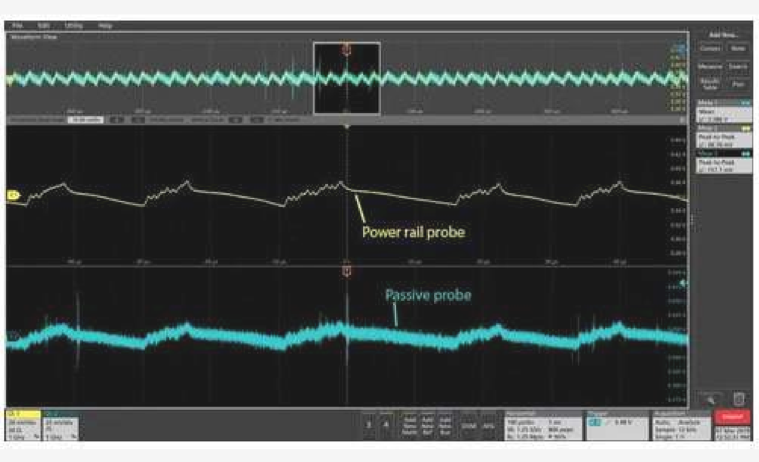
Analyzing Power Integrity on a Power Distribution Network (PDN)

Power Distribution Networks (PDNs) must provide many low-noise DC power rails for sensitive loads such as microprocessors, DSPs, FPGAs and ASICs. The quest for more speed and higher density means faster edge rates, higher frequencies and more rails, with lower voltage levels and higher currents. This places pressure on design for both signal integrity and power integrity.

The goal of making power integrity measurements is to validate that the voltage and current reaching the Point of Load (POL) meet the load's power rail specifications under all expected operating conditions. Special attention is required to accurately measure millivolts of power rail noise at GHz frequencies.

Learn how to:

- **Measure high-frequency ripple without blocking DC or loading your rails**
- **Deal with supplies from 1 V to 48 V and above**
- **Minimizing measurement system noise contribution**
- **Measuring power distribution network impedance**
- **Characterizing noise using simultaneous spectrum and waveform analysis**
- **Faster power rail measurements with automated analysis software**



Measure high-frequency ripple without blocking DC or loading your power rails

Noise specifications on power rails can go up into MHz or GHz frequency ranges with amplitudes in millivolts. This makes probing a challenge.

The high-impedance 10X passive probes that come with oscilloscopes may have enough bandwidth, but they attenuate the very noise signal you're trying to measure. 1X probes pass the noise signal without attenuation, but they are limited to several MHz bandwidth. Transmission line probes or cables with 50 Ω input impedance offer great high-frequency performance but cause significant loading at DC.

The ideal probe for making power rail measurements offers high impedance at DC and acts as a 50 Ω transmission line for high frequencies. Power rail probes such as TPR1000 and TPR4000 are designed to meet these challenges with high bandwidth, low attenuation and minimal loading.

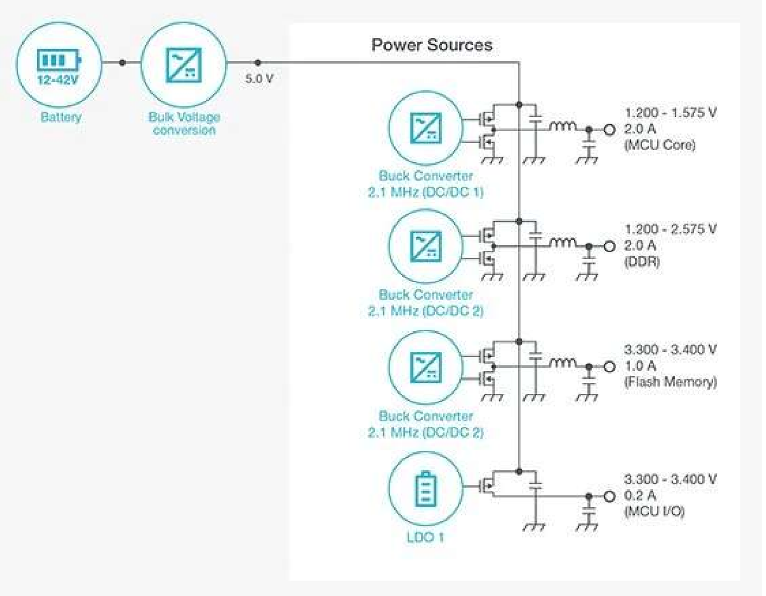
Download the "Getting Started with Power Rail Measurements" application note

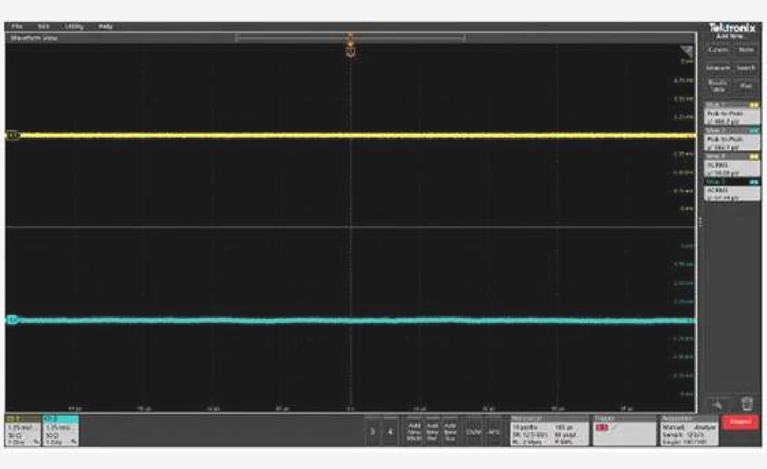
Dealing with supplies from 1 V to 48 V and above

Although the main supply voltages for many FPGAs and SoCs have dropped dramatically, these are not the only supplies to consider. On-chip I/O supplies can cover a much wider range than the main logic supplies. Bulk supplies feeding POL regulators or Voltage Regulator Modules (VRMs) are often much higher voltage.

Although many scopes and probes can provide some DC offset, it may not be enough to deal with all the power rails in your system. And at lower volts per division (higher sensitivity) settings instrument systems tend to afford less offset. While blocking DC is an option, it is often undesirable (see above).

In addition to addressing the high-frequency needs outlined above, power rail probes such as TPR1000 and TPR4000 offer high offset range to address a wide range of voltage levels.





Minimizing measurement system noise contribution

Measuring noise on the order of 10 mV requires careful attention to measurement system noise. As noted above, using non-attenuating, or 1X, probes reduces the burden on your oscilloscope's amplifiers. The scope's internal noise and measurement resolution also play critical roles.

The 6 Series MSO includes a new front end with industry-leading noise performance. The scope offers open channel noise as low as $50\mu V_{RMS}$ and $466\mu V_{peak}$. When paired with TPR1000/4000 power rail probes, the system noise can be as low as $70\mu V_{RMS}$.

The 6 Series offers 12-bit resolution at 12.5 GS/s. A High Res function boosts resolution to 16 bits at 625 MS/s and below. 4 and 5 Series MSOs also offer 12-bit resolution with up to 16 bits using High Res mode.

Measuring power distribution network impedance

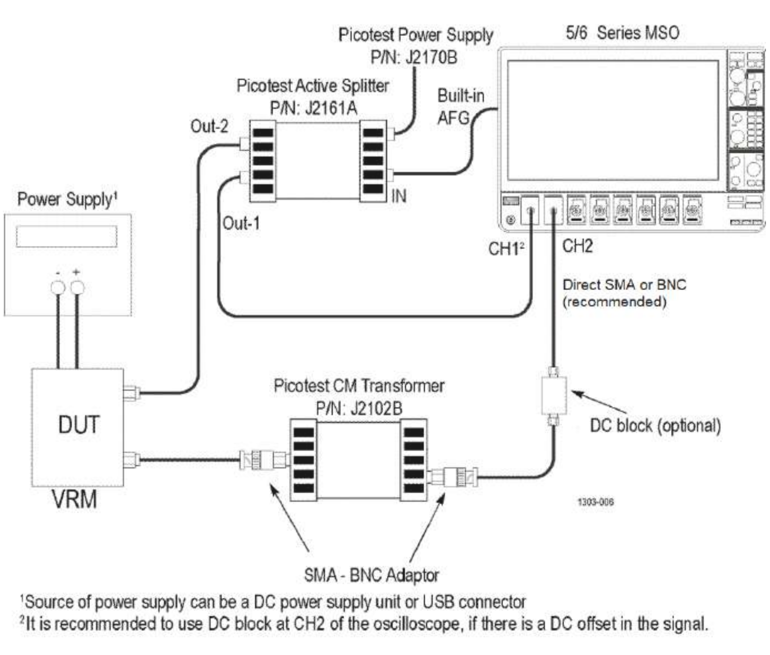
For PDNs powering FPGAs, processors and other complex IC's, power rail impedances must be low in order to deliver high current in response to rapidly changing demand. However, the network is made up of many impedances including the voltage regulator, decoupling capacitors, and PCB traces. High-speed switching involves broadband frequencies and unexpected variations in impedance can result in excessive transients or noise. Measuring the impedance of a network design over a wide frequency range provides confidence that the network won't produce unwanted surprises.

Network impedance measurements are traditionally performed using VNAs, such as the two-port TTR500 which can measure from 100 kHz to 6 GHz.

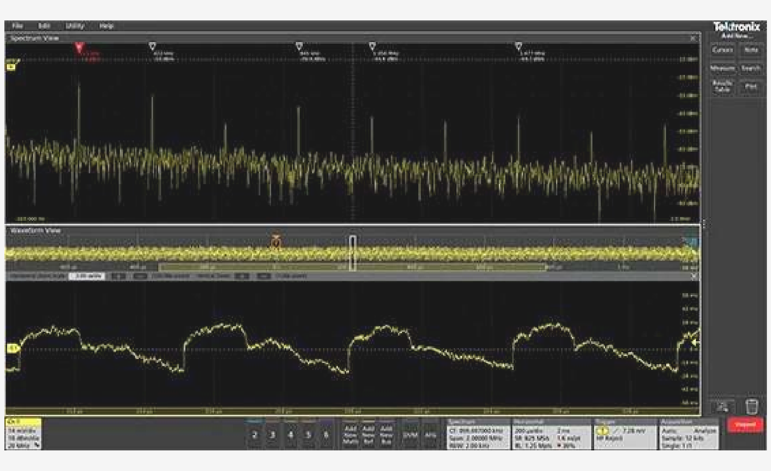
5 and 6 Series MSO oscilloscopes can measure power rail impedance down to 10 Hz using analysis software, a signal generator (built-in or AFG31000 Series), and an isolation transformer.

PWR Application Note

Measuring impedance on a power plane



[1]Source of power supply can be a DC power supply unit or USB connector
[2]It is recommended to use DC block at CH2 of the oscilloscope, if there is a DC offset in the signal.



Characterizing noise using simultaneous spectrum and waveform analysis

Let's say you've measured the power rail noise and it's out of spec. Is it coming from a DC-DC converter? The bulk supply? A PLL? A clock? Crosstalk? Spectrum analysis can provide clues to noise sources – helping to correlate noise frequencies to switching frequencies and harmonics.

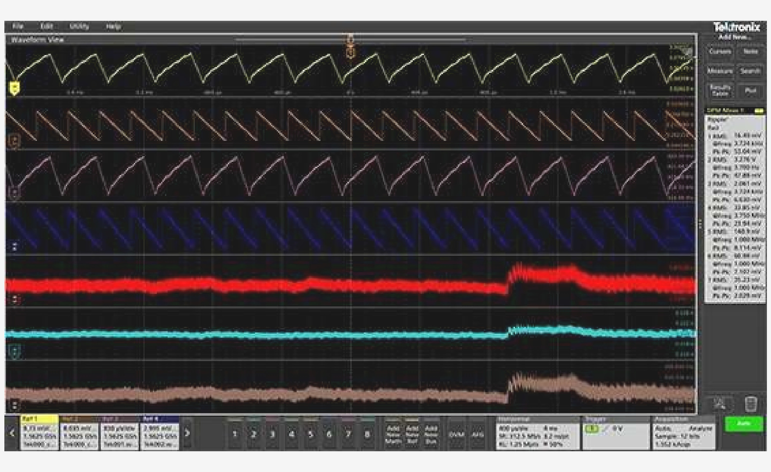
A spectrum analyzer such as an RSA306 connected to your power rail with a DC block can help provide insight into your noise.
The FFT function on your scope is also useful, but these functions use the sample clock on your scope, making it difficult or impossible to look at the spectrum and voltage waveforms at the same time. The unique spectrum view on 4, 5 and 6 Series MSOs provide independent spectrum analyzer controls so you can see synchronized time domain spectrums and frequency domain waveforms at the same time.

Spectrum View Application Note

Power rail noise impacts clock and data signal jitter

Noise on power rails often translates into jitter on high-speed data lines. Jitter and power integrity should be analyzed in both the time and frequency domains. Comparing periodic jitter (PJ) frequencies in the TIE spectrum to spurs in the power ripple spectrum is a fast and accurate way to identify signal integrity problems caused by a power distribution network (PDN). This type of analysis requires an oscilloscope with good spectrum analysis capability as well as good jitter analysis.

Learn about using mixed signal oscilloscopes to diagnose jitter caused by power integrity problems



Faster power rail measurements with automated analysis software

Making even simple measurements such as ripple, overshoot, and undershoot on dozens of power rails requires significant time and attention to detail.

The 5 and 6 Series MSOs are available with Digital Power Management software to automate these repetitive measurements and generate in-depth reports. The software also includes jitter analysis (TIE, RJ, DJ and Eye measurements) to check for excessive jitter on clocks and communications signals powered by your PDN.

Power Integrity Analysis Reference System

6 Series B MSO
Recommended for exceptionally low noise, 12-bit resolution, and up to 8 channels. From 1 to 10 GHz. Built-in arbitrary/function generator (AFG) recommended for impedance measurements

Noise Analysis

- **DPM software**
  Optional analysis software automates ripple, overshoot, under-shoot, turn-on, turn-off, time-trend, settling time, and jitter measurements
- **TPR Power Rail Probes**
  Low noise and high offset range at up to 4 GHz with DC offset ranging from -60 to +60 Vdc

Impedance Analysis

- **PWR software**
  Optional analysis software automates power quality, harmonics, amplitude, timing, switching loss, magnetic analysis, and frequency response analysis (control loop analysis, PSRR and impedance) measurements
- **Active Splitter (e.g Picotest J2161A, not shown)**
  Splits signal from oscilloscope's AFG into an oscilloscope input channels and into the power rail under test.
- **Common Mode Transformer (e.g. Picotest J2102B-BNC, not shown)**
  Eliminates ground loop error in 2-port shunt-through impedance measurements.