POWER INTEGRITY

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

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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

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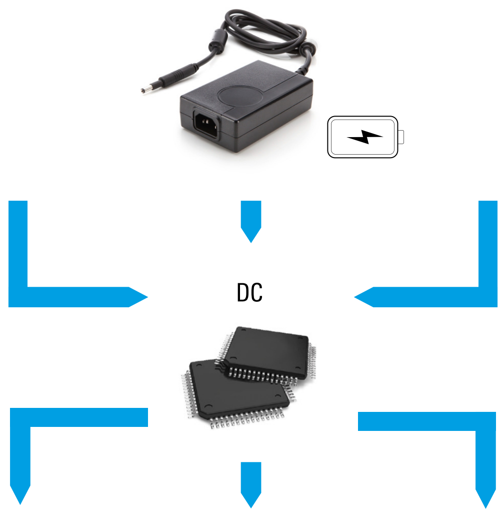
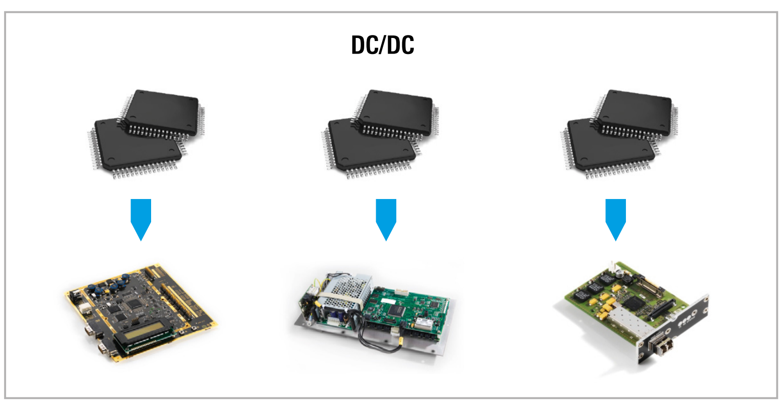
OVERVIEW

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.



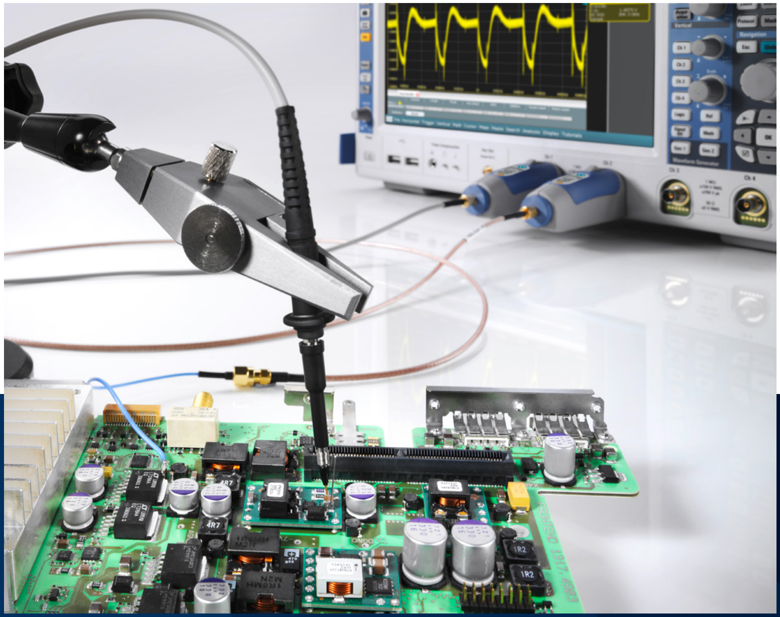
Printed circuit boards



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})

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

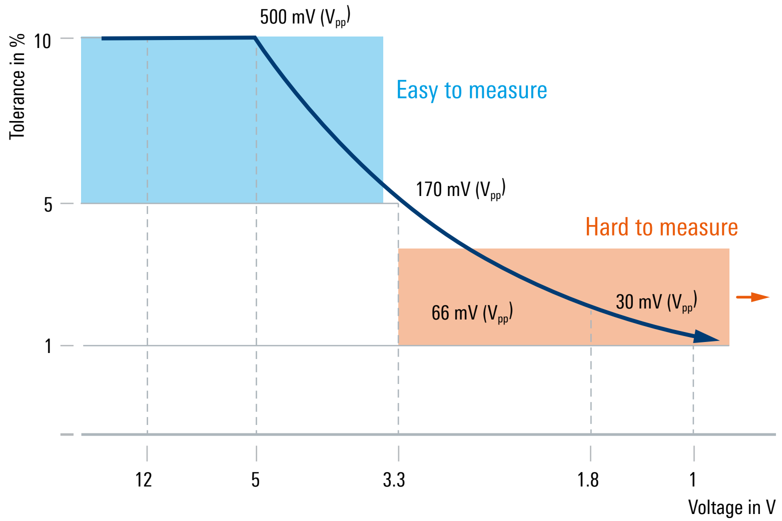
Lower rail voltages and smaller tolerances make it more difficult to make accurate power rail measurements.

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.

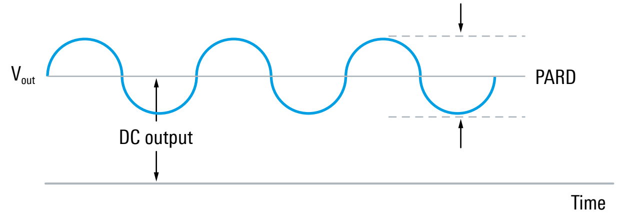
5. Capturing enough waveforms to make sure you see potential outliers can be difficult.

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

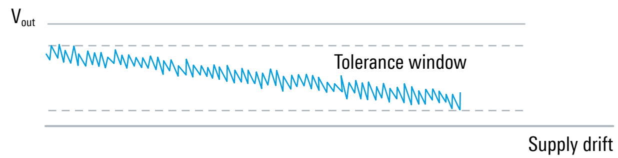
Common power integrity measurements

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

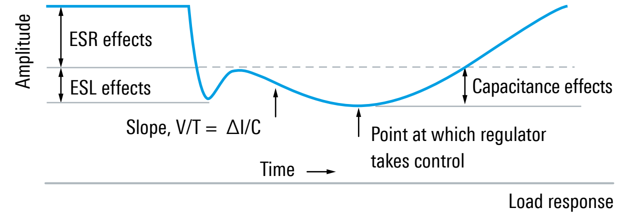
1. PARD



2. Drift



3. Load response



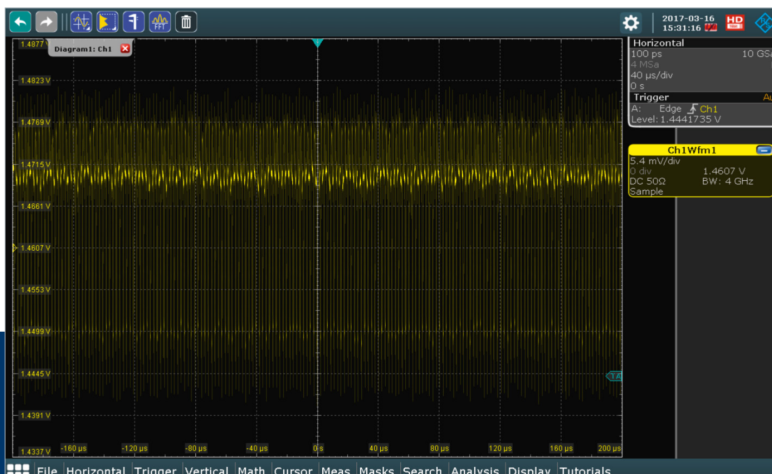
MEASUREMENT TECHNIQUES

Waveform intensity

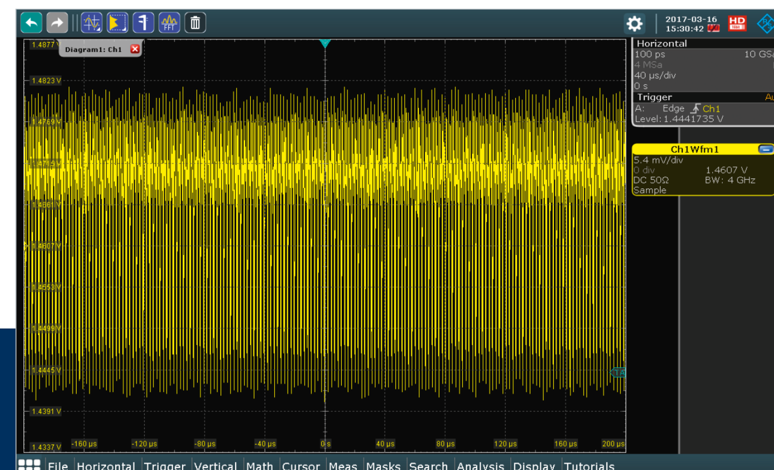
Let us start by talking about a few simple techniques to give you additional visual information about each power rail. The waveform intensity does not affect measurement accuracy, but rather makes it easier and faster to gain insight visually. Normally, an oscilloscope's default intensity is set so that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

For power integrity measurements, the majorconcern 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 %



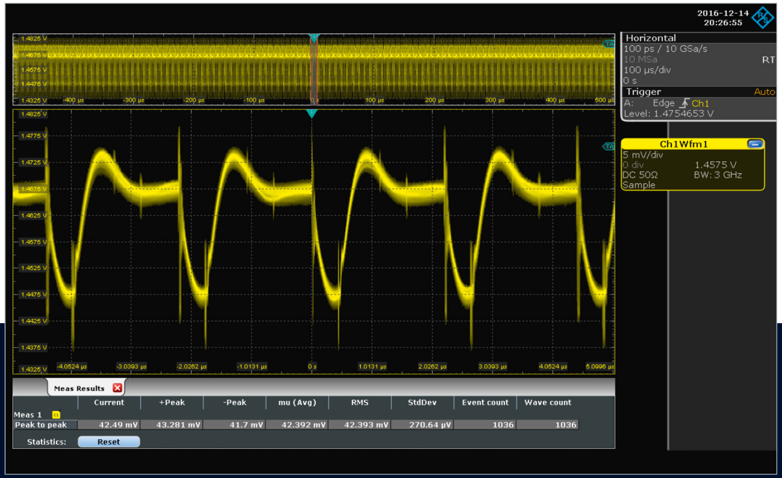
Improving the display

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.

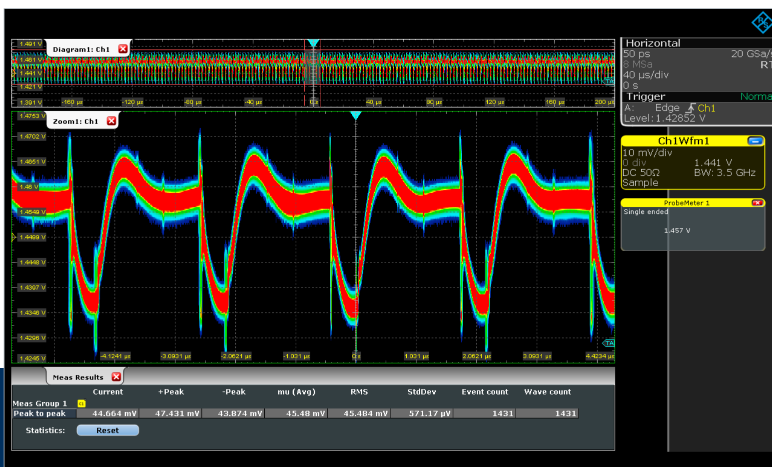
Measurement results will be the same whether infinite persistence is on or not. It is simply a way of visually seeing how much of the V_{pp} contribution is due to noise.



Color grading

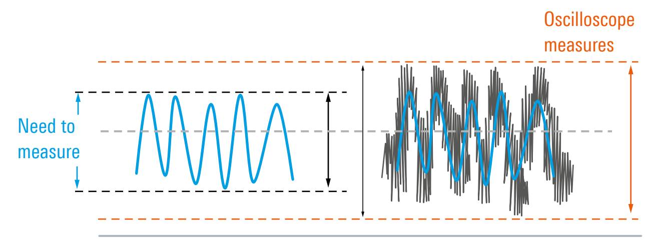
Another way to get additional visual information about each power rail is to turn on color grading. In this example, it is much easier to see transients when color grading is turned on:

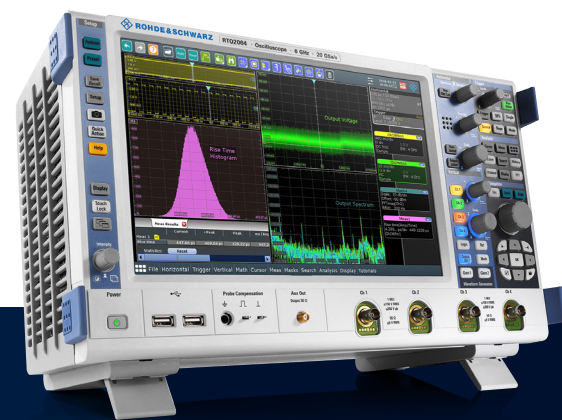
- Pixels that are hit less frequently can be identified more easily
- You can see how often anomalies occur



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

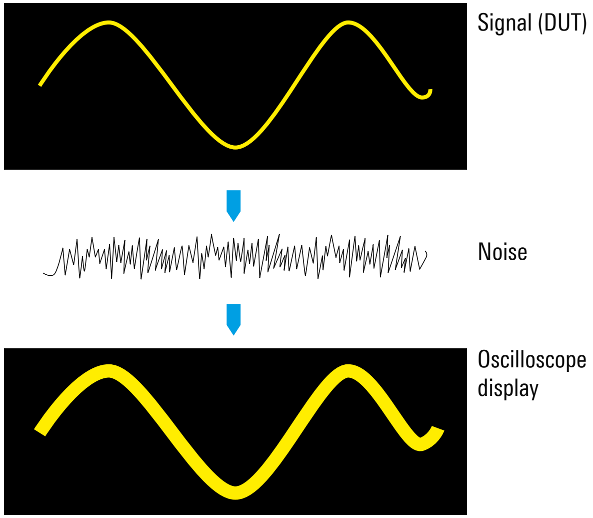




Oscilloscope and probe noise

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.



Noise limits power rail V_{pp} measurement accuracy – Consequences

- Large measurement deviation:
  On your oscilloscope, you will see this manifest with a thick waveshape
- 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 (2.4 V rail at 100 mV/div, V_{pp} = 75 mV)

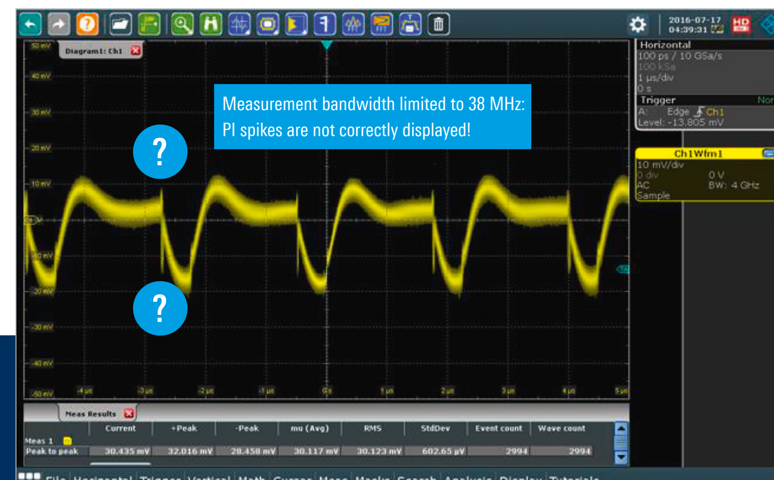
Using built-in probe offset (2.4 V rail at 5 mV/div, V_{pp} = 42 mV)

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

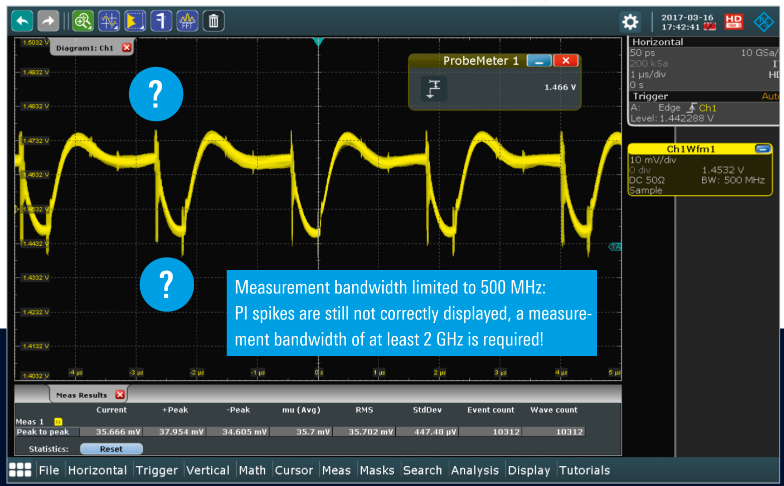
16 % underreported



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.

1:1 power rail probes:
R&S®RT-ZPR20: 2 GHz
R&S®RT-ZPR40: 4 GHz



R&S®RT-ZPR20: 1:1 active 2 GHz bandwidth, captures high frequency transients (V_{pp} = 38 mV; using 500 MHz BWL filter)

Noise due to probe attenuation ratio

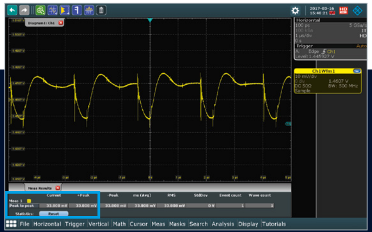
The choice of a probe is crucial for measurement accuracy. Attenuation is a critical factor for low noise. Here is a comparison of a 10:1 probe versus a 1:1 probe using 500 MHz bandwidth limit on each. Note the thickness of the trace using the 10:1 probe. This is noise and will cause overstated V_{pp}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

R&S®RTM-ZP10:
10:1 attenuation

R&S®RT-ZPR40:
1:1 attenuation

34 % overstated

10:1 attenuation (10 mV/div)
(V_{pp} = 45.2 mV)



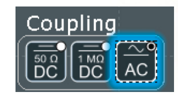
1:1 attenuation (10 mV/div)
(V_{pp} = 33.8 mV)

Challenges with insufficient oscilloscope offset

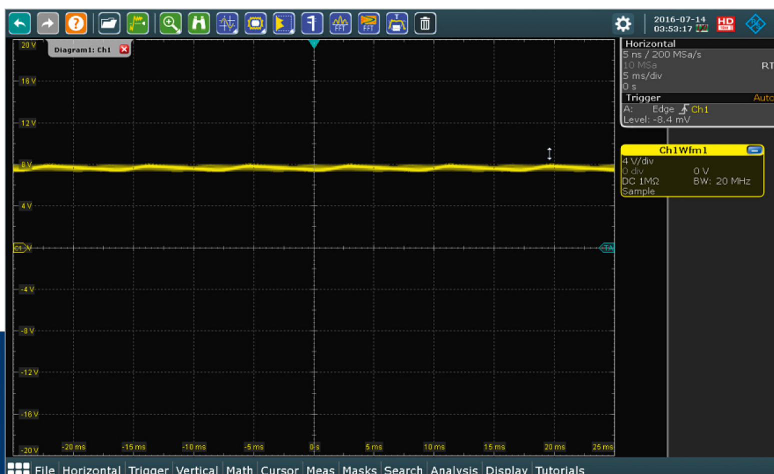
Oscilloscopes do not have enough offset to address common power rails – ranging from under a volt to 40 V. This results in two negative factors:

- 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

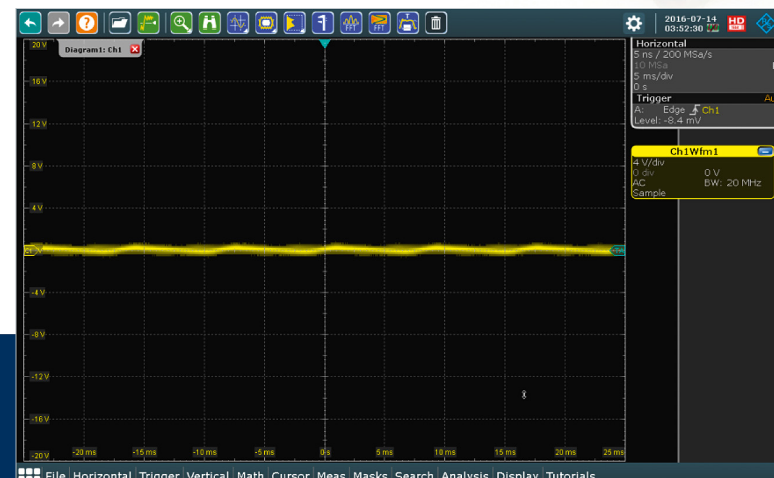
Using a blocking cap or, if offered, AC coupling mode on the oscilloscope eliminates DC offsets. This enables the oscilloscope to see power rails, even if it does not have sufficient offset. However, these approaches limit the ability to see DC values.



DC block

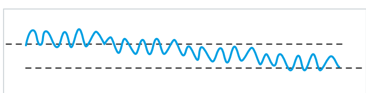


Oscilloscope shows 8 V

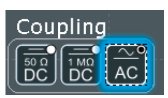


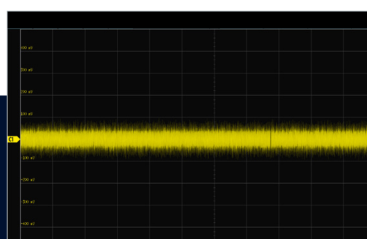
Oscilloscope shows 0 V

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

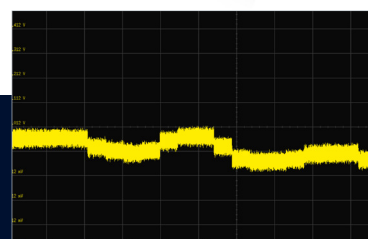


DC drift





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.

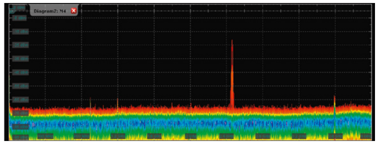
Zone triggering in frequency domain

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

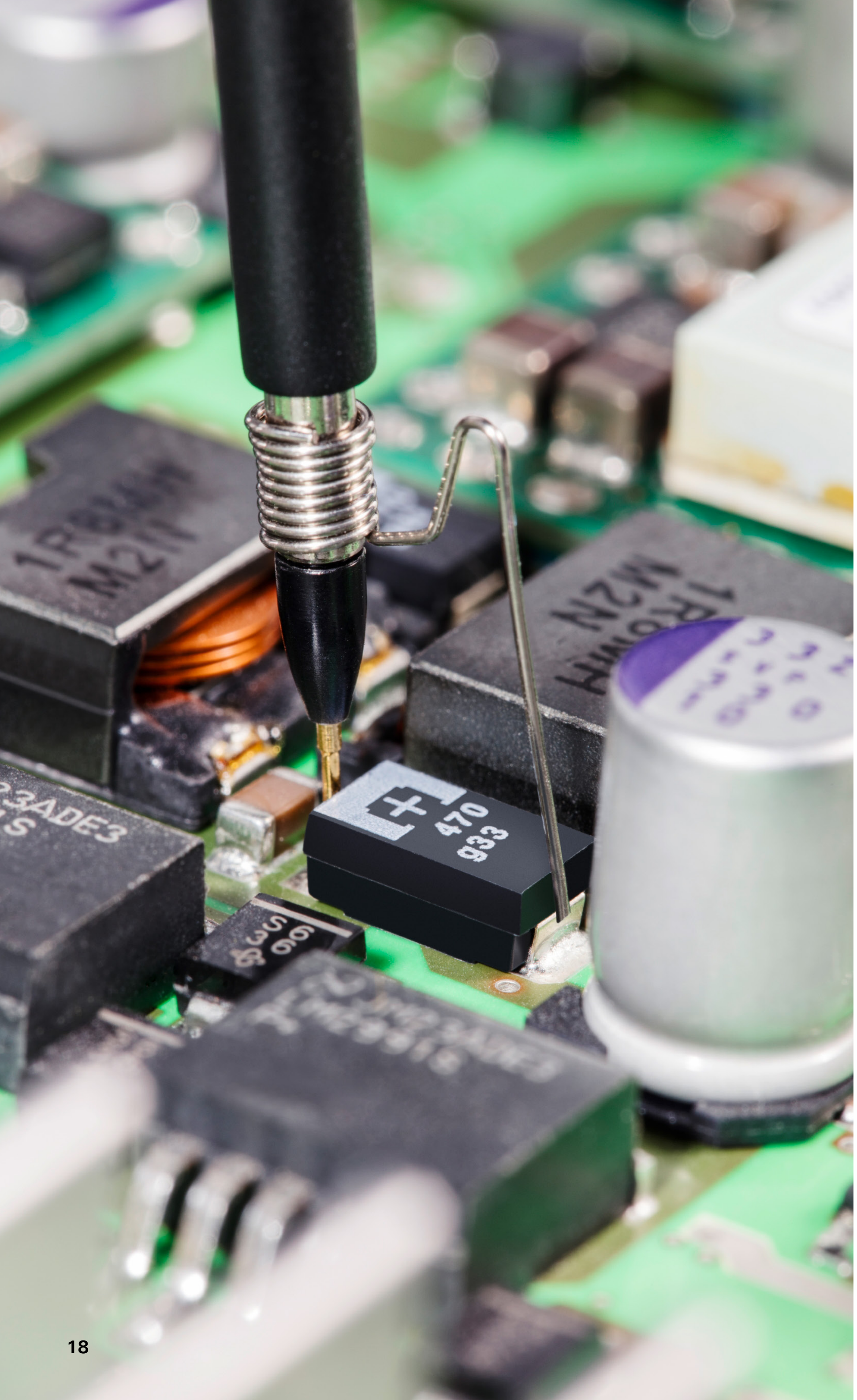
Finding these violations requires a fast update rate (how quickly the oscilloscope triggers, processes the information and plots it to the display). Slow update rates require 10 to 1000 times longer to capture the same amount of information.

V_{pp} = 37 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 mV

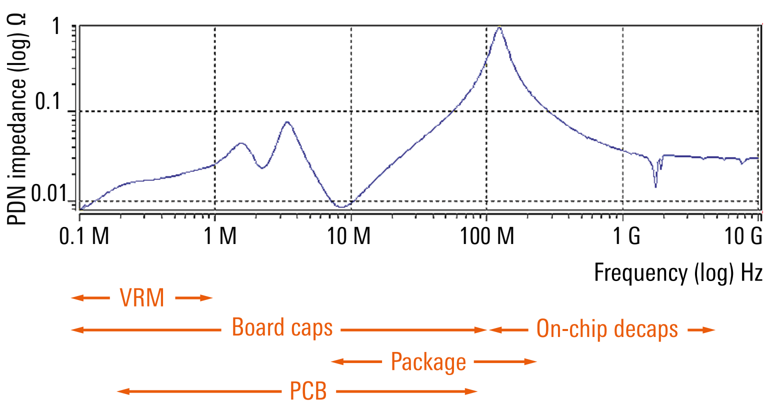
The worst-case V_{pp} measurement is more accurate due to fast update rate. This was achieved 10 times faster than a slower update rate would provide.



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

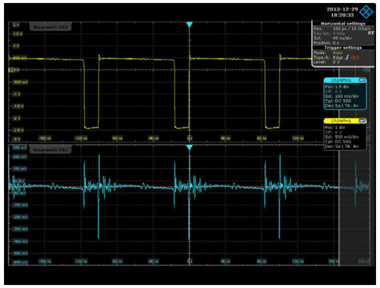


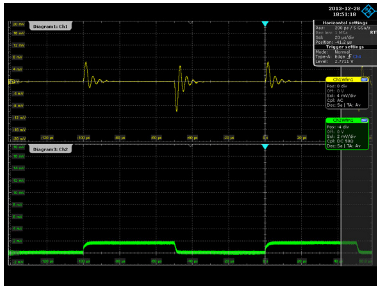
- ► Impedance profile formed by the interaction of various PDN components
- ► Impedance peak at package/chip resonance
- ► Peak impedance dependent on package, PCB, and on-chip parameters
- ► Typical impedance in the range of tens of milliohms

IMPEDANCE TELLS US ABOUT

High speed transients

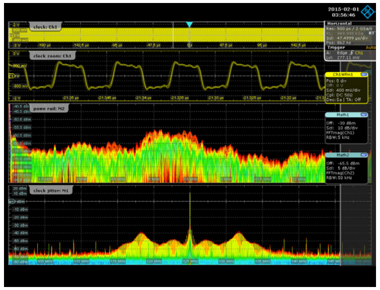
While power integrity is mainly related to high speed systems, it stretches over a wide power range. Many difficult power integrity problems also occur below 50 mW. For example, a high speed logic driver, single gate logic, with about 40 mA and 250 ps edges, is a tough challenge. The high-speed switching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

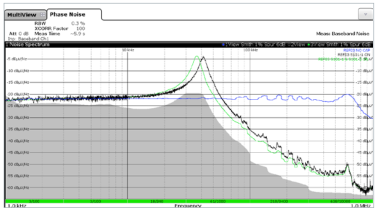




EMI, jitter and LNA noise

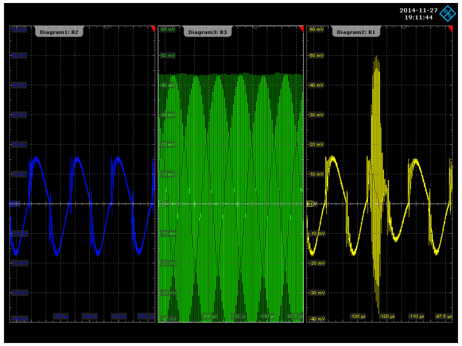
EMI, jitter and low-noise amplifier (LNA) noise are caused by power supply noise. This noise can almost always be correlated to impedance.





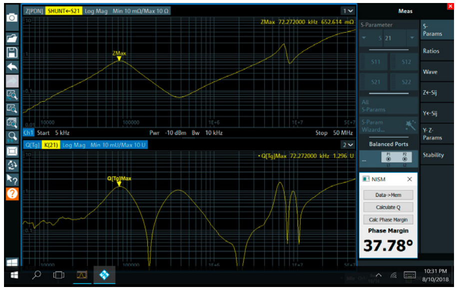
Rogue waves

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.



Control loop stability

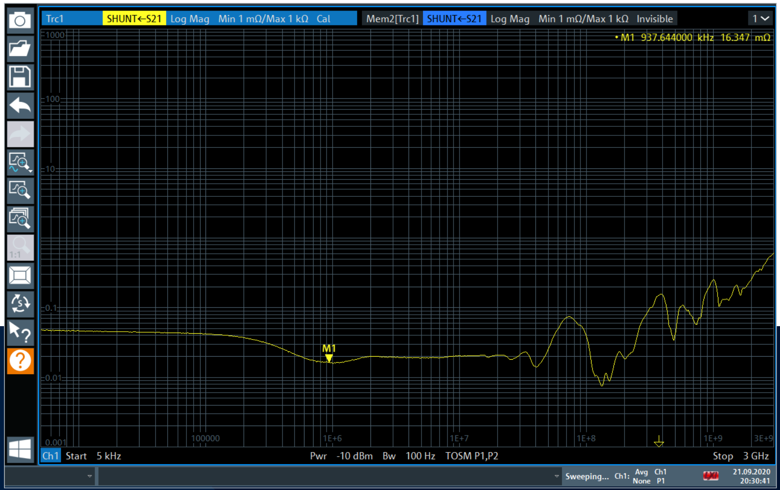
Determining control loop stability is becoming a challenge, because many voltage regulators do not allow access to the control loop. So directly measuring a Bode plot is not possible, as this would require inserting a small resistor into the control loop where a disturbance signal can be injected. Even 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.



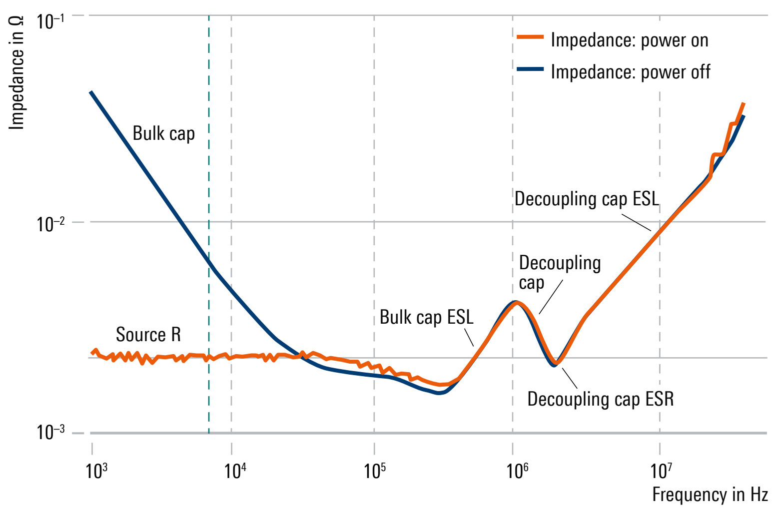
Impedance measurement, showing control loop stability with 38° phase margin

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 frontend 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



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

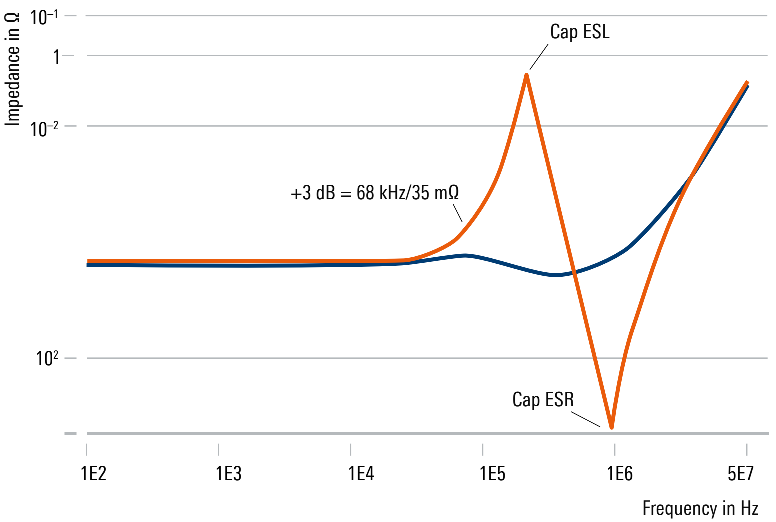
Flat = resistor | Rising = inductor | Falling = capacitor

HOW TO FIX POOR IMPEDANCE

Minimize L and maximize R.

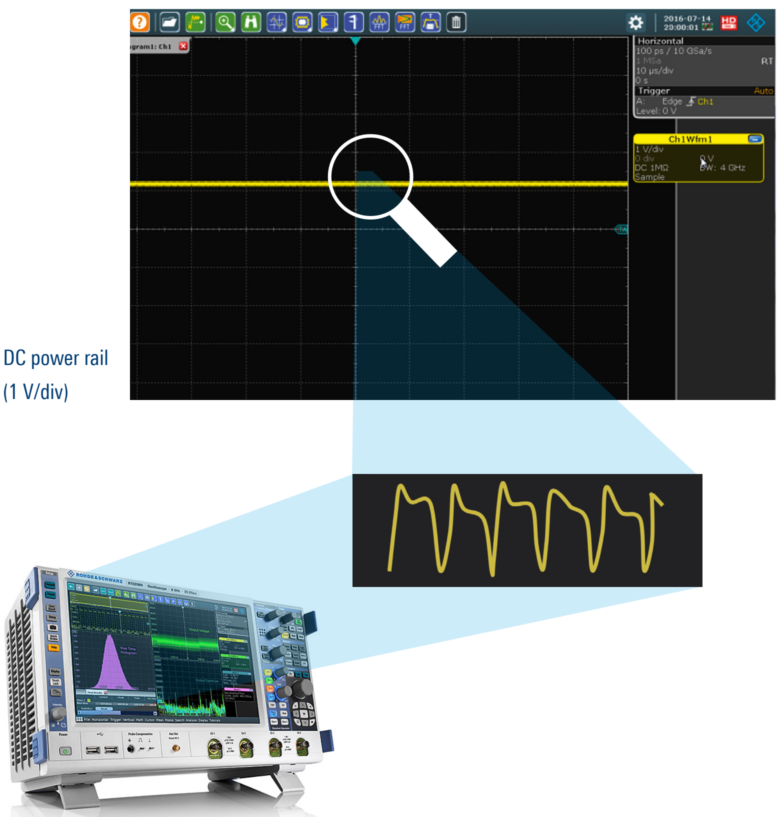
1. **Determine L from resonance or 3 dB point**
2. **Determine R from below resonant frequency**
3. **Set C = L/R2**
4. **Set Cap ESR = R**

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



OSCILLOSCOPES: THE PRIMARY TOOL FOR POWER RAIL ANALYSIS

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



DC power rail (1 V/div)

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

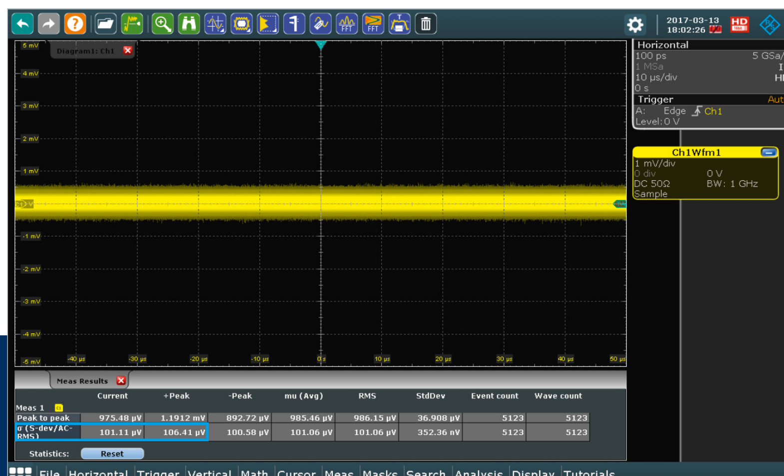
- Low noise to minimize measurement system impact on tolerance testing
- 2 GHz to 4 GHz of bandwidth to capture high frequency coupling
- Fast update rate to quickly capture worst-case outliers
- Excellent frequency domain capability to view both time and frequency content easily
- Deep acquisition memory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

50 Ω CHECK AT 1 mV/DIV

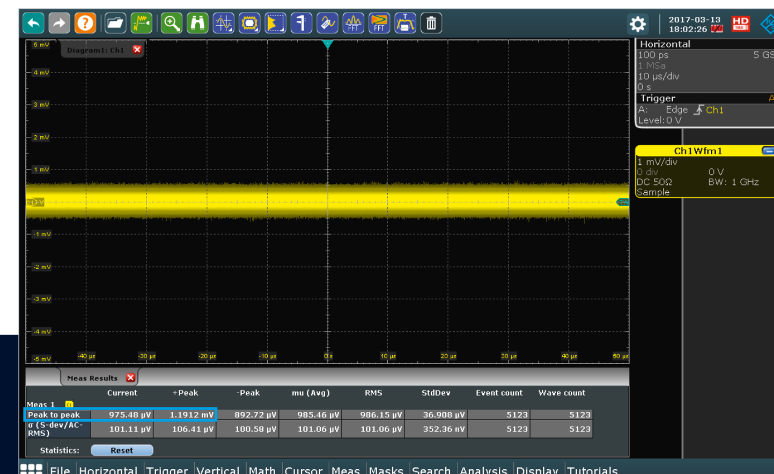
The best approach is to measure with an oscilloscope that has low noise. It is possible to measure its noise by removing all of its inputs and to measure the peak-to-peak curve at 1 mV/div..

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®RTO2000: 106 µV (RMS) at 1 GHz bandwidth, 1 mV/div



R&S®RTO2000: max. 1.19 mV (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

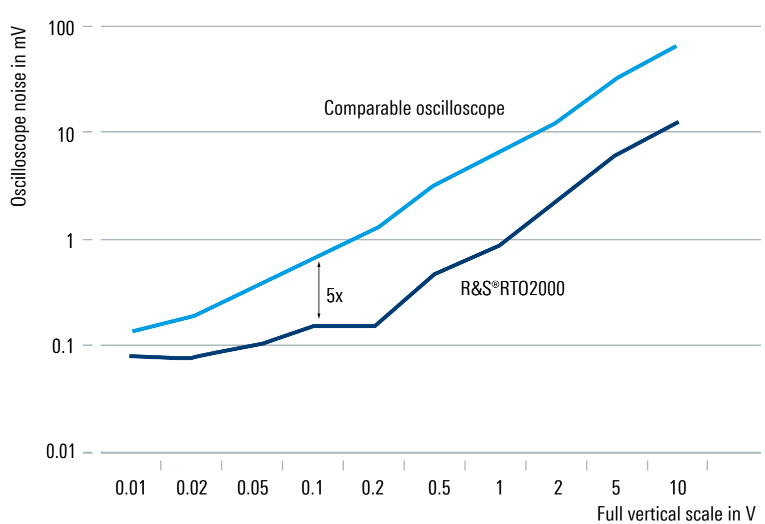
5. Record V_{pp} value

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

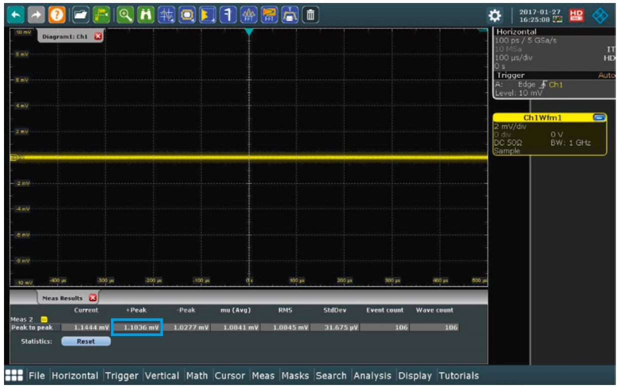
1 GHz noise comparison between two oscilloscopes with equivalent bandwidth



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 four times lower.

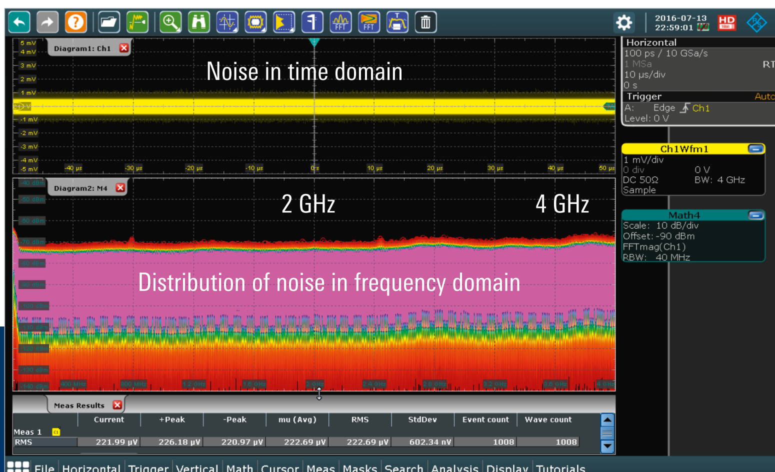
20 mV/div (noise V_{pp} = 4.1 mV)



2 mV/div (noise V_{pp} = 1.2 mV)

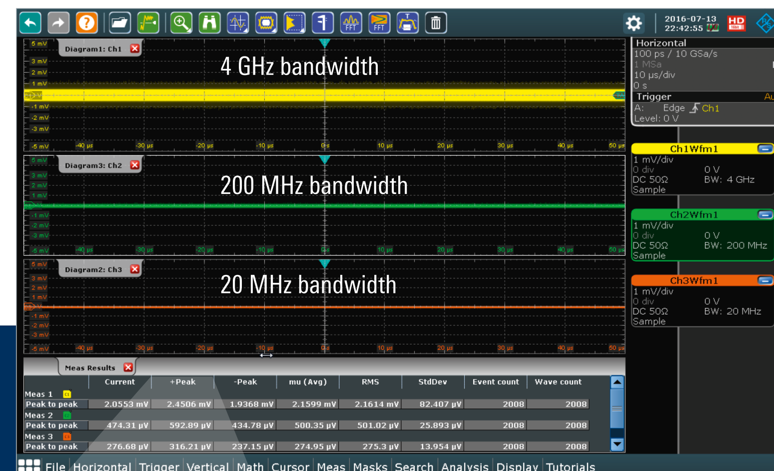
NOISE COMPARISON: TIME DOMAIN VERSUS SPECTRAL CONTENT

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} = 2.45 mV	**Highest noise**
200 MHz	V_{pp} = 0.592 mV	
20 MHz	V_{pp} = 0.316 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.

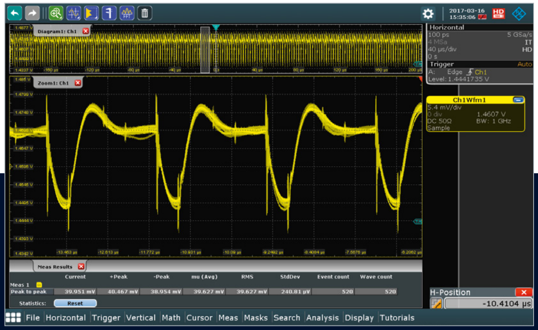
Measurement bandwidth will also impact measurement accuracy. You can get very low-noise measurements from a 1:1 probe with 20 MHz of bandwidth, but the probe misses high frequency transients that are required for a precise measurement that can be seen with a 1 GHz bandwidth.

This depends on your power rails and it is impossible to tell in the time domain. A rule of thumb is: bandwidth = 0.35/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} = 32 mV

Bandwidth = 1 GHz

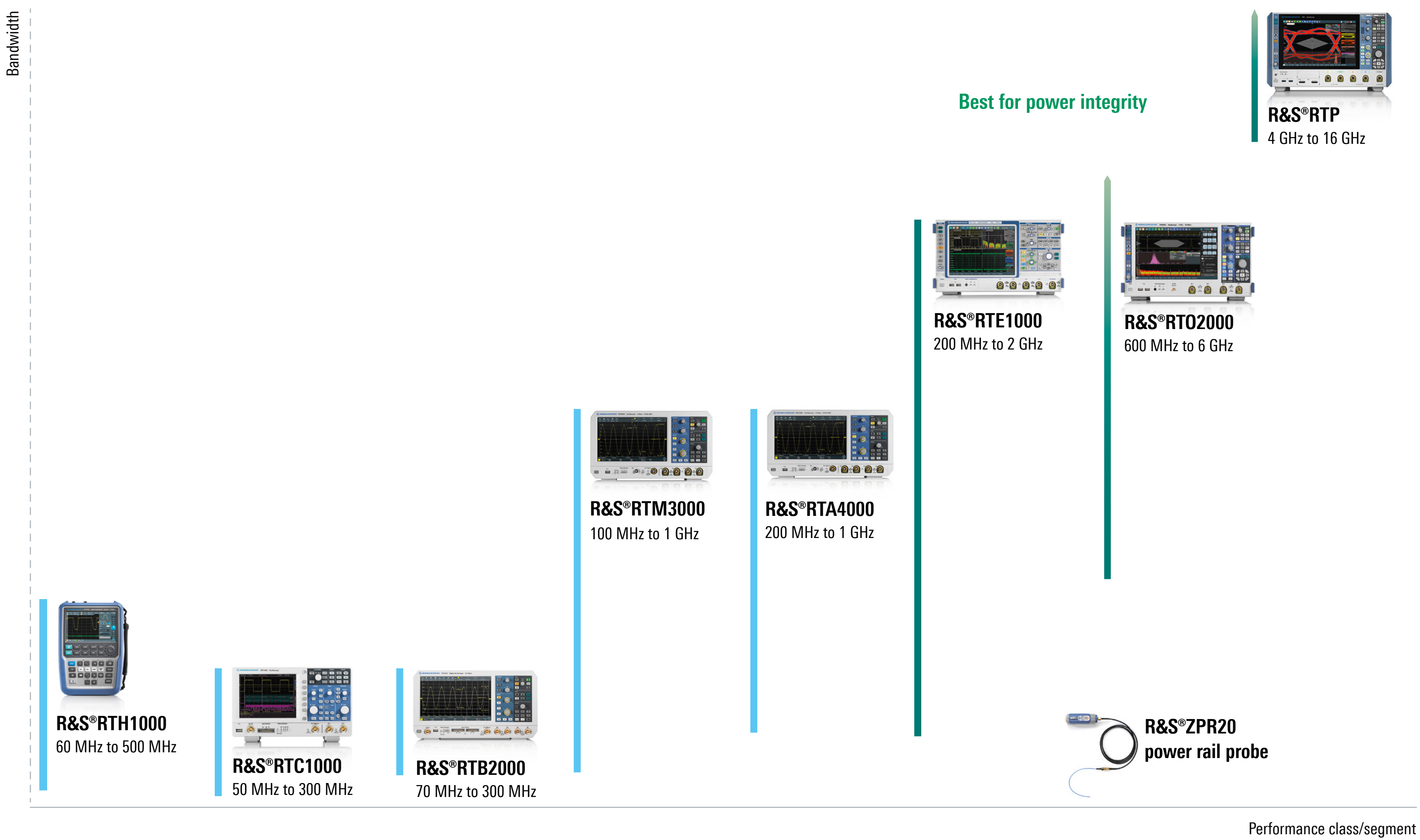


V_{pp} = 40 mV

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.

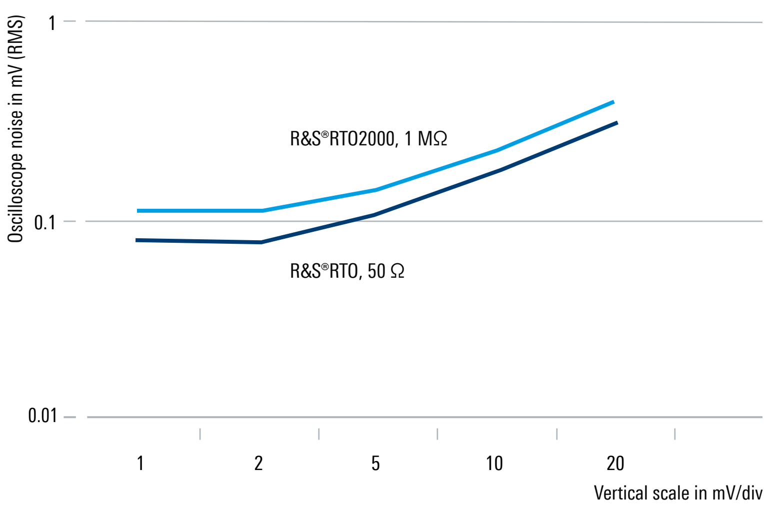


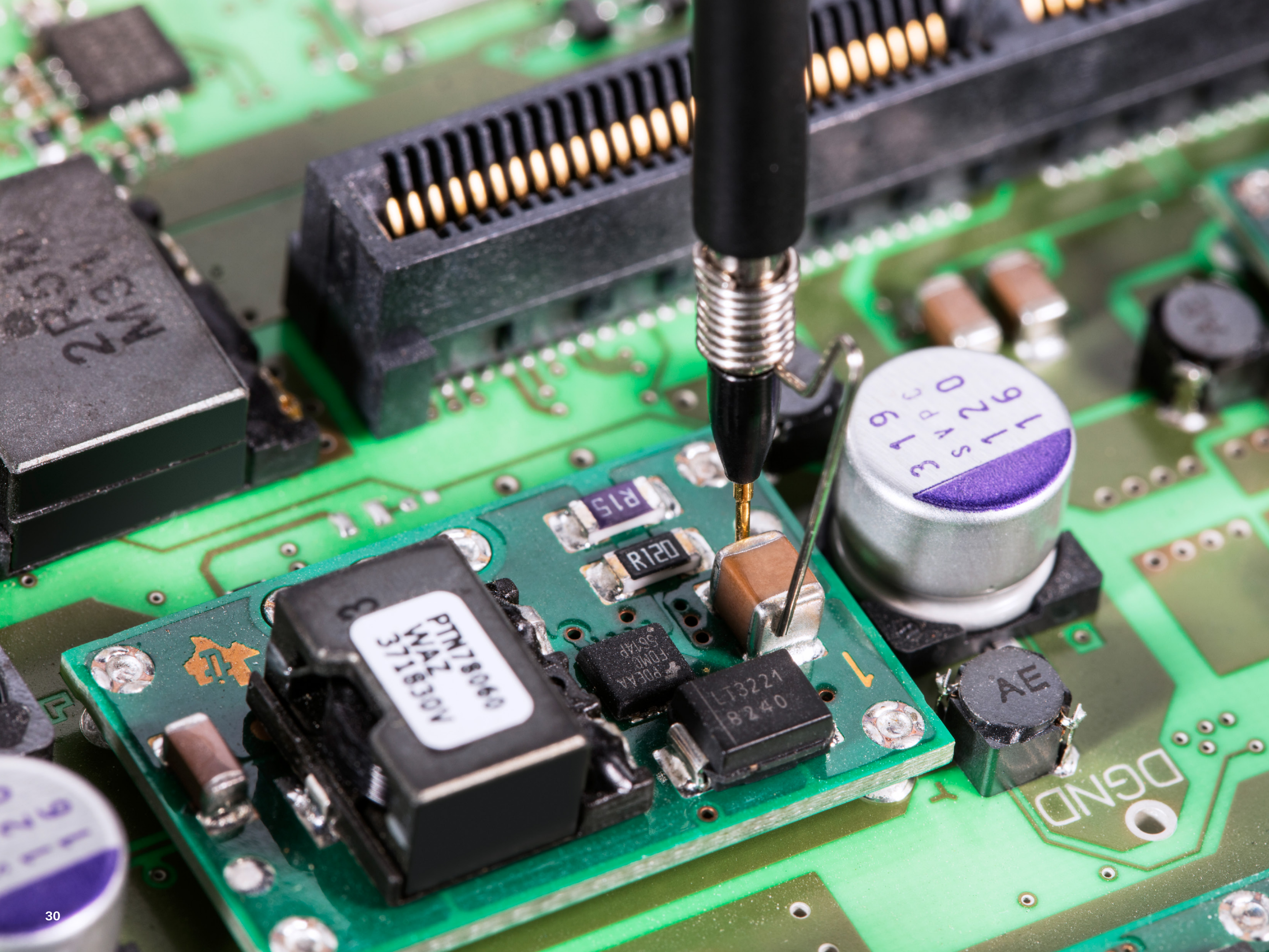
CHOOSING BETWEEN 50 Ω AND 1 MΩ

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

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

500 MHz noise comparison



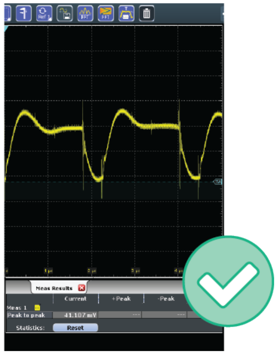

R15
R120
LT3221
AE
DGND

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	1:1 probe	Direct connect 50 Ω pigtail
		
✗ 10:1 attenuation adds noise	✓ 1:1 attenuation is low noise	✓ Direct connect is low noise
✗ < 500 MHz bandwidth	✗ < 50 MHz bandwidth limits capability	✓ Bandwidth to limit of oscilloscope
✓ Good offset due to 10:1 attenuation	✗ Offset is limited to oscilloscope offset	✓ DC block removes offset
✓ Good input impedance at very low frequencies	✓ Good input impedance at very low frequencies	✗ DC block misses drift
✗ Heavier loading at > 100 MHz		✗ Poor input impedance

10:1 probe

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

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

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

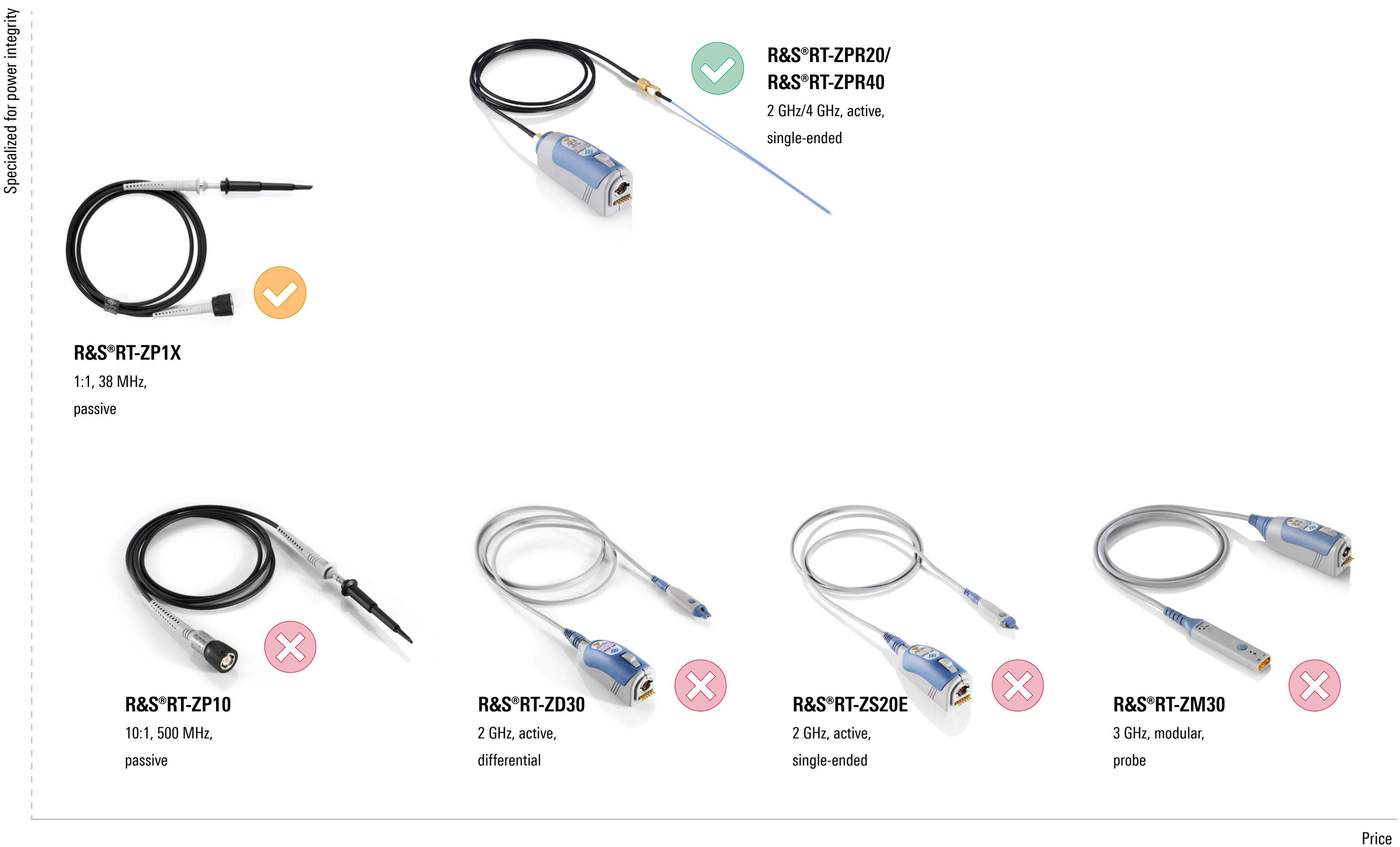
Dedicated power rail probe

- ✓ 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

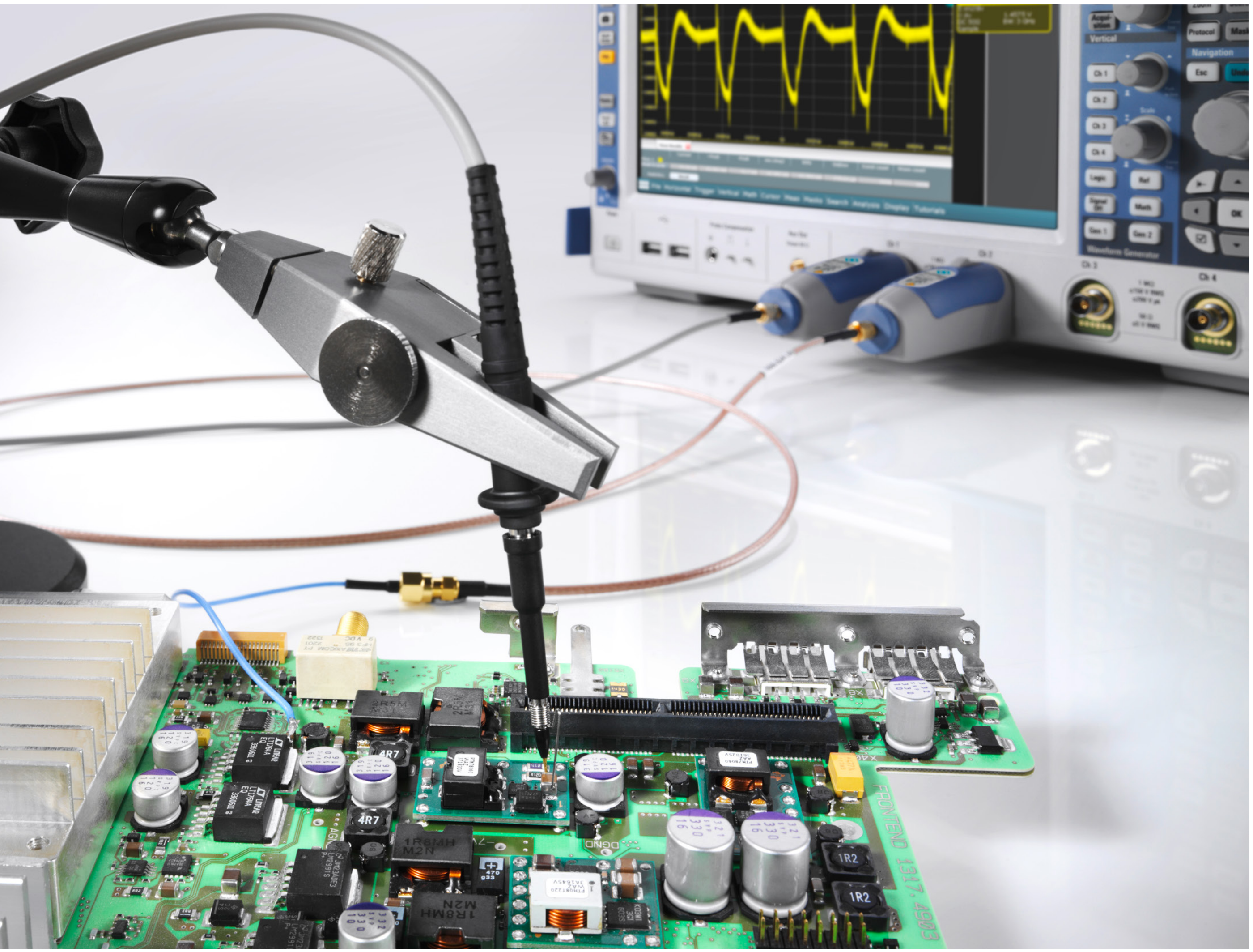
No limitations

CHOOSING THE RIGHT PROBE



R&S®RT-ZPR20/-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 [1] or 4 GHz [2]
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

1 2.4 GHz band visible due to slow frequency.
2 5 GHz band visible due to slow frequency.

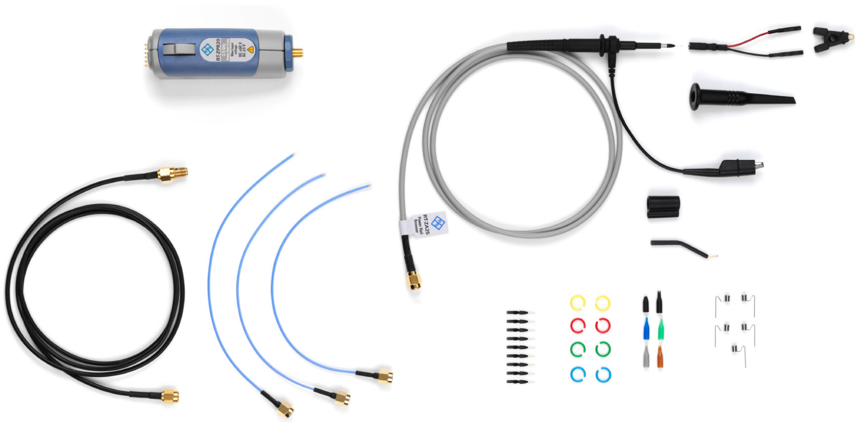
CHECK TO SEE CONNECTION OPTIONS

The probe is active, and the probe head terminates into an SMA connector for precise measurements. There are multiple ways to connect the SMA end of the main cable to your power rail. The probe can be connected to your DUT via:

- ▶ A direct SMA (full bandwidth)
- ▶ A solder-in coax cable (full bandwidth) – often soldered across a blocking cap
- ▶ An SMT clip or a two-pin plug (reduced bandwidth)

POWER RAIL BROWSER

A 350 MHz browser is included as standard and often useful to make less precise, quick measurements. The browser connects to the active probe head via an SMA connector, giving you the benefits of minimal loading and good bandwidth with high fidelity while measuring. The browser with a 2.5 mm tip is compatible with existing passive probe accessories such as the ground spring.



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.

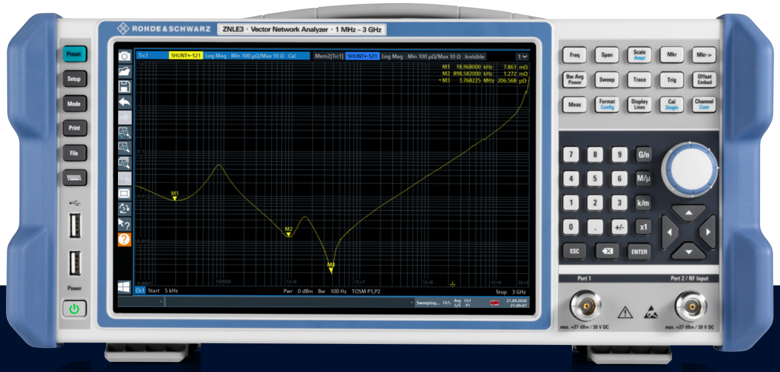
1: V_{pp} with statistics

2: Buit-in 16-bit R&S®ProbeMeter shows DC voltage

3: High bandwidth shows coupled sources

IMPEDANCE MEASUREMENTS USING A VECTOR NETWORK ANALYZER

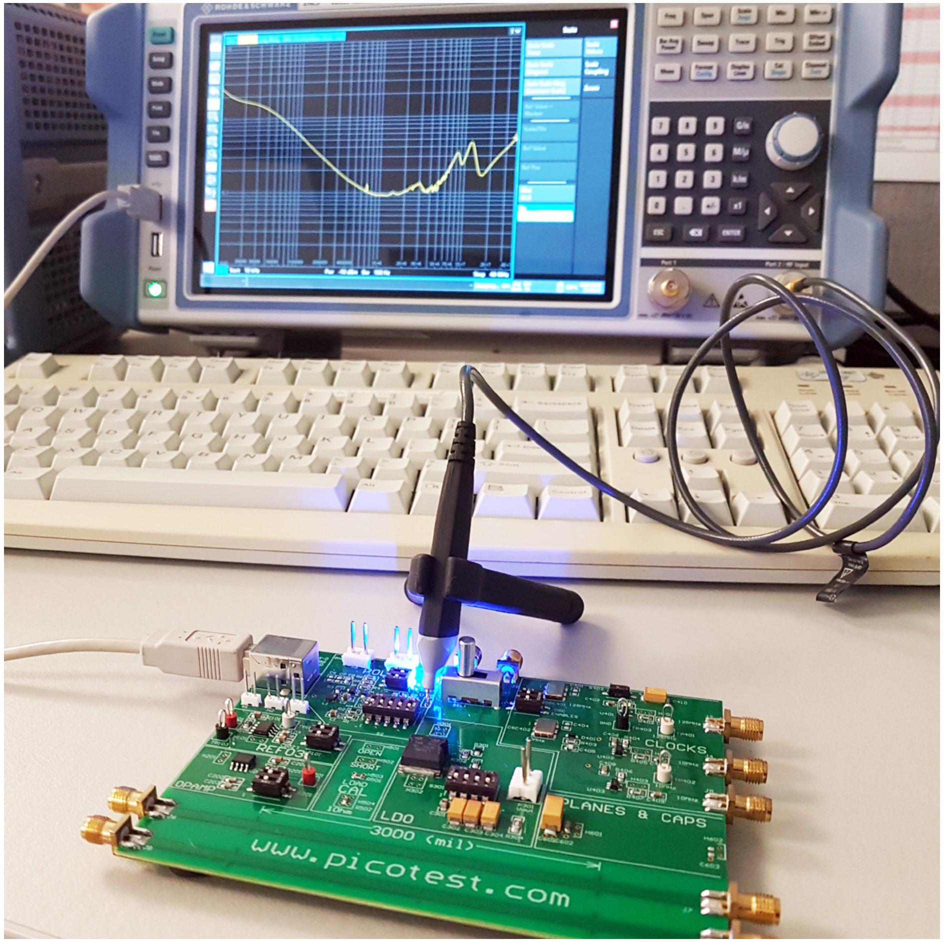
Unlike many other power integrity measurements that are measured with an oscilloscope, impedance measurements are most accurately performed on a vector network analyzer (VNA).



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.



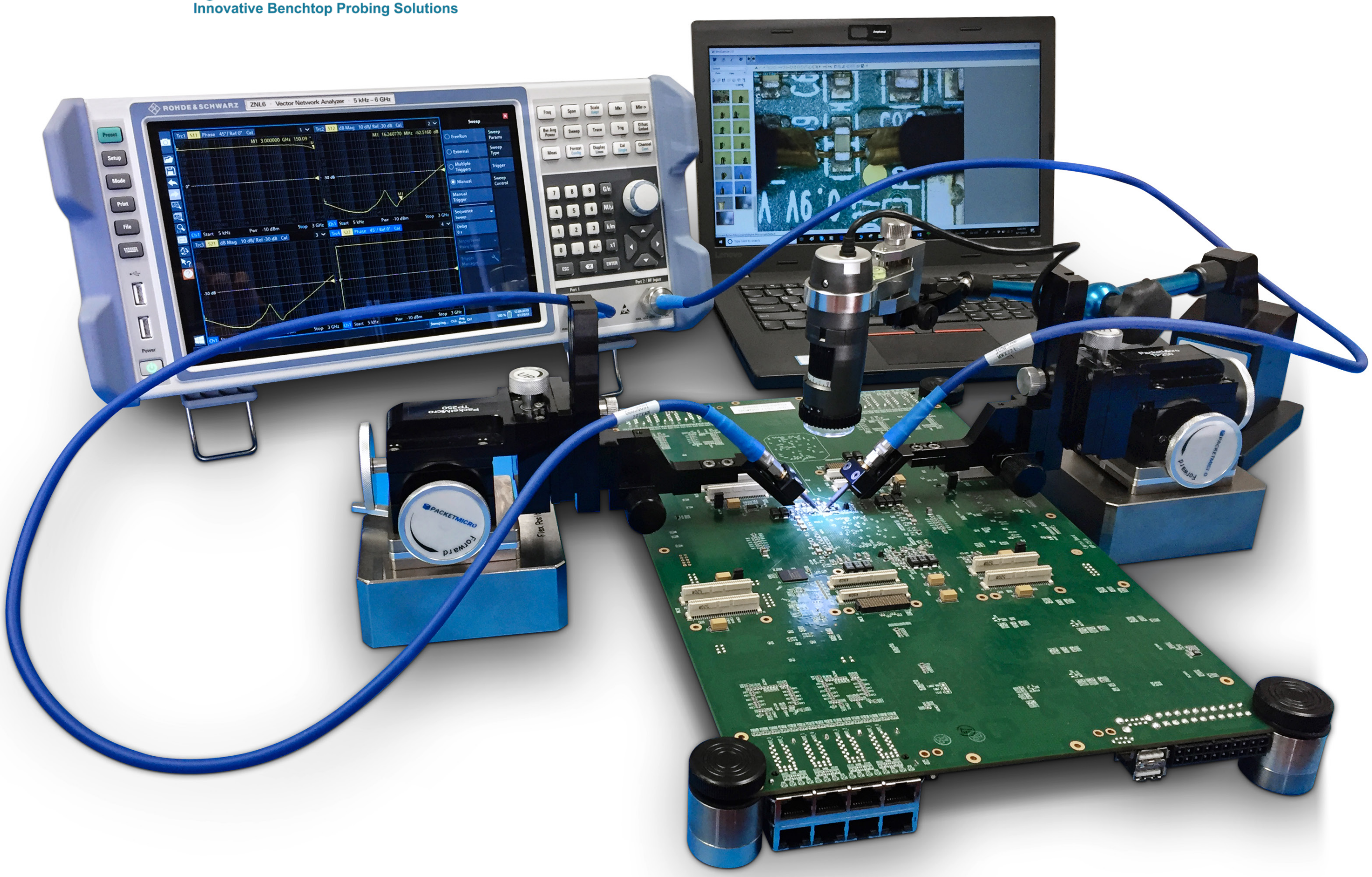
One-port measurements are rarely used because they have an impedance range that almost always disagrees with what is needed. Specifically, the one-port impedance measurement has limitations at its low impedance range. Most documents claim those measurements to be accurate above about 1 Ω. In practice, it may be required to measure impedances closer to 100 mΩ and, if calibrated well, perhaps as low as 10 mΩ. One port measurements have low uncertainty starting at about 10 Ω up to several hundred ohm, but how many of us are building power distribution networks that have target impedances above 10 Ω? 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.

PICOTEST

TWO-PORT VNA MEASUREMENTS

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

PACKETMICRO
Innovative Benchtop Probing Solutions



ROHDE & SCHWARZ VECTOR NETWORK ANALYZERS

Multiport solution

R&S®ZNBT

Economy models

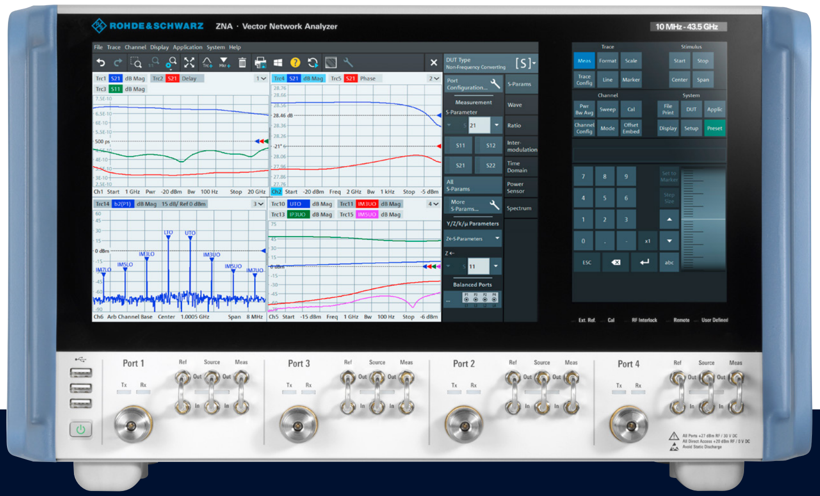
R&S®ZNL/R&S®ZND

Midrange model

R&S®ZNB

High-end model

R&S®ZNA



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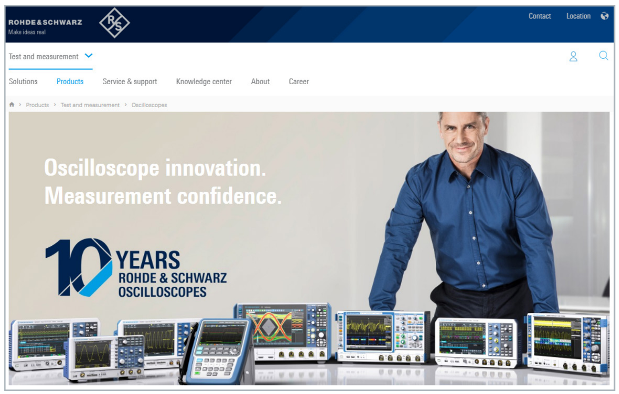

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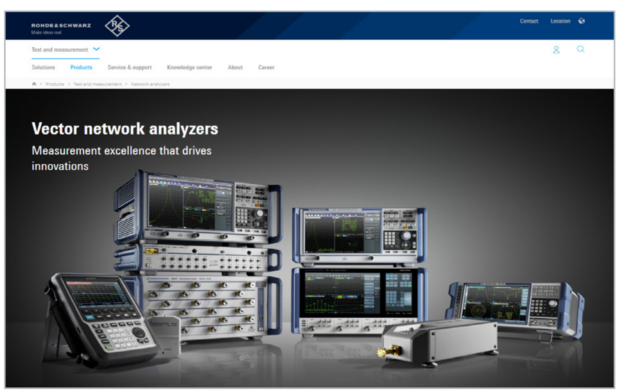

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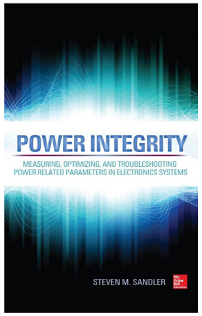

About Rohde & Schwarz
The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

www.rohde-schwarz.com

Rohde & Schwarz customer support
www.rohde-schwarz.com/support

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