Five techniques for fast, accurate power integrity measurements
Rail voltages are getting smaller, and tolerances are decreasing. As a result, making accurate power rail measurements has become much more difficult. In the past, any scope was able to measure ripple on historical 5 V rails with 10% tolerance, since the 500 mV requirement was well above the noise level of the scope.

Industry dynamics are driving both a decrease in rail voltage values as well as tighter tolerances across a wide range of rails. Making an accurate ripple measurement on a 1 V rail with 2% tolerance, for example, is difficult on all scopes. This guide describes five tips for making accurate power integrity measurements with oscilloscopes.

### Contents

Tip 1: Adjust viewing characteristics .................................................. 3
Tip 2: Lower noise .................................................................................... 4
Tip 3: Achieve sufficient offset ............................................................... 8
Tip 4: Evaluate switching and EMI ........................................................ 10
Tip 5: Accelerate measurement time ...................................................... 11
Conclusion ................................................................................................ 12
Tip 1: Adjust viewing characteristics

**Waveform intensity**
DC rail tolerance measurements require finding worst-case peak-to-peak voltage measurements ($V_{pp}$). This is best accomplished using an automated measurement. In addition, it is sometimes useful to get visual confirmation. All scopes have a display setting that allows the user to vary waveform intensity. This is typically set at about 50%. Adjusting to a higher level lets users more easily see oscilloscope pixels that the waveform crosses less frequently. The downside of turning up waveform intensity is that it makes it more difficult to tell how often any given pixel was illuminated. While important for viewing modulated signals, this distinction is generally not important for power integrity measurements.

**Infinite persistence**
Turn on infinite persistence and let the waveform build up across sequential acquisitions. Infinite persistence views can also be useful for documentation. The scope shows the range of DC voltage tolerance over a longer period of time.

**Color grading**
Turning on color grading creates more of a three-dimensional view of the power rail. Color grading combined with infinite persistence creates an insightful view of power rails signals.

Color grading and infinite persistence enables quick viewing of power rail activity. Adding a zoom window gives a more detailed view of signal characteristics.
Tip 2: Lower noise

Choose a scope that has low noise
You will never be able to measure signals that are smaller than the noise of your scope and probing/cabling system. When a signal enters the oscilloscope, front-end noise gets added to the signal before the analog-to-digital converter (ADC). Each stored sample now includes the value of the original signal, but with some offset based on how much noise was present when the sample was acquired. Users will see this on the scope’s display as thick waveforms, not to be confused with fast update rate. Peak-to-peak voltage values greater than what the true signal values are will be shown and measured.

The best approach is to start with a scope that has lower noise than other scopes. How do you determine how much noise a scope has? Most oscilloscope manufacturers will have a data sheet with typical RMS noise values for a specific scope, and these values will have been characterized across a large sample of scopes. Noise is a characteristic and not a specification. Moreover, manufacturers only publish RMS noise typical noise value, but peak-to-peak noise values are really what matters for accurate ripple measurements.

Noise is the primary source of DC rail ripple measurement inaccuracy

A simple method is to do a check yourself. A quick characterization takes just a couple minutes and requires no external equipment. Disconnect all inputs from the front of the scope, turn on a Vpp measurement, set the vertical scale and sample rate you are likely to use for your measurement and let the scope run until you have a stable and consistent Vpp noise value. Noise levels are dependent on the vertical sensitivity setting, the bandwidth setting and the path selection (50 Ω or 1 MΩ) and will vary slightly from channel to channel on the same scope.

Oscilloscopes from different manufacturers will have noise levels that may vary as much as 100%. If you need to make precise ripple measurements, make sure you choose a scope that has low noise.
Choose the signal path that has the lowest noise

Oscilloscopes used for power integrity measurements commonly offer both 50 Ω and 1 MΩ signal paths. Users may have a probe that requires one of these paths, or may have a cabled power rail measurement.

The 50 Ω path is typically the quietest for all scopes that have both paths and allows for full oscilloscope bandwidth. Noise on the 1 MΩ path may be two to three times the noise of the 50 Ω path, and typically bandwidth is limited to 500 MHz on the 1 MΩ path, making the 50 Ω path a better choice for power integrity measurements.

Power rail impedance is generally measured in the mΩ range. For cabled measurements without any probes, the 50 Ω path has 50 Ω DC input impedance and therefore cause some resistive loading, reducing power rail DC amplitude values. Using a specialized power rail probe, such as the R&S®RT-ZPR20 with 50 kΩ input impedance, minimizes this issue.

It is not wise to connect a 50 Ω cable, such as a 50 Ω pigtail coax, directly to the scope’s 1 MΩ inputs due to reflections that will occur between the 1 MΩ and 50 Ω transmission line mismatch.

Use the most sensitive vertical scale

Noise is a function of full screen vertical value on the scope. So, using a more sensitive vertical resolution will reduce the amount of total noise measured. In addition, when you scale your signal to fill the majority of vertical space, the scope uses more of its ADC resolution and your V_{pp} measurements will be more accurate.
**Limit bandwidth**

Noise is broadband. With no inputs connected to the scope, turn on an FFT and you’ll see how much noise there is across the full bandwidth of the scope. Turning on bandwidth limit filters reduces broadband noise and will give you a more accurate power rail measurement. The tradeoff is that higher frequency anomalies won’t show if bandwidth limiting is set too low.

What is the right bandwidth to use? The answer is that it depends on your signals. While switching speed may be in the kHz range, fast edges produce harmonics that go into the MHz range. If you have higher frequency coupled signals, including clock harmonics, you will need more bandwidth to capture these. Both the R&S®RTO and R&S®RTE digital oscilloscopes come as standard with bandwidth limit filters. In addition, the HD mode option further reduces broadband noise and increases vertical resolution up to 16 bit.

---

**Do an FFT of your scope without any inputs connected, then compare with the FFT with signal connected.** You will get a good feel for where signal content occurs and where higher frequency is just broadband noise from the scope and probing system. You can then set the bandwidth limit appropriately.

Bandwidth limiting reduces broadband noise, resulting in more accurate time domain measurements. With no inputs connected to scope channels, here’s a comparison of noise at 1 mV/div at 20 MHz, 200 MHz and 4 GHz. 20 MHz V_{pp} noise is about 50% of noise at 200 MHz, and 13% of the amount of noise at full 4 GHz bandwidth.
Choose the right probe (attenuation, bandwidth and connection)

Making accurate power integrity measurements can be greatly enhanced by using probes that have a 1:1 attenuation ratio. Probes that have higher attenuation ratios amplify noise. In addition, higher attenuation ratios limit vertical sensitivities that can be used. For example, a 1:1 probe on a scope with an input that goes down to 1 mV/div allows the user to scale at 1 mV/div, while a probe with a 10:1 attenuation ratio only allows users to scale down to 10 mV/div.

How you probe your power rail is as important as the other techniques we’ve talked about. Some users bring power rails out to SMA connectors where signal quality and accessibility is high. Other users choose to solder a connection. Still others will use a clip over a bypass capacitor as an easy access point. Others will probe using a handheld probe browser. Each technique has tradeoffs in terms of ease, required up-front planning and signal quality.

For highly accurate measurements, Rohde & Schwarz recommends the R&S®RT-ZPR20 power rail probe with a direct SMA or soldered 50 Ω SMA pigtail coax (included with the probe). This delivers extremely low noise with full 2 GHz bandwidth. While the probe is specified at 2.0 GHz bandwidth, its frequency response has a slow roll-off and will capture 2.4 GHz Wi-Fi signals that may be coupled on the power rail. While 2.4 GHz amplitude values will be attenuated by about 3 dB, the ability to view these coupled signals can be important in finding coupled sources.

When using the R&S®RT-ZPR20 browser, R&S®RT-ZA25, bandwidth is reduced to 350 MHz. Using a ground that minimizes ground loop area, such as a ground spring, enables best measurement accuracy.

Using probes with 1:1 attenuation ratios for more accurate measurement results for small signals

10:1

1:1

Vpp = 61 mV, 50% overstated

Vpp = 41 mV
Tip 3: Achieve sufficient offset

**AC coupling and blocking caps**
Scopes typically don’t have sufficient built-in offset to allow users to place the waveform at the center of the display and zoom in. This results in two negative factors: the scope uses only a fraction of its ADC vertical resolution and uses a bigger vertical scale, causing additional noise. This makes for a low-quality measurement.

Blocking caps or using the AC coupling mode on the scope will remove the signals, DC component, if available for the selected path and probe. This solves part of the problem, but eliminates the ability to see true DC values and drift.

With a block cap or AC coupling, the scope doesn’t see DC values or drift. With up to ±60 V built-in offset, even when zoomed with small vertical scaling, the R&S®RT-ZPR20 power rail probe enables users to see the absolute DC value including low-frequency DC changes.
Probes with built-in offset
Some probes offer additional built-in offset. They have the advantage of allowing users to have sufficient offset to see true DC values and low-frequency characteristics such as drift and sag. For example, the R&S® RT-ZPR20 power rail probe has a built-in offset of ±60 V and a dynamic range of 850 mV. This means that users can look at AC characteristics up to 850 mV in height on DC rails anywhere between –60 V and +60 V.

The dynamic range specifies the maximum AC amplitude the probe will measure correctly. With a dynamic range of just 850 mV, the probe is really a specialized tool for measuring small AC perpetrations on DC rails. It is not a tool for measuring signals for other applications that require greater than 850 mV of AC amplitude.
**Tip 4:**
Evaluate switching and EMI

**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 a scope’s FFT.

How much bandwidth is needed for frequency domain views? It 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. The R&S®RT-ZPR20 power rail probe has a specified bandwidth of 2 GHz and a typ. –3 dB bandwidth of 2.4 GHz. This allows users to still see coupled signals at 2.4 GHz.
Tip 5: Accelerate measurement time

Update rate impact on speed of power integrity measurements

Power rail measurements involve finding the worst-case amplitudes. Developing high confidence can mean taking hundreds or thousands of measurements across an extended window of time. This can take time, and can be tedious. Power integrity measurements are unique in that they often require large time spans. In order to retain higher bandwidth, the scope needs to maintain a faster sample rate, resulting in significant usage of memory.

For example, capturing a millisecond at 10 Gsample/s results in a memory size of 10 Msample. Ten milliseconds capture results in 100 Msample memory usage.

Waveform update rate describes how fast the oscilloscope can process memory, show the result on the display and begin capturing a new acquisition. The R&S®RTO and R&S®RTE digital oscilloscopes for example have a maximum update rate of 1 million waveforms/s. Fast update rates mean that measurements such as $V_{pp}$ and FFT will be done more quickly. Many scopes have a maximum update rate in the range of tens or hundreds of acquisitions per second. This means gaining confidence in finding worst-case tolerance violations will take orders of magnitude longer than a scope with fast update rate. Having an oscilloscope with fast update rate enables users to gain confidence more quickly.

Comparison of the R&S®RTO and R&S®RTE update rate with other oscilloscopes in the industry (log scale)

Best shown using a log scale due to the difference, the R&S®RTO and R&S®RTE have significantly faster update rates of up to 1 million waveforms/s in normal mode, the fastest in the industry. Both also have hardware-accelerated FFT. This performance advantage delivers faster power rail testing results.

Impact of measurements, memory depth increases, and the use of an FFT on the update rate of the R&S®RTO oscilloscopes (log scale)

The R&S®RTO and R&S®RTE maintain faster update rates than other scopes in the industry, resulting in quicker characterization of power rails.
Conclusion

This guide covers five tips for making accurate power integrity measurements with oscilloscopes:

- Choosing a scope with low noise is critical to accurate power integrity measurements.
- Coupling the scope with a 1:1 probe with built-in offset, high bandwidth, high DC impedance and an integrated R&S®ProbeMeter delivers superior capability and measurements.
- Understanding and correctly setting a number of oscilloscope attributes such as vertical scaling and bandwidth limit filters increases the accuracy of results.
- Adding frequency domain view enables users to quickly isolate coupled signals.
- Fast update rates let users test power rails more quickly.

When coupled with the R&S®RT-ZPR20 power rail probe, the R&S®RTO and R&S®RTE digital oscilloscopes give you faster, highly accurate power integrity measurements.
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.

Sustainable product design
- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Rohde & Schwarz GmbH & Co. KG
www.rohde-schwarz.com

Regional contact
- Europe, Africa, Middle East | +49 89 4129 12345
customersupport@rohde-schwarz.com
- North America | 1 888 TEST RSA (1 888 837 87 72)
customer.support@rsa.rohde-schwarz.com
- Latin America | +1 410 910 79 88
customersupport.la@rohde-schwarz.com
- Asia Pacific | +65 65 13 04 88
customersupport.asia@rohde-schwarz.com
- China | +86 800 810 82 28 | +86 400 650 58 96
customersupport.china@rohde-schwarz.com

Certified Quality Management
ISO 9001

Certified Environmental Management
ISO 14001