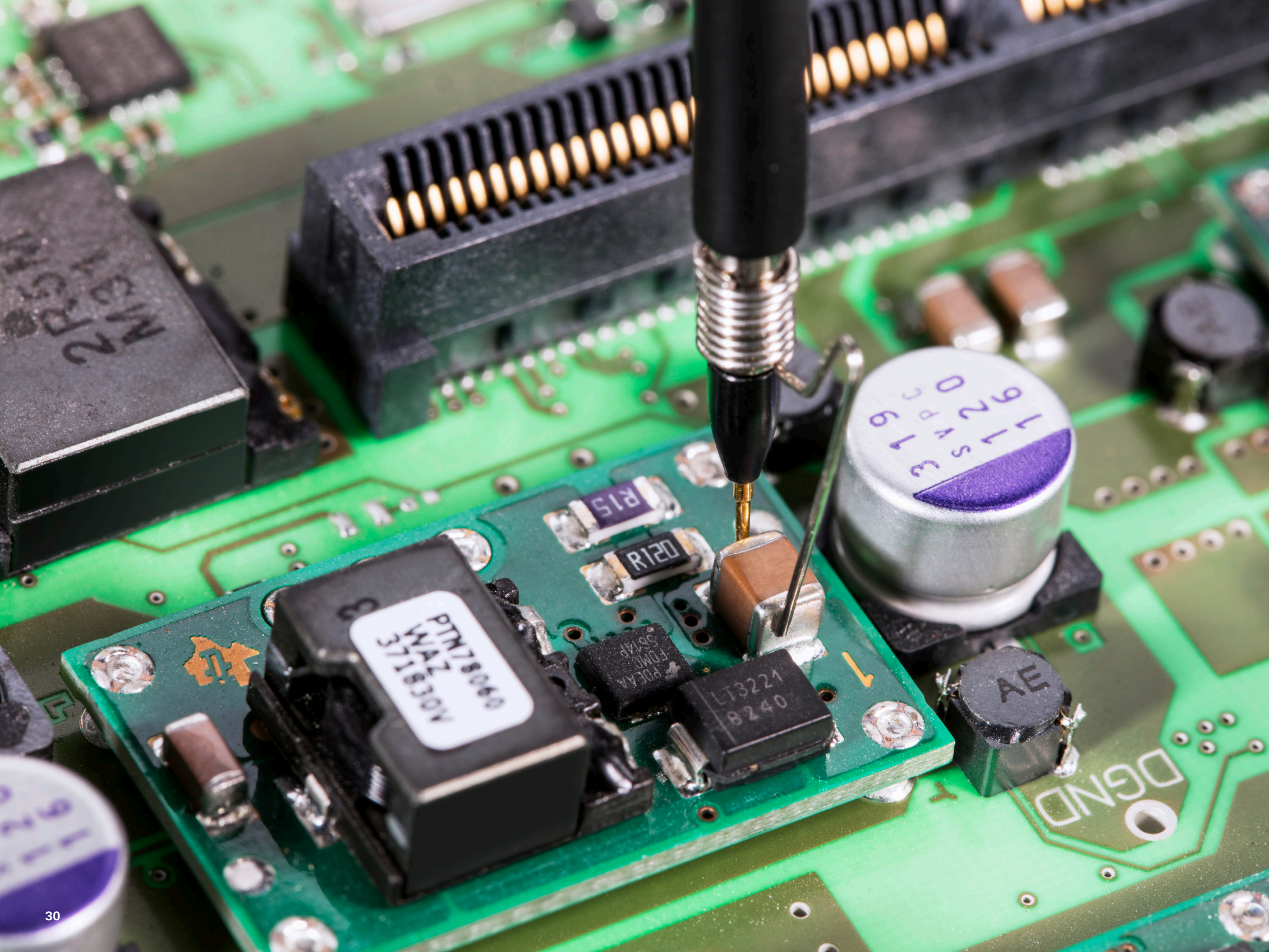
# CHOOSING BETWEEN 50 $\Omega$ AND 1 M $\Omega$

- ▶ Are measurements more accurate using the oscilloscope's 1 M $\Omega$  input? Which has good DC impedance, but more noise and is bandwidth limited to 500 MHz?
- ▶ Is it better to use the 50  $\Omega$  path, which is quieter and offers more bandwidth, but has only 50  $\Omega$  loading at DC and therefore a bigger impact on getting accurate DC values?

The best approach is to use the lower-noise 50  $\Omega$  path with more bandwidth and couple it with a power rail probe that provides high DC impedance.

## 500 MHz noise comparison of R&S®RT06

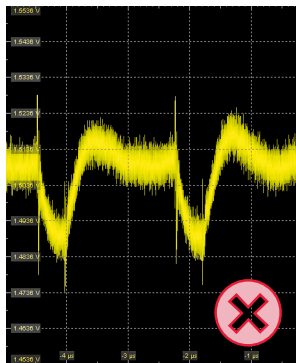




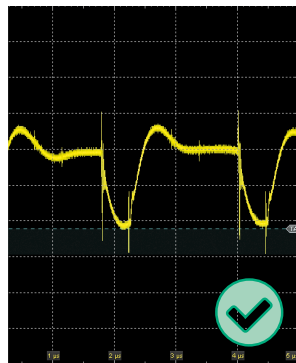
# WHAT TO LOOK FOR IN A PROBE

- ▶ 1:1 attenuation and low noise
- ▶ High offset
- ▶ High bandwidth (> 4 GHz)
- ▶ High input impedance

Passive probe



Power rail probe



# WHAT SHOULD YOU LOOK FOR IN A PI SOLUTION FROM A PROBE?

- ▶ 1:1 attenuation and low noise
- ▶ High offset
- ▶ High bandwidth (> 4 GHz)
- ▶ High input impedance



# PROBING METHODS

There are many methods for probing a power rail:

## 10:1 probe



- ❌ 10:1 attenuation adds noise
- ❌ < 500 MHz bandwidth
- ✅ Good offset due to 10:1 attenuation
- ✅ Good input impedance at very low frequencies
- ❌ Heavier loading at > 100 MHz

### Benefits

- ▶ Most common probe
- ▶ 10:1 increases oscilloscope's offset capability

### Limitations

- ▶ 10:1 attenuation increases noise, eating in to tolerance level
- ▶ Limited bandwidth
- ▶ Higher loading, especially at frequencies above 100 MHz

## 1:1 probe



- ✅ 1:1 attenuation is low noise
- ❌ < 50 MHz bandwidth limits capability
- ❌ Offset is limited to oscilloscope offset
- ✅ Good input impedance at very low frequencies

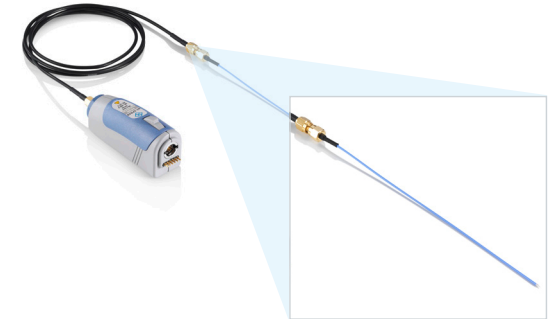
### Benefits

- ▶ Lower noise
- ▶ Inexpensive
- ▶ Easy to use/connect

### Limitations

- ▶ Very limited bandwidth (typically less than 50 MHz)
- ▶ Relies on oscilloscope's offset capability or AC coupling to remove offset

## Direct connect 50 Ω pigtail



- ✅ Direct connect is low noise
- ✅ Bandwidth to limit of oscilloscope
- ✅ DC block removes offset
- ❌ DC block misses drift
- ❌ Poor input impedance

### Benefits

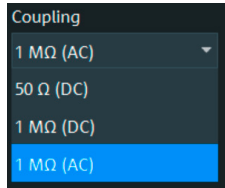
- ▶ Lower noise
- ▶ Inexpensive
- ▶ Bandwidth up to oscilloscope bandwidth

### Limitations

- ▶ Relies on oscilloscope's offset capability or DC block to remove offset
- ▶ Higher loading on DUT



## AC coupling



- ✓ Direct connect is low noise
- ✓ AC coupling removes offset
- ✓ High input impedance of AC (1 MΩ) path
- ✗ Lower bandwidth and higher noise of AC (1 MΩ) path than 50 Ω path
- ✗ AC coupling misses drift

### Benefit

- ▶ Removes DC component to zoom in on waveform

### Limitations

- ▶ Typically only 1 MΩ path limits bandwidth
- ▶ Eliminates the ability to see drift over time
- ▶ Eliminates the ability to see absolute vertical value

## DC block



- ✓ Direct connect is low noise
- ✓ Bandwidth to limit of oscilloscope
- ✓ DC block removes offset
- ✗ DC block misses drift
- ✗ Poor input impedance

### Benefit

- ▶ Removes DC component to zoom in on waveform

### Limitations

- ▶ Eliminates the ability to see drift over time
- ▶ Eliminates the ability to see absolute vertical value

## Dedicated power rail probe



- ✓ 1:1 is low noise
- ✓ Bandwidth > 4 GHz to capture high frequency coupling
- ✓ Built-in offset supports up to 60 V
- ✓ Excellent input impedance minimizes loading

### Benefits

- ▶ 1:1 attenuation and low noise
- ▶ Over 4 GHz bandwidth captures high speed transients and coupling
- ▶ Built-in offset to zoom in on the waveform for more accurate measurements
- ▶ High input impedance limits impact to DUT
- ▶ Integrated 16-bit DC voltmeter for fast voltage level confirmation

### No limitations

# CHOOSING THE RIGHT PROBE

Specialized for power integrity



**R&S®RT-ZP1X**  
1:1, 38 MHz,  
passive



**R&S®RT-ZPR20/  
R&S®RT-ZPR40**  
2 GHz/4 GHz, active,  
single-ended



**R&S®RT-ZP10**  
10:1, 500 MHz,  
passive



**R&S®RT-ZD30**  
2 GHz, active,  
differential



**R&S®RT-ZS20E**  
2 GHz, active,  
single-ended



**R&S®RT-ZM30**  
3 GHz, modular,  
probe

Price

# R&S® RT-ZPR20/RT-ZPR40 POWER RAIL PROBE

- ▶ Designed uniquely for measuring small perturbations on power rails
- ▶ Active, single-ended probe
- ▶ Low noise with 1:1 attenuation
- ▶ Best-in-class offset compensation capability



## Specifications in brief

Attenuation	1:1
Bandwidth	
Probe	2 GHz <sup>1)</sup> or 4 GHz <sup>2)</sup>
Browser	350 MHz
Dynamic range	±850 mV
Offset range	> ±60 V
Noise	
R&S®RTO2000 oscilloscope	107 µV AC (RMS)
Oscilloscope + probe noise (at 1 GHz, 1 mV/div)	120 µV AC (RMS)
Input resistance	50 kΩ at DC
R&S®ProbeMeter	integrated
Coupling	DC or AC

<sup>1)</sup> 2.4 GHz band visible due to slow frequency.

<sup>2)</sup> 5 GHz band visible due to slow frequency.



# R&S® RTE/RTO/RTP OSCILLOSCOPES AND POWER RAIL PROBE

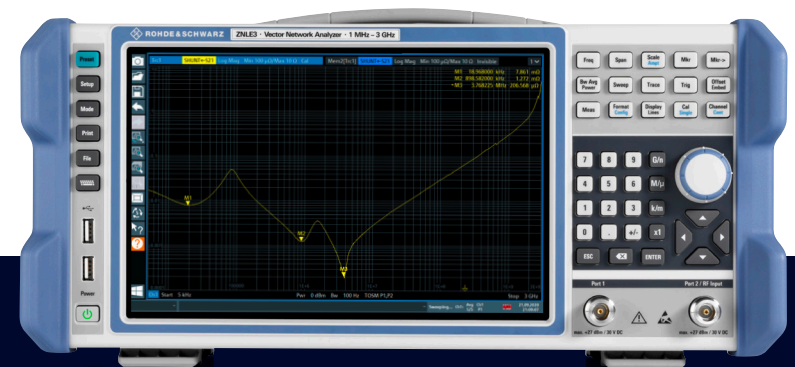
When combined with an R&S®RTP, R&S®RTO or R&S®RTE oscilloscope, the R&S®RT-ZPR20/R&S®RT-ZPR40 power rail probes will quickly help you characterize your power rail. In addition to the industry's fastest update rate (1 million waveforms/s), that will help you find worst-case violations more quickly than any other solution.



- 1:  $V_{pp}$  with statistics
- 2: Built-in 16-bit R&S®ProbeMeter shows DC voltage
- 3: High bandwidth shows coupled sources

# IMPEDANCE MEASUREMENTS USING A VECTOR NETWORK ANALYZER

Unlike many other power integrity measurements that are measured with an oscilloscope, impedance measurements are most accurately performed on a vector network analyzer (VNA).

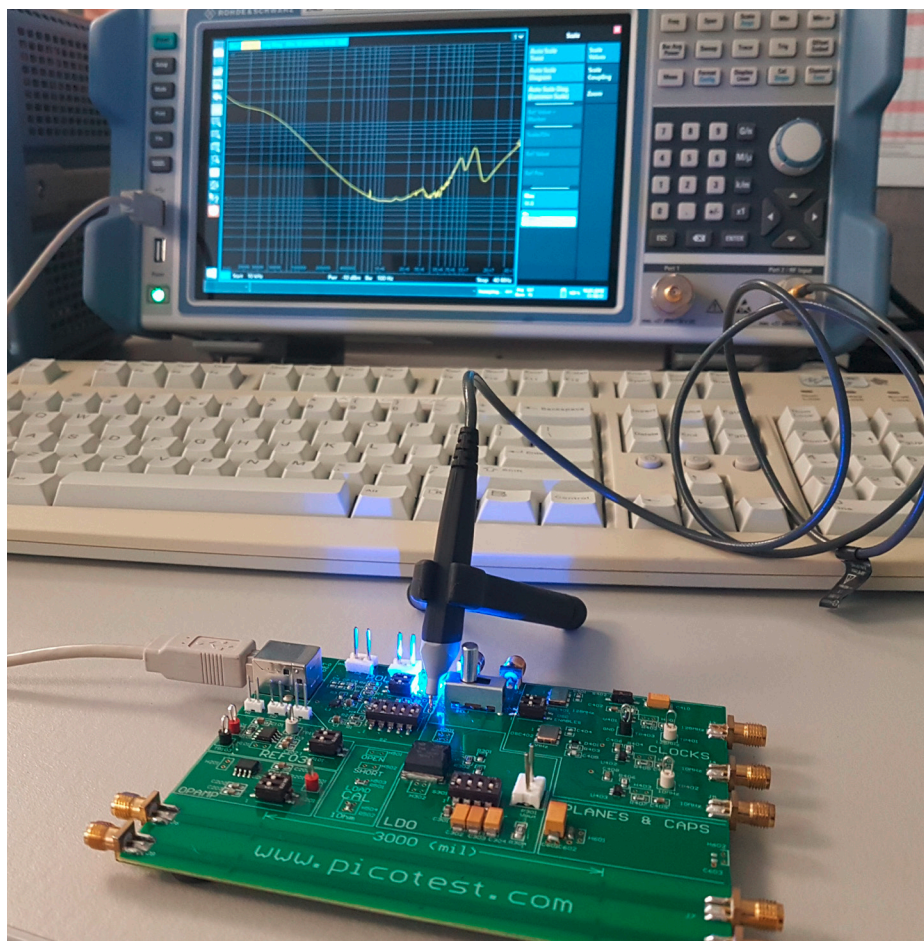


# ONE-PORT VNA MEASUREMENTS

The simplest impedance measurement to make with a vector network analyzer (VNA) is a one-port measurement (reflection measurement). Every vector network analyzer can do it, and it requires a basic open short match (OSM) calibration, which is simple to do.

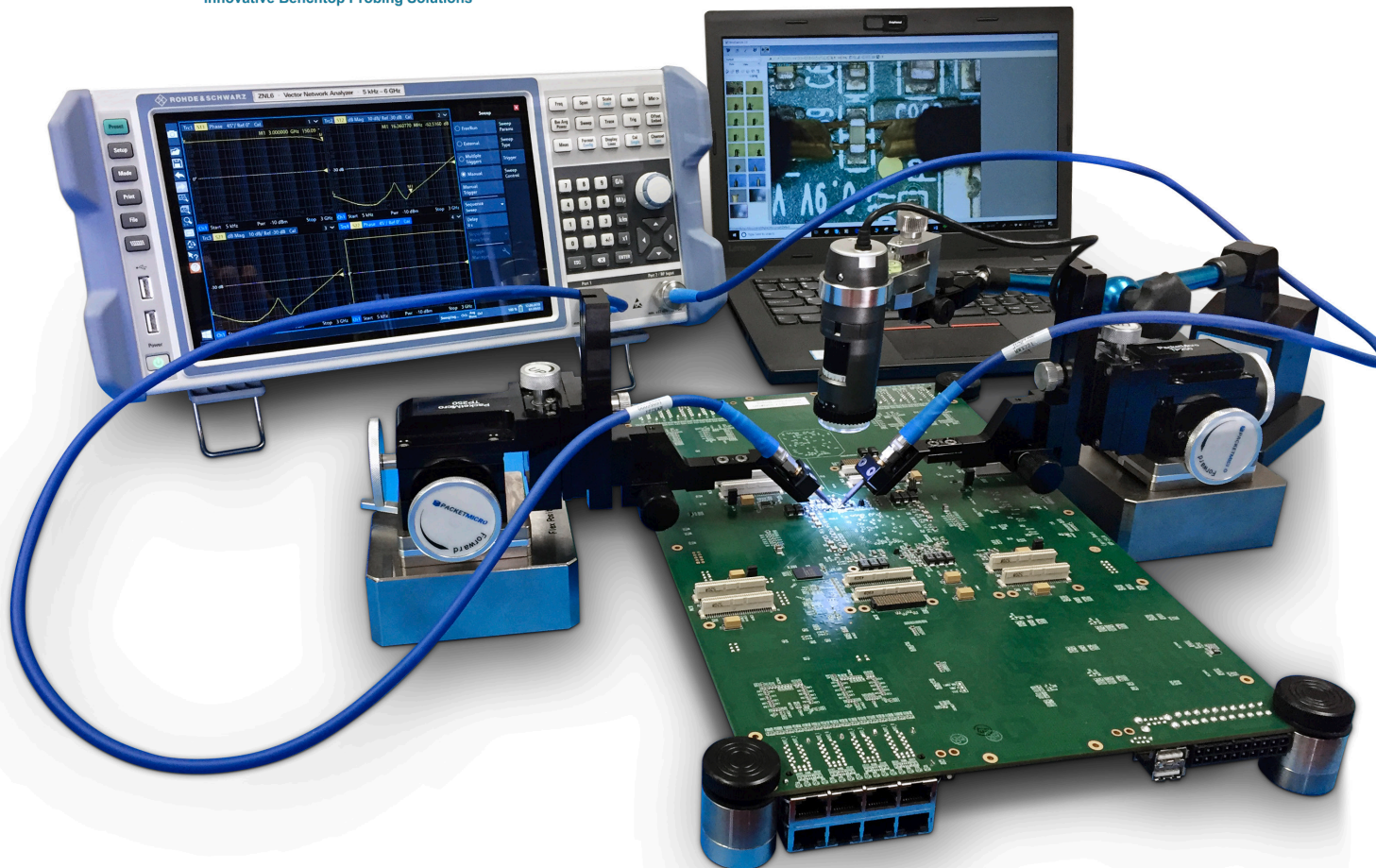
However, the interface provided from the VNA is a coaxial one, and in order to be able to perform measurement on a PCB board for example, you need an adapter such as a Picotest handheld transmission line probe.

One-port measurements are rarely used because they have an impedance range that often disagrees with what is needed. One port measurements have low uncertainty starting at about  $10\ \Omega$  up to several hundred ohm, but how many of us are building power distribution networks that have target impedances above  $10\ \Omega$ ? Not many. So, this turns out to be a reasonably good measurement for measuring the stability of operational amplifiers and voltage references, and generally not so much for power distribution networks.



# TWO-PORT VNA MEASUREMENTS

Two-port shunt measurements are perfect for power integrity. The measurement uncertainty for this configuration is low from about 1 m $\Omega$  to about 1 k $\Omega$ , also perfectly covering the low impedances of power delivery networks (PDN). You can e.g. use PacketMicro probes to make these measurements on your PCB.



# ROHDE & SCHWARZ VECTOR NETWORK ANALYZERS

**Multiport solution**  
R&S®ZNB



**Economy models**  
R&S®ZNL/R&S®ZND

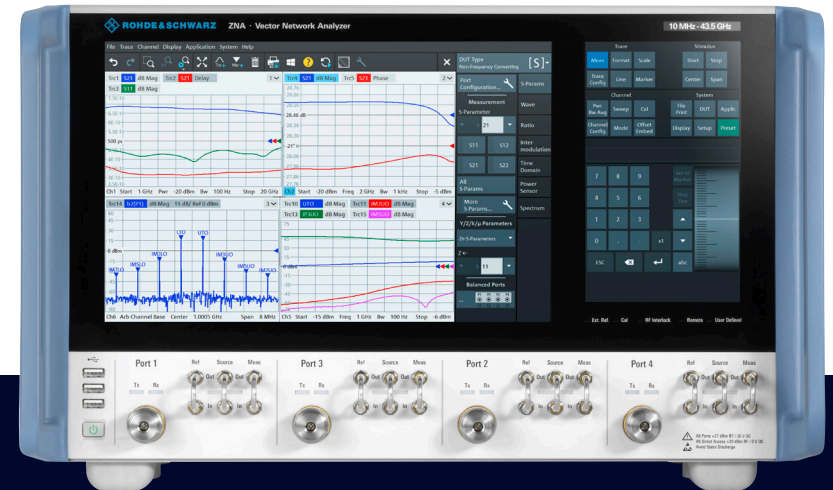




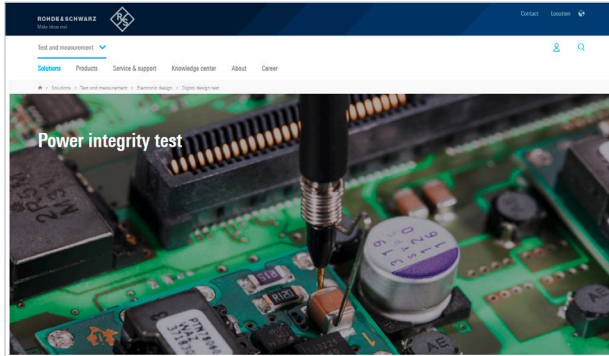
**Midrange model**  
R&S®ZNB



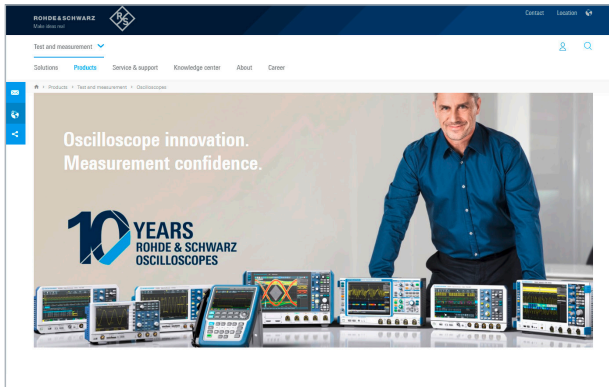
**High-end model**  
R&S®ZNA



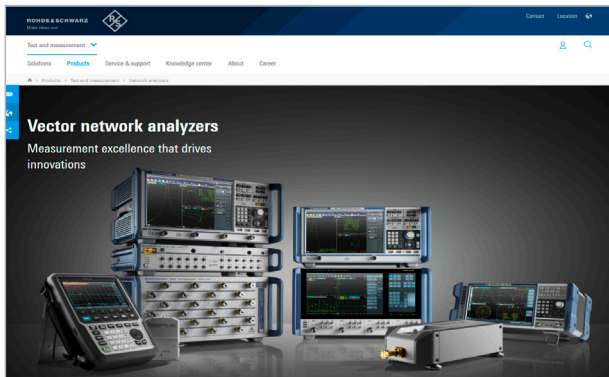
# REFERENCES



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[www.rohde-schwarz.com/oscilloscopes](http://www.rohde-schwarz.com/oscilloscopes)



[www.rohde-schwarz.com/networkanalyzers](http://www.rohde-schwarz.com/networkanalyzers)

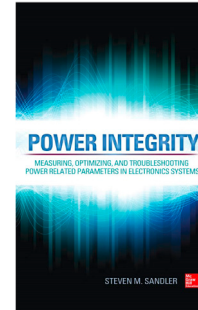
[www.picotest.com/measurements/rohde.html](http://www.picotest.com/measurements/rohde.html)



[www.packetmicro.com](http://www.packetmicro.com)



"Power Integrity: Measuring, Optimizing, and Troubleshooting Power Related Parameters in Electronics Systems." by Steven M. Sandler, McGraw-Hill Education, 2014.





## About Rohde & Schwarz

The Rohde & Schwarz technology group is among the trailblazers when it comes to paving the way for a safer and connected world with its leading solutions in test & measurement, technology systems and networks & cybersecurity. Founded more than 85 years ago, the group is a reliable partner for industry and government customers around the globe. The independent company is headquartered in Munich, Germany and has an extensive sales and service network with locations in more than 70 countries.

[www.rohde-schwarz.com](http://www.rohde-schwarz.com)

## Rohde & Schwarz customer support

[www.rohde-schwarz.com/support](http://www.rohde-schwarz.com/support)

