7 Common Oscilloscope Probing Pitfalls to Avoid

Take the mystery out of probing

eBook

KEYSIGHT

INTRODUCTION

Understanding Common Probing Pitfalls

Understanding common probing pitfalls and how to avoid them is crucial to making better measurements.

In an ideal world, all probes would be nonintrusive wires attached to your circuit with infinite input resistance and zero capacitance and inductance. They would provide exact replicas of the signals you are measuring. But the reality is that probes introduce loading to the circuit. The resistive, capacitive, and inductive components on the probe can change the response of the circuit under test.

Every circuit is different and has its own set of electrical characteristics. Therefore, every time you probe your device, you should consider the characteristics of the probe and choose one that will have the smallest impact on the measurement. This includes everything from the connection to the oscilloscope input down through the cable to the very point of connection on the device under test (DUT), including any accessories or additional wiring and soldering used to connect to the test point.

Learn about pitfalls you might be making in your tests and how to improve your measurements with better practices.

The electrical behavior of your probe affects both your measurement results and the operation of your circuitry. Taking action to ensure these effects are within acceptable limits is a key step to successful measurements.

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Hidden Noise Impacts

PITFALL 1

Hidden Noise Impacts

Probe and oscilloscope noise levels can exaggerate your DUT noise. Selecting the correct probe for your application with the correct attenuation ratio will lower the added noise from the probe and oscilloscope. As a result, you will have a signal that is a cleaner representation of what is on your DUT.

Many probe manufacturers characterize the probe's noise as equivalent input noise and list it in volts root mean square . Higher attenuation ratios enable you to measure larger signals, but the downside is that the oscilloscope will sense these ratios and amplify your signal and its noise. To see this effect in action, Figure 1 shows the overstated noise using the 10:1 probe on the green trace.

> One easy way to estimate the amount of your probe noise is to check the attenuation ratio and the probe noise level from the probe's data sheet or manual.

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

Learn more

Video: Decrease Noise with Good Probing

In addition, all oscilloscopes have some intrinsic noise. Any noise present in the oscilloscope will ride on top of your signal and skew your measurements. The lower your oscilloscope's noise floor, the less the oscilloscope impacts the signal you are measuring. In addition, you will not be able to see signal detail smaller than the noise level of the oscilloscope. This is important to consider for any signal, but it's even more critical when measuring very small voltages.

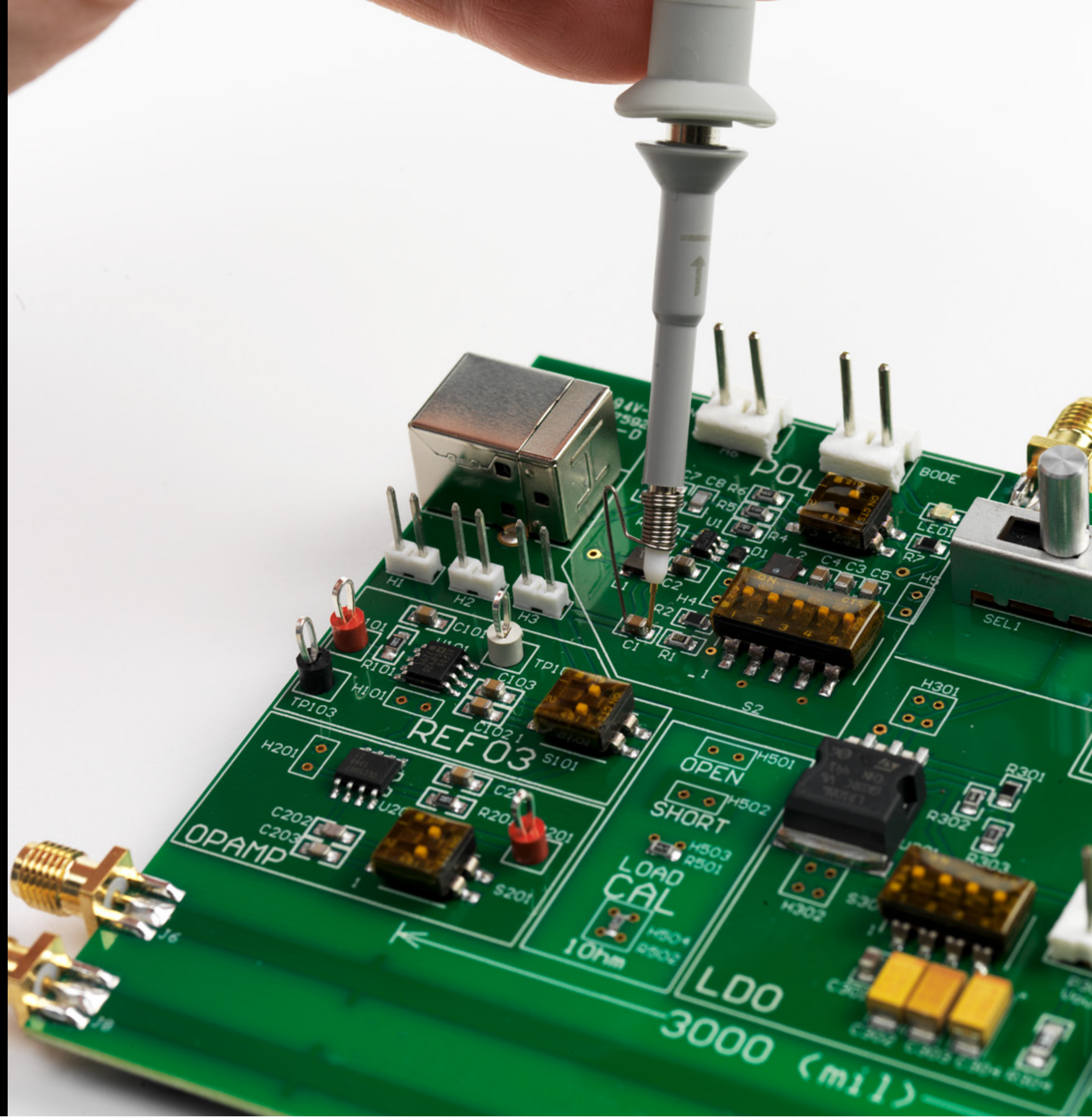
For example, Figure 2 shows a 53 μV signal. On the left, we are measuring with a Keysight InfiniiVision 3000G X-Series oscilloscope. At 2mV / div, the 3000G has a noise floor of 372 μV_{RMS}, so it is impossible to see a 53 μV tone on the fast Fourier transform (FFT) of this oscilloscope. There is too much noise coming from the oscilloscope to see the tone in the FFT on the left. On the right, we are measuring with a Keysight HD3 Series scope, which has a noise floor of less than 50 μV_{RMS} at 2mV / div. Here, we can very clearly see the small 53 μV tone on the FFT of the HD3 Series because the noise is low enough. You want the least amount of oscilloscope noise so that you can capture every part of your signal — even the smallest parts.

Figure 2. A 53 μV signal measured with a Keysight InfiniiVision 3000G X-Series oscilloscope (left) and a Keysight HD3 Series oscilloscope (right)

Web: Explore the InfiniiVision HD3 Series oscilloscopes

PITFALL 2

Unknown Bandwidth Constraints



Unknown Bandwidth Constraints

Choosing a probe with adequate bandwidth is crucial for making important measurements. Inadequate bandwidth will distort your signals, making it difficult for you to make good engineering test or design decisions.

The universally accepted formula for bandwidth states that bandwidth times the rise time equals 0.35 when evaluating a rising edge from 10% to 90%:

$$BW \times T_R = 0.35$$

It's worth noting that your entire system bandwidth is also important to consider. You should factor in both the bandwidth of your probe and your oscilloscope to determine the bandwidth of your system. Here is the formula for calculating your system bandwidth.

$$\text{System bandwidth} = \frac{1}{\sqrt{\dfrac{1}{\text{scope bandwidth}^2} + \dfrac{1}{\text{probe bandwidth}^2}}}$$

For example, say both your oscilloscope and probe bandwidths are 500 MHz. Using the formula, the system bandwidth would be 353 MHz. You can see a significant degradation in the system's bandwidth compared to the separate bandwidth specifications of the probe and the oscilloscope.

Now, if the probe bandwidth is only 300 MHz and the oscilloscope bandwidth is 500 MHz, the system bandwidth falls to 257 MHz.

Learn more

Video: Selecting the Right Probe Bandwidth

> The probe and oscilloscope are a "system." Combined, they impact your bandwidth more than they would individually.

PITFALL 3

Failing to Calibrate Your Probe

PITFALL 3

Failing to Calibrate Your Probe

Your probes arrive already calibrated but not to the front end of your oscilloscope. If they are not calibrated to the input on your oscilloscope, you will get inaccurate measurements.

Active probes

Active probes not calibrated to your oscilloscope will result in differences in your vertical voltage measurement and rising edge timing (and possibly some distortion). Most oscilloscopes provide a reference or auxiliary output and instructions to walk you through probe calibration.

Figure 3 shows a 50-MHz signal input to the oscilloscope with an SMA cable and adaptor on channel 1 (yellow trace). The green trace is the same signal input to the oscilloscope with an active probe on channel 2. Note that the generator output on channel 1 is 1.04 V_{pp} (volts peak-to-peak), and the probed signal on channel 2 is 965 mV (millivolts). In addition, the skew from channel 1 to channel 2 is a massive 3 ms (milliseconds), so the rise times do not line up.

Figure 3. Generator output and probed signal

If we calibrate this probe, the results improve drastically. You can see the results after proper amplitude and skew calibration in Figure 4. The amplitude improves to 972 mV_{pp} with the skew corrected, leaving both rise times aligned.

Passive probes

You can adjust a probe's variable capacitance so that the compensation perfectly matches the oscilloscope input you are using. Most oscilloscopes have a square wave output for calibration or reference. Probe this connection and check that the wave is square. Adjust the variable capacitance as needed to get rid of any undershoot or overshoot.

Tip: Your oscilloscope may have a feature that will adjust the probe compensation, or you can change it manually.

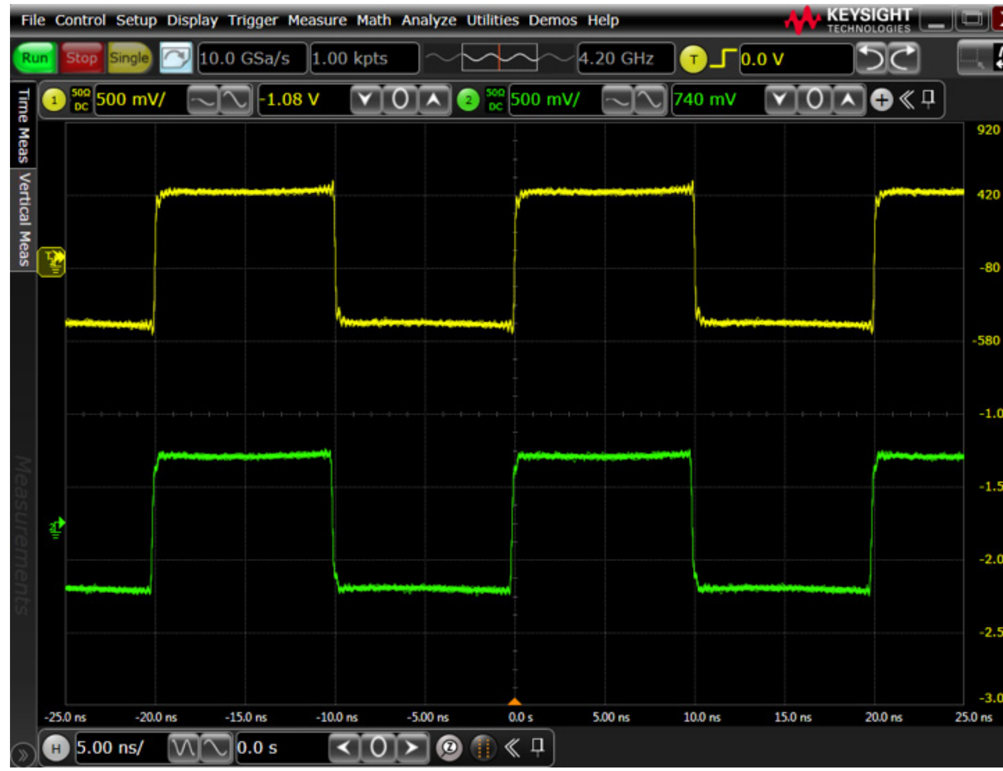


Figure 4. After amplitude and skew calibration

Calibrate your probes to your oscilloscope to get the most accurate representation of your measured signal.

Learn more

Video: How to Compensate Your Probe

PITFALL 4

Increasing Probe Loading

PITFALL 4

Increasing Probe Loading

As soon as you connect a probe to your oscilloscope and touch it to your device, the probe becomes part of your circuit. The resistive, capacitive, and inductive loading that a probe imposes on your device will affect the signal you see on your oscilloscope screen. These loading effects can change the operation of your circuit under test. Understanding these loading impacts will help you avoid the pitfalls of selecting the wrong probe for your circuit or system. Probes have resistive, capacitive, and inductive properties, as shown in Figure 5.

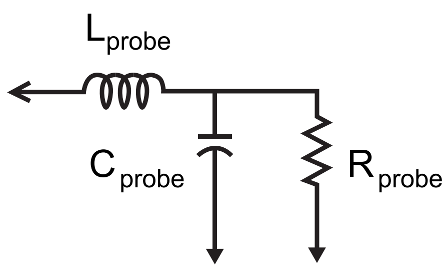
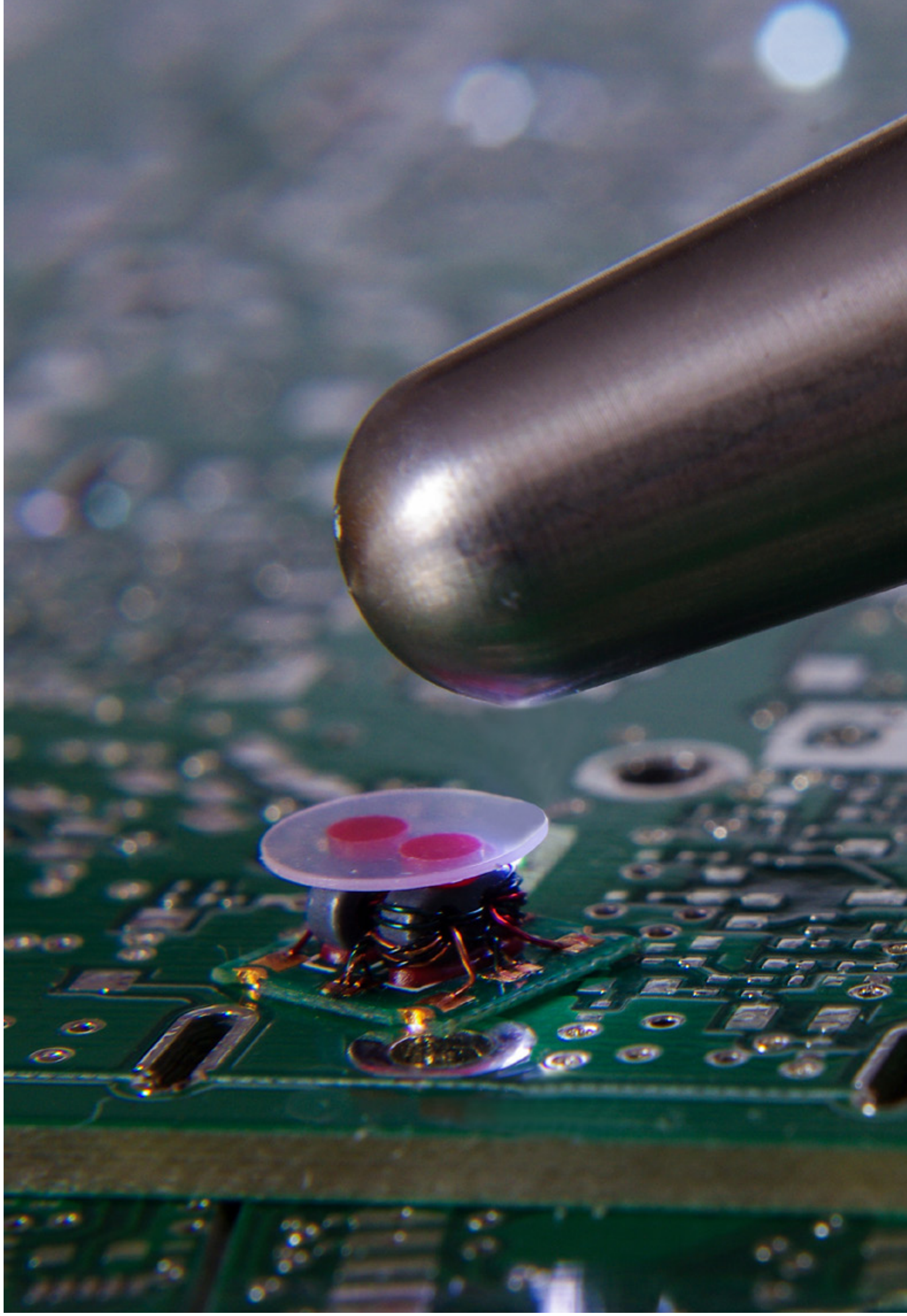
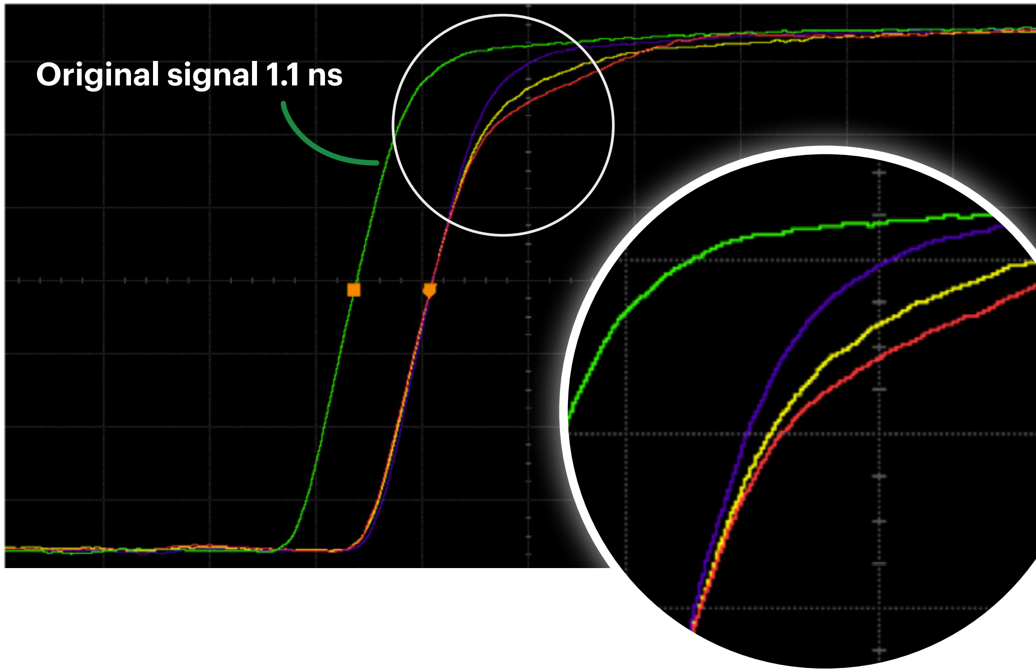


Figure 5. The basic electrical circuit of a probe

To reach a tight probe point, you might get creative by adding long leads or wires. However, adding accessories or probe tips to a probe can decrease bandwidth, increase loading, and cause a non-flat frequency response.



Typically, the longer the input wires or leads of a probe tip, the more the bandwidth will decrease. There might not be a significant effect on lower-bandwidth measurements, but be careful which probe tip and accessories you use as you go up in bandwidth, especially above 1 GHz. As the bandwidth of your probe decreases, you lose the ability to measure fast rise times. Figure 6 demonstrates how the rise time displayed on the oscilloscope becomes slower with longer accessories. For the most accurate measurements, it is best to use the shortest tip possible.



> Use the shortest leads possible to maintain your probe's bandwidth and accuracy.

Figure 6. Probe loading effects of different probe-lead lengths

Also, keep ground leads short because the longer they get, the more inductance they add. Keeping ground leads as short and as close to the system ground as possible will ensure repeatable and accurate measurements.

Tip: If you absolutely must add a wire to the probe tip to reach difficult probe points, add a resistor at the tip to dampen the resonance of the added wire. You may not be able to do much about bandwidth limitations when adding long leads, but you can flatten the frequency response. To determine what size resistor to use, probe a known square wave like the reference square wave on your oscilloscope.

If the resistance is correct, you will see a clean square wave (but you may incur limited bandwidth). To address ringing on the signal, increase the size of the resistor. A single-ended probe will need only one resistor on the probe tip. If you are using a differential probe, use two resistors — one per lead.

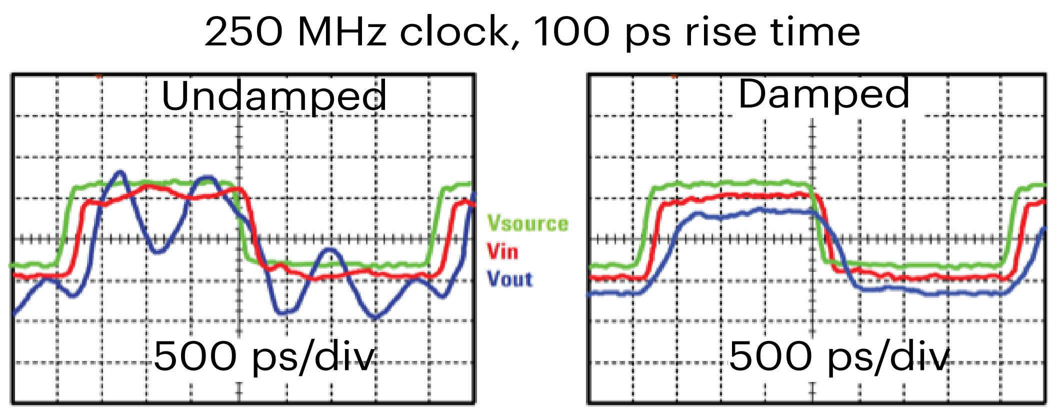


Figure 7. Adding a resistor to a probe tip can overcome resonance from long probe connections and reduce ringing and overshoot. However, this method will not prevent bandwidth limiting caused by the added leads.

Use a resistor to dampen peaking caused by long probe leads.

Learn more

Video: Effects of Oscilloscope Probe Loading

PITFALL 5

Underutilizing Your Differential Probe

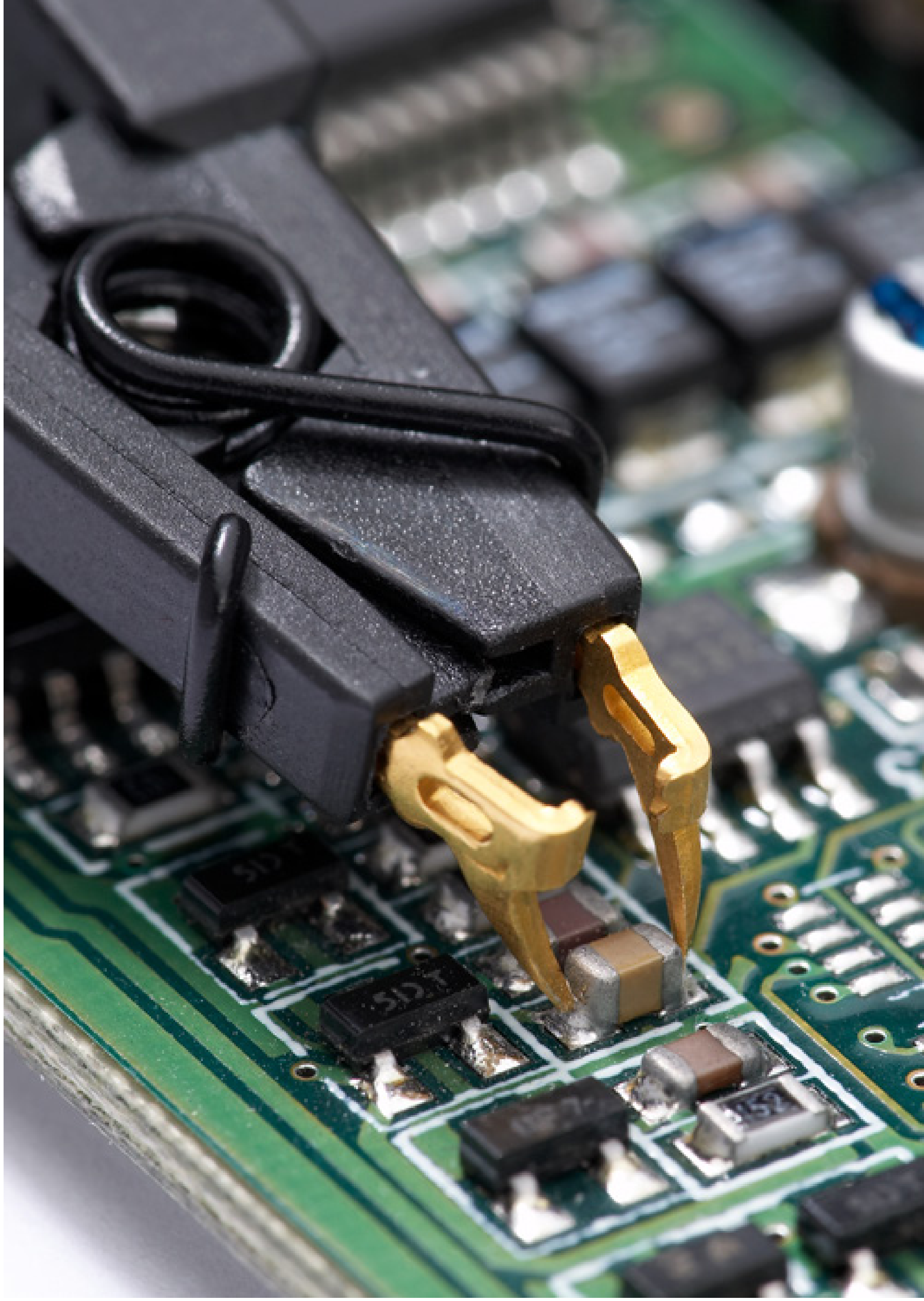
PITFALL 5

Underutilizing Your Differential Probe

Many people think differential probes examine only differential signals. Did you know you can also probe single-ended signals with your differential probe? This will save you time and money and increase your measurement accuracy. Maximize the use of your differential probe and get the best signal fidelity possible.

Differential probes can make the same measurements as single-ended probes. Because of the common mode rejection on both inputs of the differential probe, the differential measurements can have significantly less noise. This enables you to see a better representation of your DUT's signals and avoid confusion from random noise introduced during probing.

You can see the single-ended measured signal in blue in Figure 8 and the differential-measured signal in red in Figure 9. The single-ended measurement in blue has significantly more noise than the differential measurement in red because of less common mode correction by the single-ended probe.



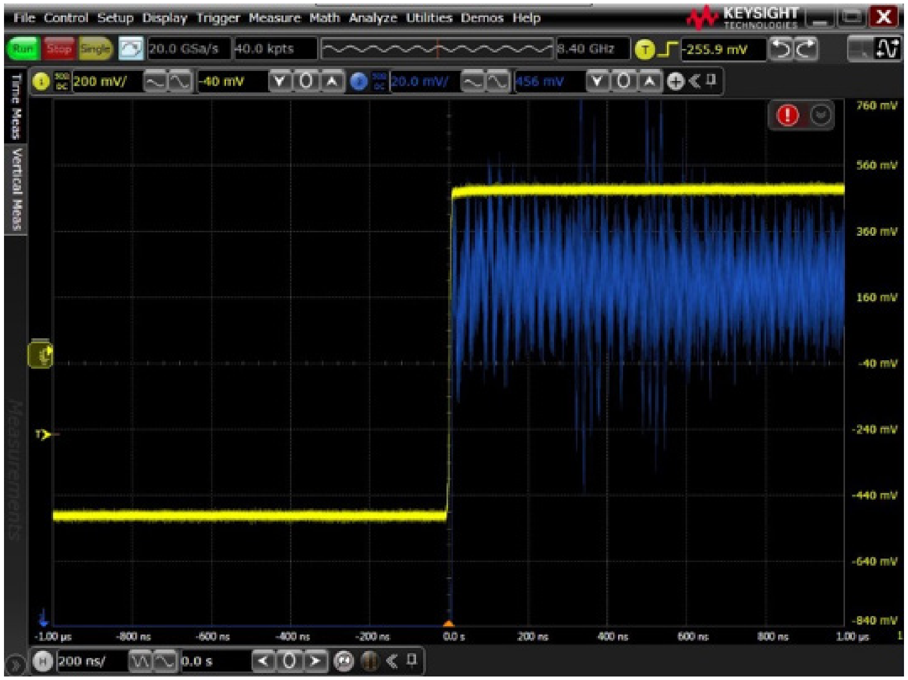


Figure 8. Single-ended measurement

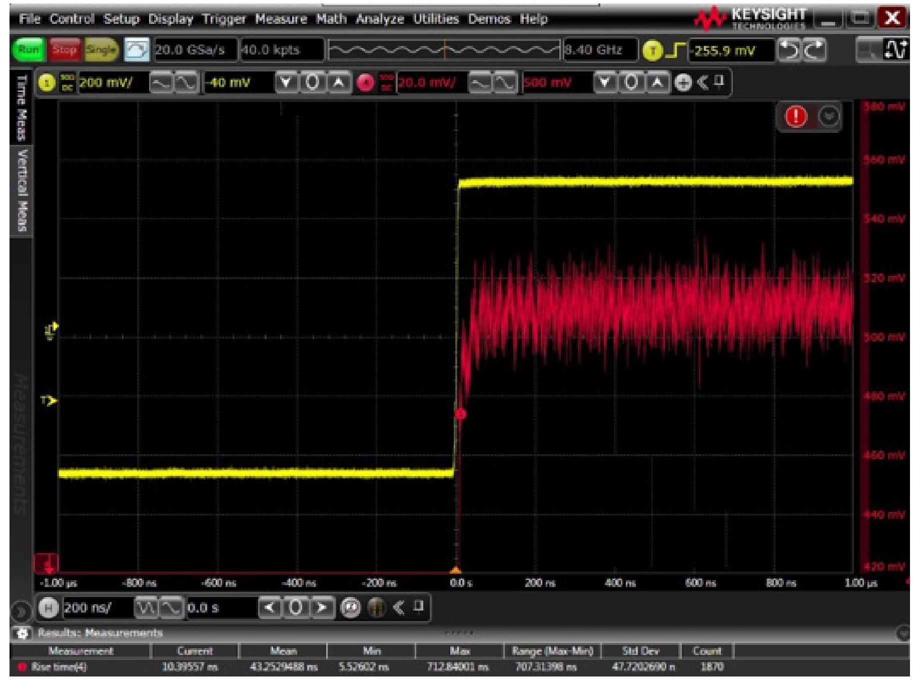


Figure 9. Differential measurement

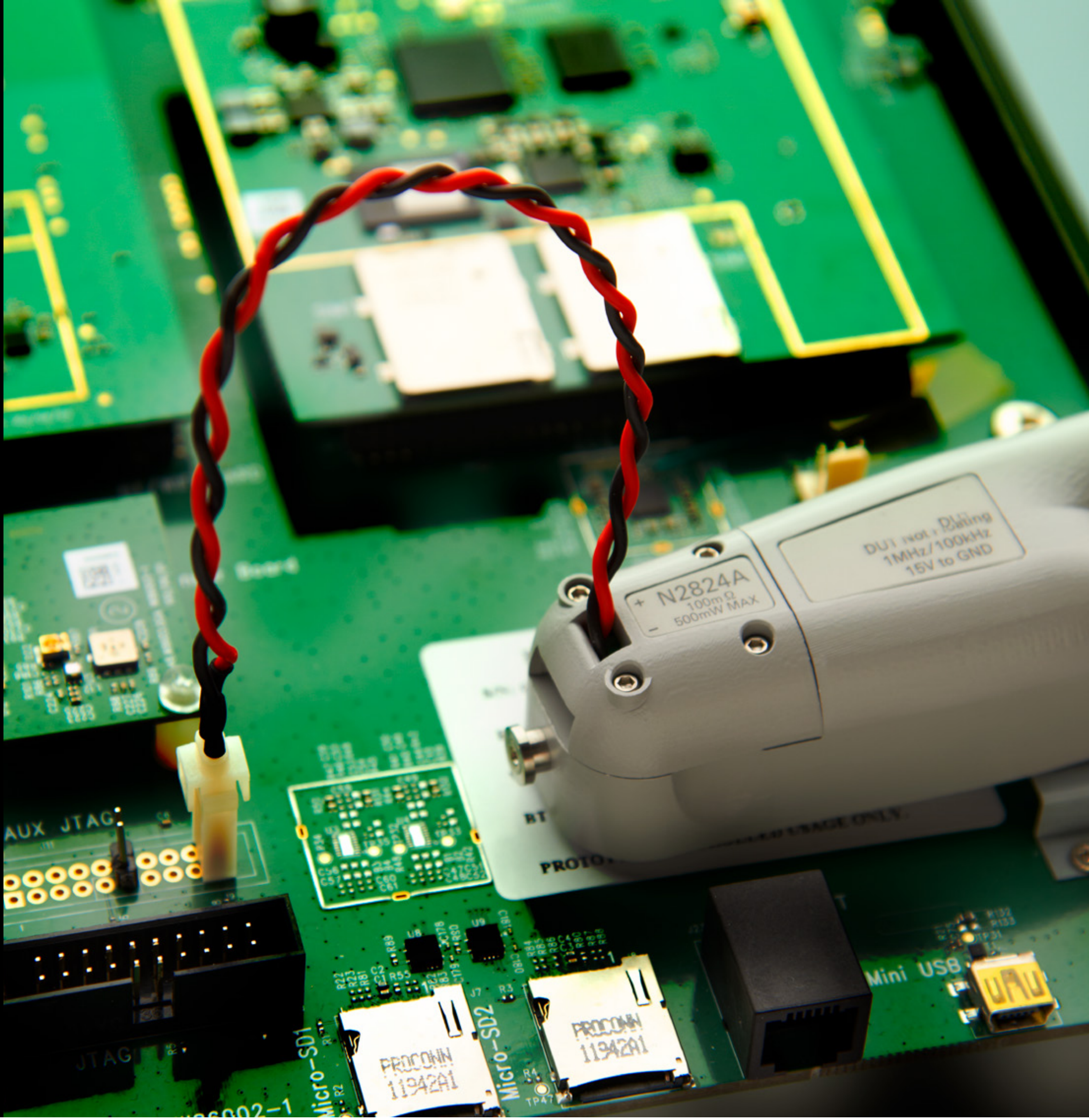
> Differential probes can make the same type of measurements as single-ended probes with significantly less noise because of common mode rejection.

Learn more

Video: Single-Ended or Differential Probe?

PITFALL 6

Selecting the Wrong Current Probe



PITFALL 6

Selecting the Wrong Current Probe

High current and low current measurements require the capture of different details. You need to know which current probe to use for your application and the trouble you could run into when using the wrong probe.

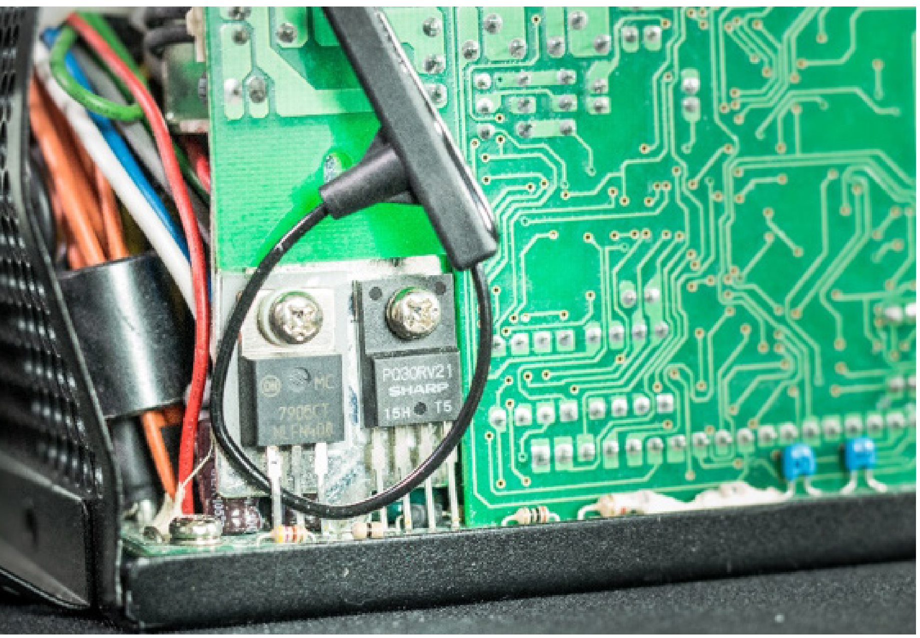


Figure 10. A Rogowski probe tip wrapped around a component

High current measurements

Use a clamp-on probe to measure high current (10 A to 3,000 A) only if your device is small enough to fit in the original clamp. Engineers with this probe type will get creative and add wires to their probe clamp to measure devices that do not fit in the clamp-on tip, but this can change the characteristics of the DUT. It is better to use the right tool.

The best solution is to use a high-current probe with a flexible loop probe head. You can wrap this flexible loop around any device. This type of probe is known as a Rogowski coil. It enables you to probe your device without adding components with unknown behaviors, maintaining high signal integrity for your measurement. It also enables you to measure large currents from milliamps to hundreds of kiloamps. Just be aware that it measures AC only, with the DC components blocked. It also has a lower sensitivity than some current probes. This generally isn't a problem for high-current measurements. Sensitivity and viewing of the DC component become more of a concern when you are looking at small currents. Keep in mind that what works for one measurement does not necessarily work for another.

Use a high-current probe that fits your device under test.

Low current measurements

If you are measuring current in a battery-powered device, the dynamic range can vary greatly. When a battery-powered device is idle or performing small background tasks, current peaks can be small. When the device switches to a more active state, the current peaks can be drastically higher. Using a large vertical-scale oscilloscope setting, you can measure a large portion of the signal, but the small current signals will be lost in the noise of the measurement. On the other hand, if you use a small vertical setting, you will clip the large signal, resulting in a distorted and invalid measurement.

Choose a current probe that can measure a wide range, from microamps to amps, and has multiple amplifiers to view large and small current deviations at once. Two variable gain amplifiers in a probe enable you to set a zoomed-in view to see the small current fluctuations and a zoomed-out view to see large current spikes simultaneously (see Figure 11).

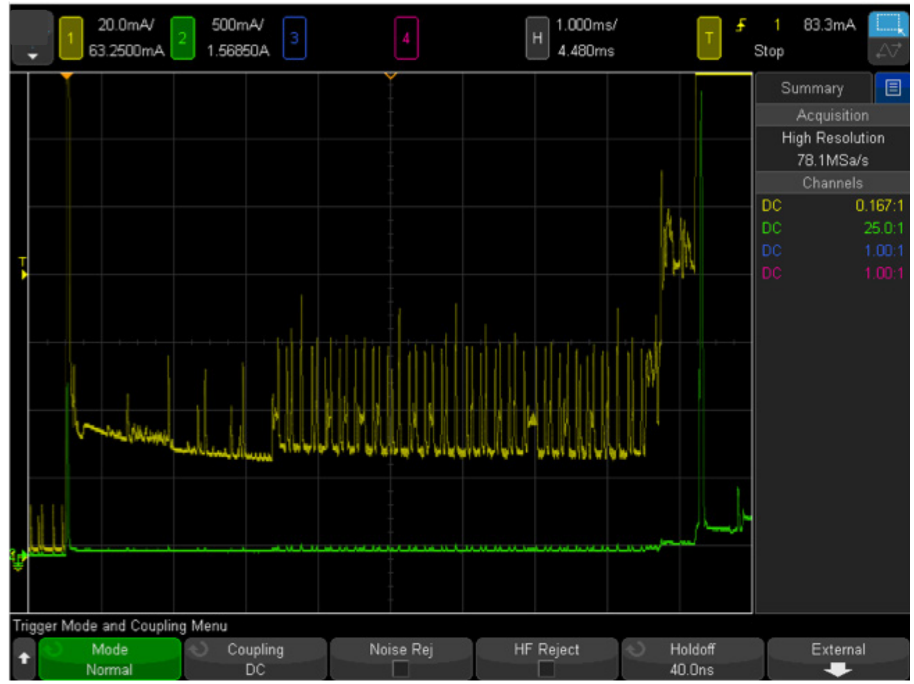


Figure 11. Current probes with two variable gain amplifiers enable you to view large and small current deviations at once. This example shows the Keysight N2820A / 21A high-sensitivity current probes.

Learn more

Video: How to Measure Current with an Oscilloscope?

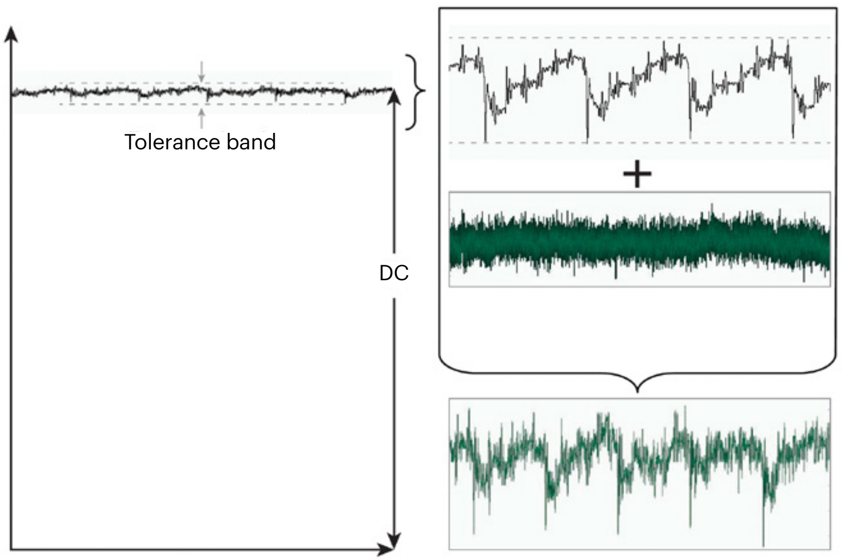
Use a low current probe with enough sensitivity and dynamic range to capture all aspects and details of your signal.

PITFALL 7

Mishandling DC Offset During Ripple and Noise Measurements

PITFALL 7

Mishandling DC Offset During Ripple and Noise Measurements



Ripple and noise on a DC supply consist of small AC signals on top of a relatively large DC signal. With a large DC offset, you may need to use a larger volt per division setting on the oscilloscope to get the signal viewable on screen. Doing this decreases the sensitivity of the measurement and increases noise compared to the small AC signal. Therefore, you will not get an accurate representation of the AC portion of your signal.

If you use a DC block to get around this, you will inherently block some of the low-frequency AC content, keeping you from seeing the signal the way the components on your device do.

Use a power rail probe with a large offset capability to center the waveform on the screen without removing the DC offset. This enables you to keep the entire waveform on screen while keeping the vertical scale small and zoomed-in. With these settings, you can view transients, ripple, and noise in detail.

> Using a power rail probe with large offset capability enables you to see transients, ripple, and noise in detail without eliminating the DC portion of your signal.

Learn more

Video: Characterize Output Ripple with Oscilloscopes and Power Rail Probes

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