APPLICATION NOTE

How to Make Ripple and Noise Measurements

For DC Voltage Lines and Power Rails

KEYSIGHT

Introduction

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

You must scrutinize DC power rails and voltage lines for quality and integrity. Ripple, noise and transients are riding on those voltage rails, and 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 (PDN) will pass, and 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 that is riding on top of the DC signal. This application brief is designed to help you get the very best measurement of that AC signal.

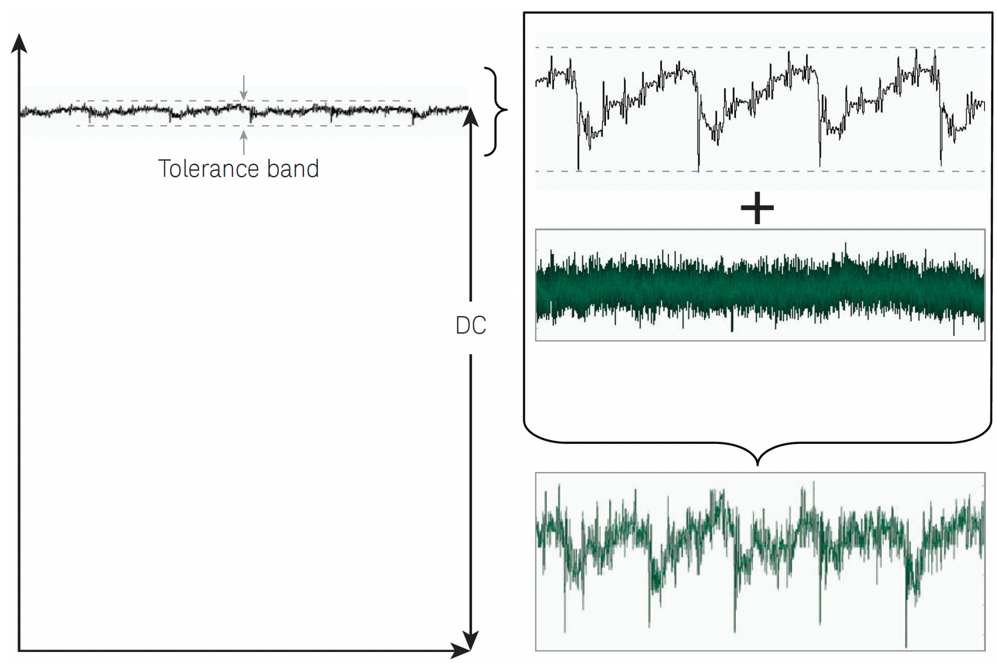


Figure 1. In order to solve the challenge of measuring small AC signals on top of large DC signals is it critical to overcome the impacts of measurement system noise and large signal offset.

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

All oscilloscopes introduce *some* amount of noise to your system. Just like there is inherent noise in every electronic design. It is an unavoidable fact of life. 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.

All scopes are designed differently. There are some out there designed with cheap components so they are a low cost to the user, but the cheaper the scope the more front-end noise they will have. There are also scopes designed specifically for more sensitive measurements like power integrity with extremely low noise front-end systems, like the HD3 Series. The HD3 is engineered to have the lowest front-end noise in the industry. The completely custom components designed by Keysight ensure the oscilloscope is not impacting your sensitive measurements, like ripple on a power rail.

You want the noise 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 noise possible so it does not affect your measurements.

Keysight's InfiniiVision HD3 series offers the lowest noise front-end in class!

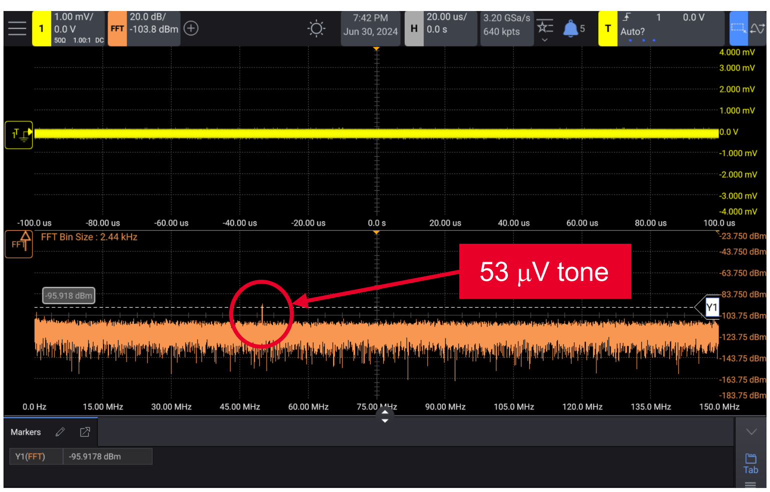


Figure 2a and 2b. In figure 2a on the left, we can see an extremely low voltage tone on our FFT (53uV) thanks to the low noise front-end of the HD3 Series oscilloscope. It is not even possible to see this tone on other oscilloscopes in this class because their noise floor is just too high, the tone is "in the noise". If you can't detect small tones like this that might interfere with the functionality of your supply, you can't eliminate them. Figure 2b (right) shows the HD3 Series, specifically engineered to have the lowest-noise front-end in class.

Hint 2: Use 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 allows you to measure signals that otherwise would 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 being measured increases as well. In Figure 3, a 10:1 probe and a 1:1 probe is 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% due to 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 as small an attenuation ratio as possible.

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

Hint 3: Use 50Ω input path of the oscilloscope

The oscilloscope measurement path includes the oscilloscope being used, 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, you can add your probes and short the input to ground (or short the inputs together on a differential probe) and measure the baseline noise with the probe now connected.

Hint 3

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

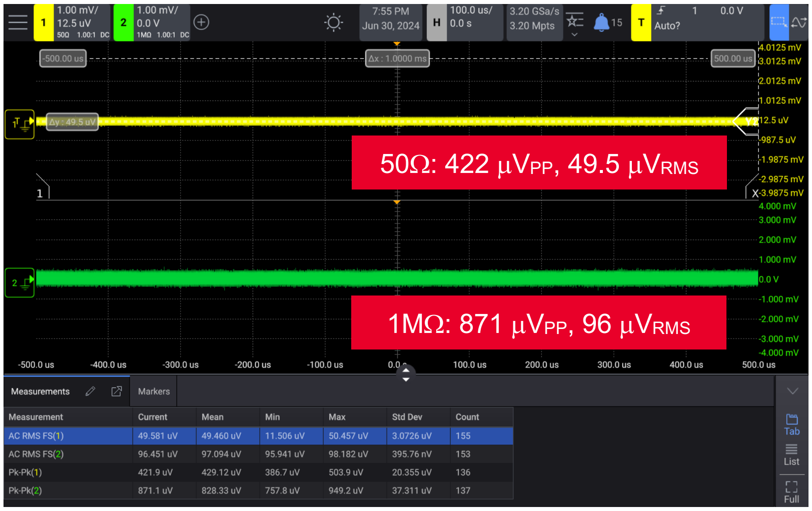


Figure 4. Baseline noise on the 50 Ω input compared to 1 MΩ input path of the HD3 oscilloscope.

Hint 4: Use probe offset to increase dynamic range

Ripple and noise on the DC power supply is 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 signals being measured. 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 increases the oscilloscope measurement system noise. And 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.

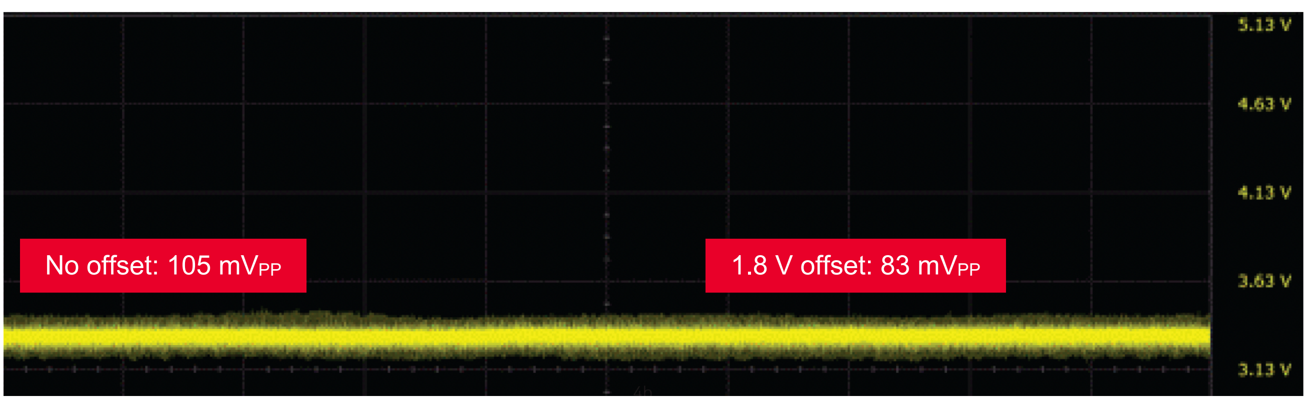


Figure 5. Measuring the noise on a 1.8 V DC supply with no offset and with the use of probe offset.

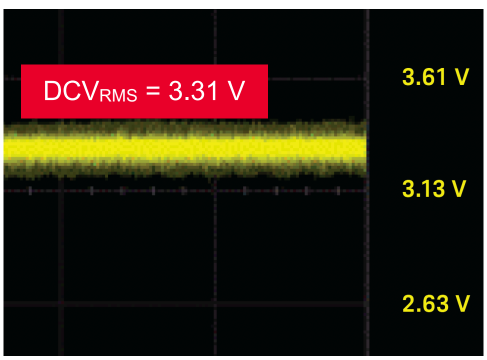
Hint 5: Minimize oscilloscope and probe loading of the supply

Any time an oscilloscope probes a system, it becomes part of that system due to the electrical contact being made. This contact changes the behavior of the system being measured 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 6a and 6b show a comparison of power rail measurements. First, the power rail was measured by a DMM with a result of 3.31 V. Next, the supply was probed with a 50 kΩ input impedance, still resulting in 3.31 V. Finally, the supply was probed 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 IC.

Hint 5

Use a probe with a high input impedance to minimize excess load on the circuit being tested.

N7020A 50kΩ at DC



50Ω cable at DC

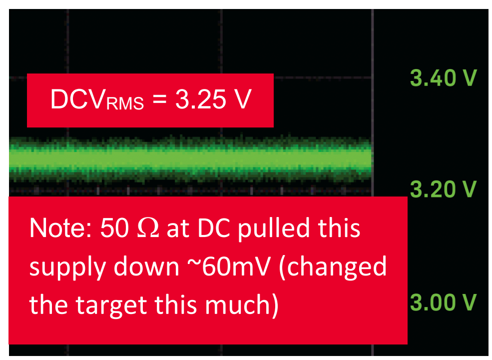


Figure 6a and 6b. Comparison of noise on 3.3 V power rail measurements, showing input impedance of 50 kΩ on the left and input impedance of 50 Ω on the right.

The N7020A and N7024A power rail probe combined with the InfiniiVision HD3 Series oscilloscope

The previously mentioned hints will help minimize oscilloscope measurement system noise and will help 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 they are used with specialized tools that are designed to measure power supply noise. The N7020A power rail probe is the first probe that is specifically designed 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 Keysight HD3 Series oscilloscope, the N7020A has 2 GHz bandwidth to capture high-frequency noise and transients that can cause clock and data jitter.

With Keysight's N7020A power rail probe and the HD3 Series oscilloscope, you can more easily find and analyze the AC signals of your DC power supply that you were unable to see before – giving you the measurement insight that you need.

See What You've Been Missing

4x the resolution and up to 10x less noise

The HD3 Series brings Keysight's industry-leading capabilities from high-performance scopes to the high-volume level, making precision portable from 200 MHz to 1 GHz. Leveraging custom hardware technology from the UXR Series, the HD3 boasts the most impressive resolution on the market with 4x the vertical accuracy and up to 10x less noise than the competition. Paired with our fast, uncompromised waveform update rate and 25x more memory, the HD3 Series is truly set apart from other oscilloscopes in this class.

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

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