APPLICATION NOTE

5 Tips for Measuring Ripple and Noise

For DC voltage lines and power rails

KEYSIGHT

Introduction

Power in an integrated circuit design is a tightly controlled commodity. Growth in the affordable microcontroller market has increased demands on power distribution networks, resulting in lower supply voltages. Lowering supply voltages helps reduce power consumption. Many designs today have 3.3 V, 1.8 V, and even 1.1 V supplies. As those supplies have become smaller, so have their tolerances. Tolerances have dropped from 10% to a range of 1% to 5%.

You must scrutinize DC power rails and voltage lines for quality and integrity. Ripple, noise, and transients ride on those voltage rails. Before you can reduce them, you need to measure them. The goal is to make sure that the power rail is clean. Fundamentally, you need to measure ever-smaller and faster AC signals riding on top of the DC ones.

Challenge: Measuring Small AC Signals on Top of Large DC Signals

In your circuit, you have a DC signal and a tolerance band around the top of that DC signal (Figure 1). So, as long as you stay inside the tolerance band, your power distribution network will pass. If you go outside the tolerance band, it will fail, in which case, you will have to reduce the noise. In either case, you have to be able to see and measure the AC signal riding on top of the DC signal. This application brief presents five tips to help you get the very best measurement of that AC signal.

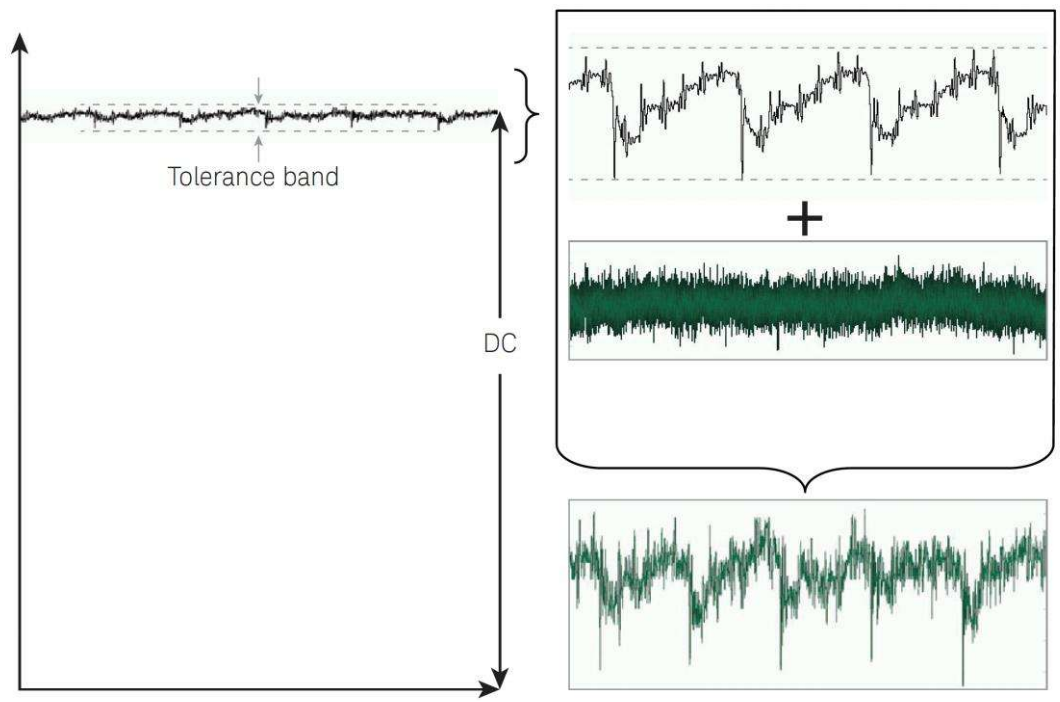


Figure 1. To solve the challenge of measuring small AC signals on top of large DC signals, you must overcome the impacts of measurement system noise and large signal offset

Hint 1: Choose an Oscilloscope with the Lowest Front-End Noise

All oscilloscopes introduce some noise to your system, much like the inherent noise found in any electronic design. The question is, how much noise does the oscilloscope have? Any noise in the oscilloscope is going to ride on top of the signal you are measuring, which will make a significant difference in the measurement values you see.

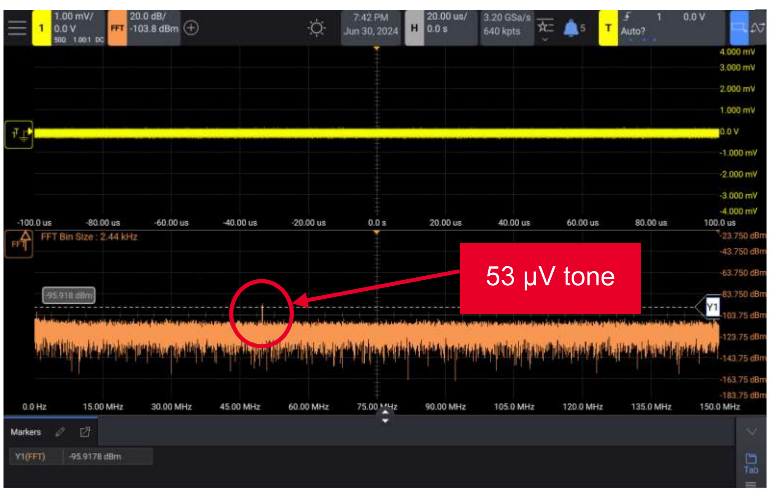
Oscilloscope designs vary. Some scopes use inexpensive components to keep user costs down. But the cheaper the scope, the more front-end noise it will have. Some scopes, like the Keysight InfiniiVision HD3 Series, are meant for more sensitive measurements, like power integrity, and have extremely low-noise front-end systems. The custom components designed by Keysight ensure that the oscilloscope does not affect your sensitive measurements, like ripple on a power rail.

You want the noise level of your oscilloscope measurement system to be as small as possible so it does not overshadow your results.

Hint 1

All oscilloscopes have *some* noise. This noise will ride on top of your signals. Use an oscilloscope with the least amount of noise possible so it does not affect your measurements.

The Keysight InfiniiVision HD3 Series offers an extremely low noise frontend.



Figures 2a and 2b. Figure 2a (left) shows an extremely low-voltage tone on our fast Fourier transform (53 µV) thanks to the low-noise front end of the Keysight InfiniiVision HD3 Series oscilloscope. It is not even possible to see this tone on other oscilloscopes in this class because their noise floor is too high. If you cannot detect small tones that might interfere with the functionality of your supply, you cannot eliminate them. Figure 2b (right) shows the HD3 Series, engineered to have an extremely low noise front end.

Hint 2: Use a 1:1 Probe

Oscilloscope probes come in a variety of attenuation ratios. The ratio defines how much the signal is divided down before being viewed on the screen. For example, a 10:1 probe enables you to measure signals that would otherwise exceed the maximum input to the scope.

The downside of attenuation is that the size of the scope noise relative to the size of the signal you are measuring increases as well. In Figure 3, a 10:1 probe and a 1:1 probe are measuring the same output ripple on a power supply with the same scope settings. The 10:1 probe overstates the measurement by at least 50% because of the reduced signal-to-noise ratio resulting from the higher attenuation ratio. The 1:1 probe more accurately measures the signal when noise can be problematic.

> ### Hint 2
>
> When measuring small signals where oscilloscope noise can be problematic, it is best to use the smallest possible attenuation ratio.

Figure 3. Noise comparison of a 1:1 and 10:1 probe measuring the output ripple on a power supply

Hint 3: Use 50 Ω Input Path of the Oscilloscope

The oscilloscope measurement path includes the oscilloscope you are using, the scope input termination (either 50 Ω or 1 MΩ), and the probe that accesses the signal. For many oscilloscopes, the 50 Ω input is a lower-noise path than the 1 MΩ input termination path.

Figure 4 shows the baseline noise of the 50 Ω input and 1 MΩ input. The 50 Ω (yellow) clearly is smaller and, in this case, the better choice.

Check the noise of the input terminals of your oscilloscope without any probes connected. Next, add your probes, short the input to ground (or short the inputs together on a differential probe), and measure the baseline noise with the probe connected.

Hint 3

Use the lowest oscilloscope noise path. Often this is the 50 Ω input.

Figure 4. Baseline noise on the 50 Ω input compared to the 1 MΩ input path of the HD3 oscilloscope

Hint 4: Use Probe Offset to Increase Dynamic Range

Ripple and noise on the DC power supply are mostly likely small compared to the DC signal, resulting in a small AC signal riding on top of a relatively large DC signal. Offset is a feature in some oscilloscopes and active probes that enables you to remove DC content from the signals you are measuring. Figure 5 shows the noise measurement results on a 1.8 V supply with and without the use of probe offset.

Although most active probes provide offset, they also have large attenuation ratios, which increase the oscilloscope measurement system noise. While a DC block can block DC content, it can also block low-frequency content in the signal.

Hint 4

Use probe offset to zoom in on the small AC signal.

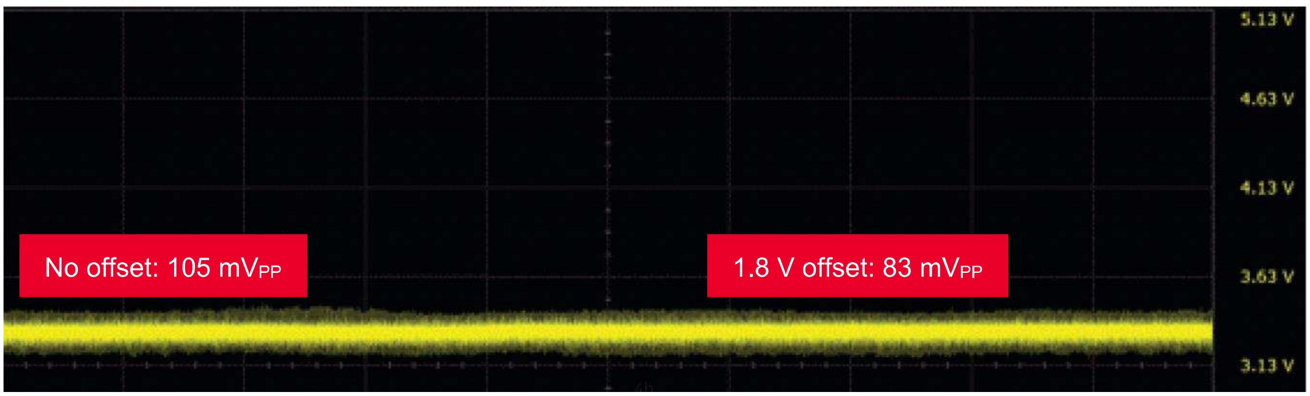


Figure 5. Measuring the noise on a 1.8 V DC supply with no offset and with the use of probe offset

Hint 5: Minimize Oscilloscope and Probe Loading of the Supply

Any time an oscilloscope probes a system, it becomes part of that system because of the electrical contact. This contact changes the behavior of the system you are measuring by creating an additional path to ground. When measuring small signals, one goal is to minimize this loading from the measurement system as much as possible.

In the context of measuring DC supplies, a common source of excessive loading happens when a user attaches a 50 Ω coaxial cable to the supply and to the 50 Ω input of the oscilloscope. Figure 6 shows a comparison of power rail measurements. First, we measured the power rail using a digital multimeter and achieved a result of 3.31 V. Next, we probed the supply with a 50 kΩ input impedance, still resulting in 3.31 V. Finally, we probed the supply by connecting directly to the 50 Ω oscilloscope input, and the supply dropped from 3.31 V to 3.25 V. Some supplies will have enough excess capacity to drive this additional load, but some will not. This additional load could affect the behavior of the power management integrated circuit.

Hint 5

Use a probe with a high input impedance to minimize excess load on the circuit you are testing.

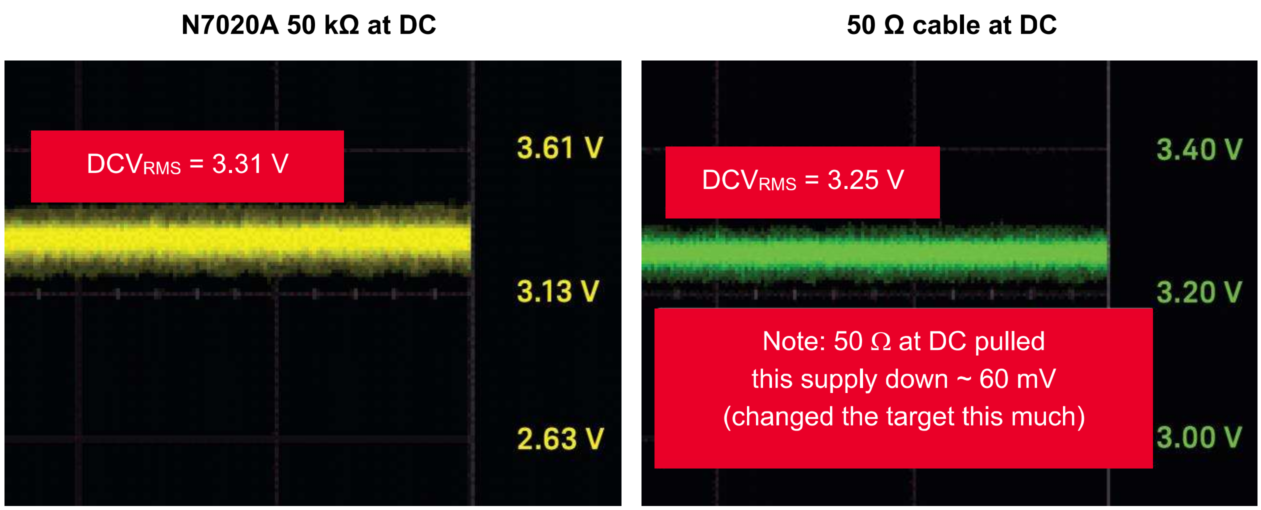


Figure 6. Comparison of noise on 3.31 V power rail measurements, showing input impedance of 50 kΩ on the left and input impedance of 50 Ω on the right

N7020A Power Rail Probe Combined with the HD3 Series Oscilloscope

Our hints will help minimize oscilloscope measurement system noise and identify sources of noise and ripple in a DC power supply, no matter what brand of oscilloscope you use. These techniques work even better when used with specialized tools for measuring power supply noise. The Keysight N7020A power rail probe is the first probe designed specifically for measuring noise on DC power supplies. It has a 1:1 attenuation ratio, ± 24 V of offset, and a 50 kΩ input impedance. When used with the InfiniiVision HD3 Series oscilloscope, the N7020A has 2 GHz bandwidth to capture high-frequency noise and transients that can cause clock and data jitter.

Using the N7020A power rail probe and the HD3 Series oscilloscope makes it easier to find and analyze the AC signals of your DC power supply that you were unable to see before. This approach gives you the measurement insight you need.

See What You've Been Missing: 4x the Resolution and Half the Noise

The InfiniiVision HD3 Series oscilloscope enables you to capture small signals accurately with its low noise frontend and 14-bit ADC. This offers you four times more vertical resolution relative to other 12-bit general-purpose oscilloscopes. Combine this with an uncompromised waveform update rate, powerful new features such as Keysight Fault Hunter, deep memory, and hardware accelerated testing, the HD3 Series enables you to debug your designs.

Learn more about the portable precision of the HD3 at keysight.com/find/HD3.