Take the Mystery Out of Probing

# 7 Common Oscilloscope Probing Pitfalls to Avoid

eBook

KEYSIGHT

INTRODUCTION

# Understanding Common Probing Pitfalls

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

In an ideal world, all probes would be a non-intrusive wire attached to your circuit having infinite input resistance with zero capacitance and inductance. It would provide an exact replica of the signal being measured. 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 want to consider the characteristics of the probe and choose one that will have the smallest impact to the measurement. This includes everything from the connection to the oscilloscope input down through the cable to the very point of connection on the 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 your measurements can be improved 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.

# Contents

**PITFALL 1**

# Not Calibrating Your Probe

PITFALL 1

# Not Calibrating Your Probe

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


Figure 1. Generator output and probed signal.

## Active Probes

If your active probes are not calibrated to your oscilloscope, you will see 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 1 shows a 50-MHz signal being input to the oscilloscope with an SMA cable and adaptor on channel one (yellow trace). The green trace is the same signal being input to the oscilloscope with an active probe on channel two. Note that the generator output on channel one is 1.04 Vpp (volts peak-to-peak) and the probed signal on channel two is 965 mV (millivolts). In addition, the skew from channel one to channel two is a massive 3 ms (milliseconds), so the rise times do not line up at all.

If we calibrate this probe, the results improve drastically. You can see the results after proper amplitude and skew calibration in Figure 2. The amplitude is now improved to 972 mVpp, and the skew has been corrected, leaving both rise times aligned.

## Passive probes

A probe's variable capacitance can be adjusted so 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.

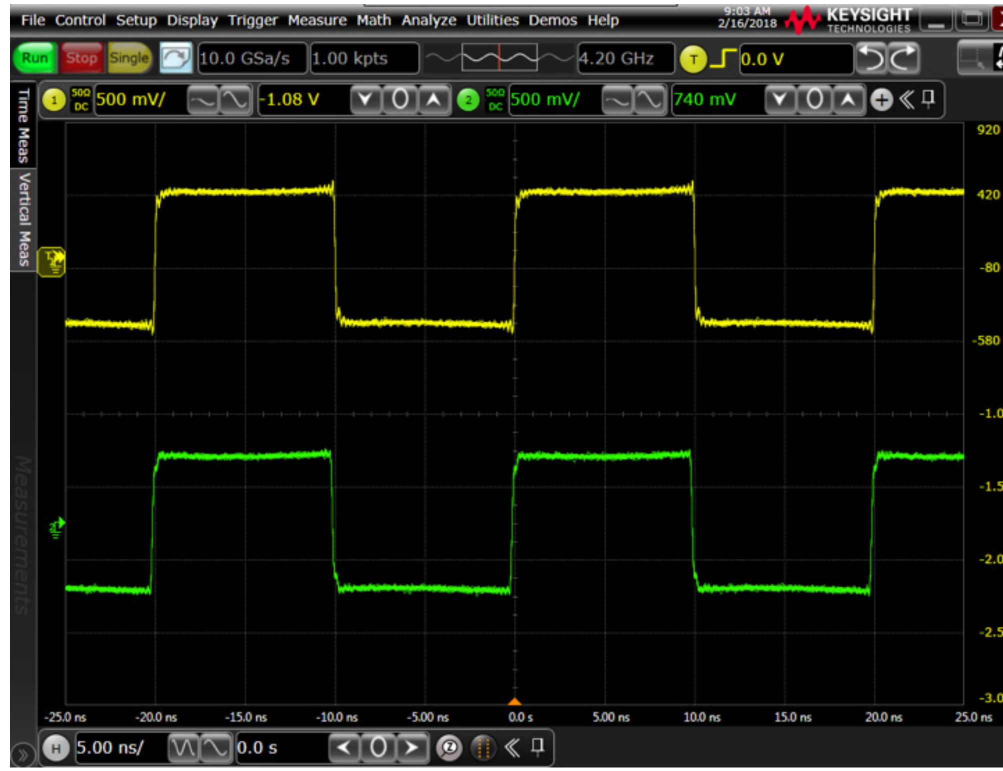


Figure 2. After amplitude and skew calibration.

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

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Video: How to Compensate Your Probe

**PITFALL 2**

# Increasing Probe Loading

PITFALL 2

# 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 affects 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 specific circuit or system. Probes have resistive, capacitive, and inductive properties, as shown in Figure 3.

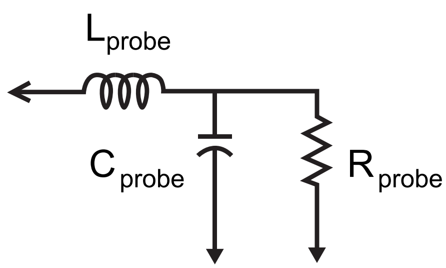
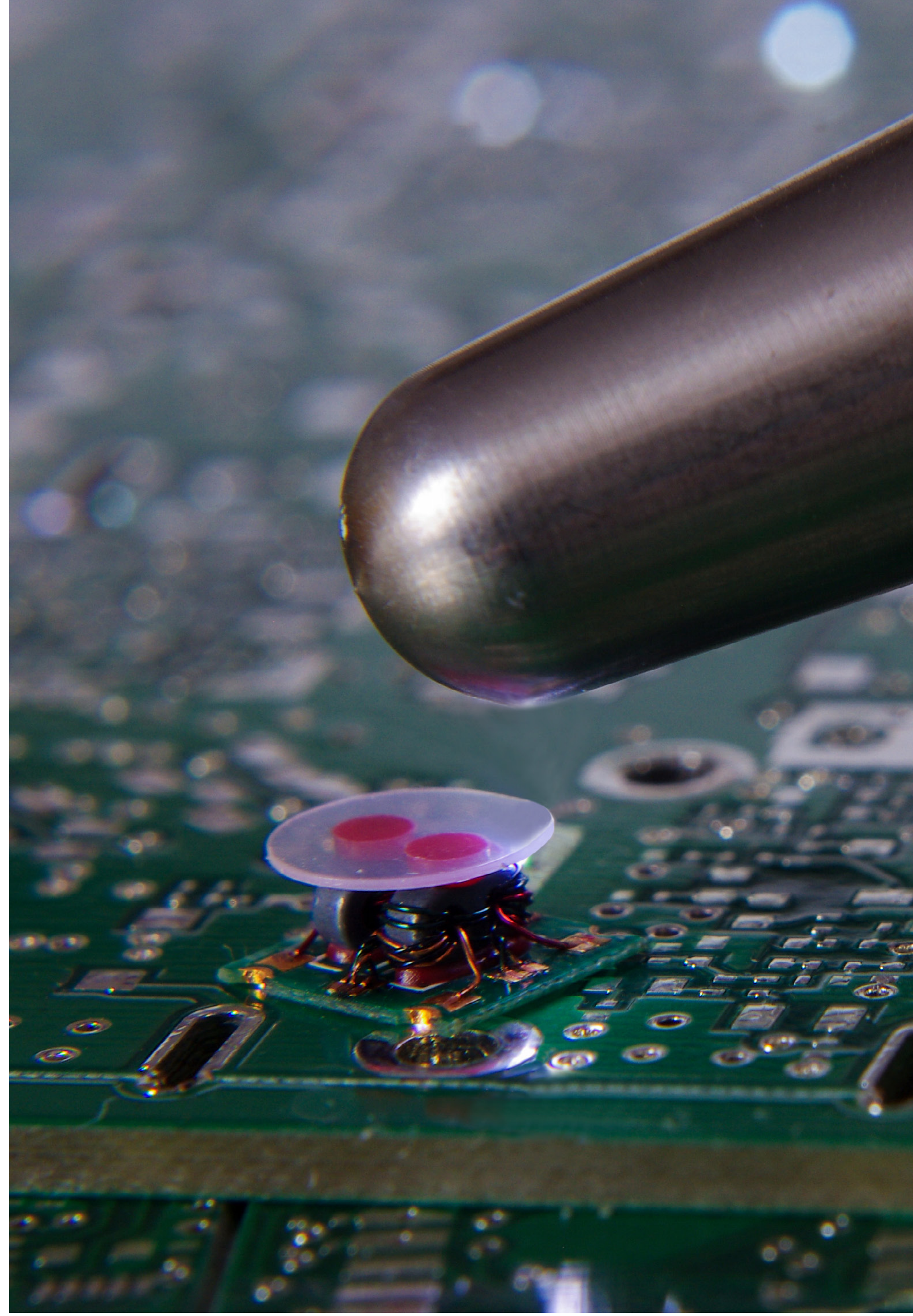



Figure 3. The basic electrical circuit of a probe.

To reach a tight probe point, you might get creative in adding long leads or wires. But 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. Lower bandwidth measurements may not be as affected, 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 4 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.

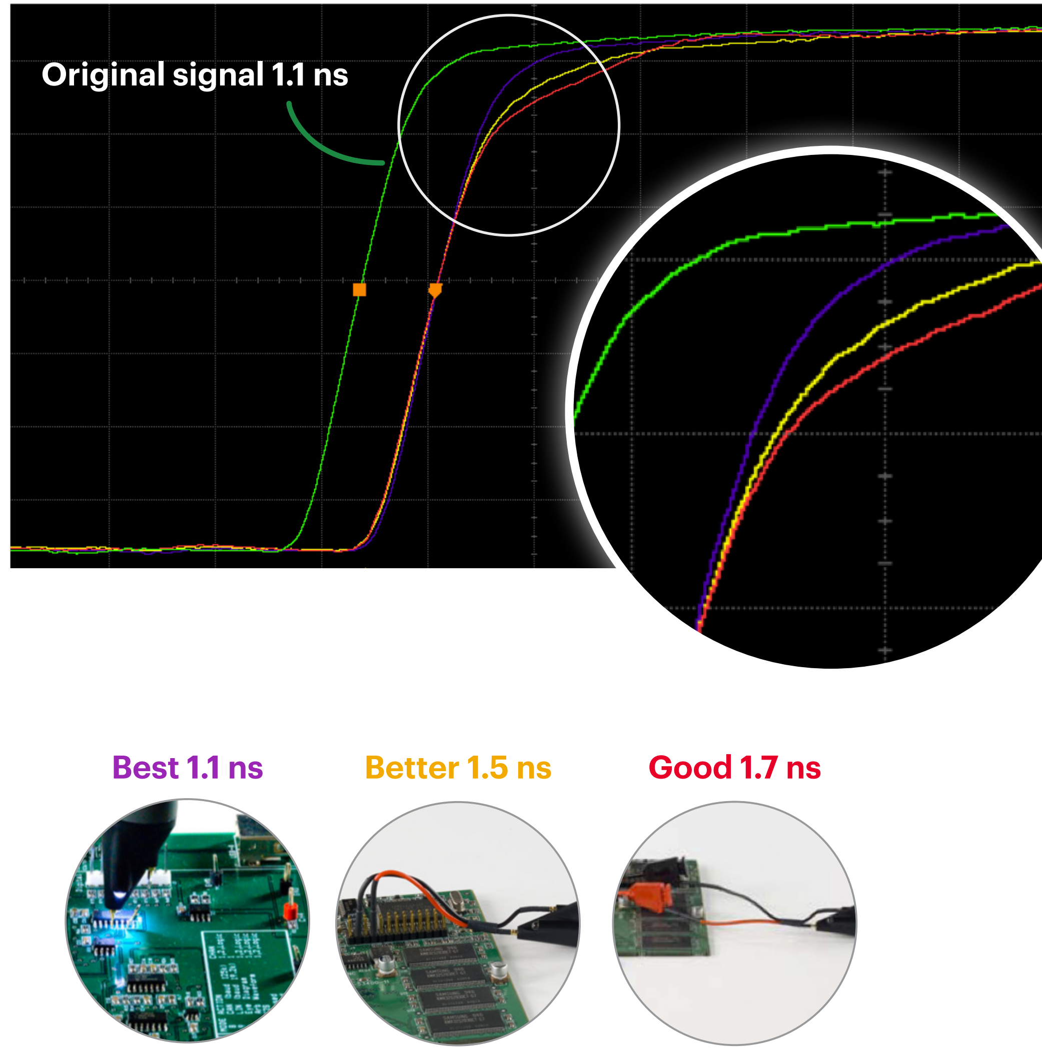



Figure 4. Probe loading effects of different probe-lead lengths.

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

Also keep ground leads short since 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 in order to reach difficult probe points, add a resistor at the tip to damp 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 find out the size of 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 (with the exception that it may be bandwidth limited). If there is ringing on the signal, increase the size of the resistor. A single-ended probe will only need one resistor on the probe tip. If you are using a differential probe, use two resistors—one per lead.

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Video: Effects of Oscilloscope Probe Loading

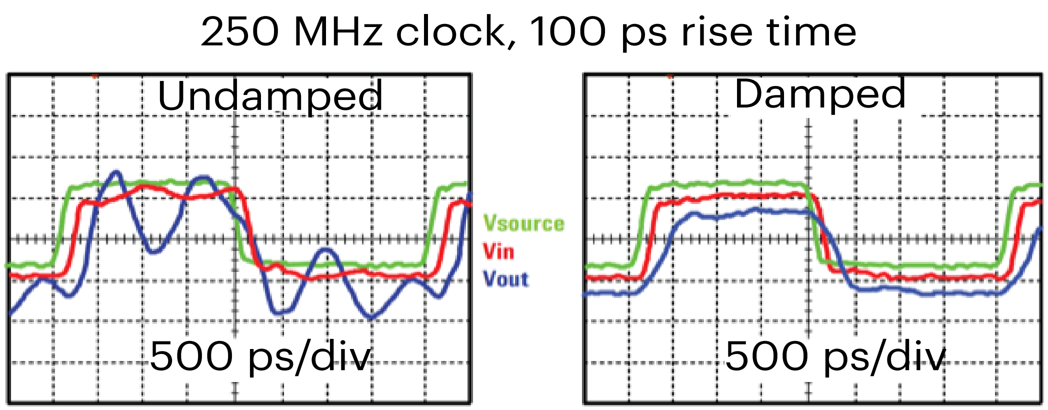



Figure 5. Adding a resistor to a probe tip can overcome resonance from long probe connections, reduce ringing and overshoot. However, it will not prevent bandwidth limiting caused by the added leads.

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

**PITFALL 3**

# Not Fully Utilizing Your Differential Probe

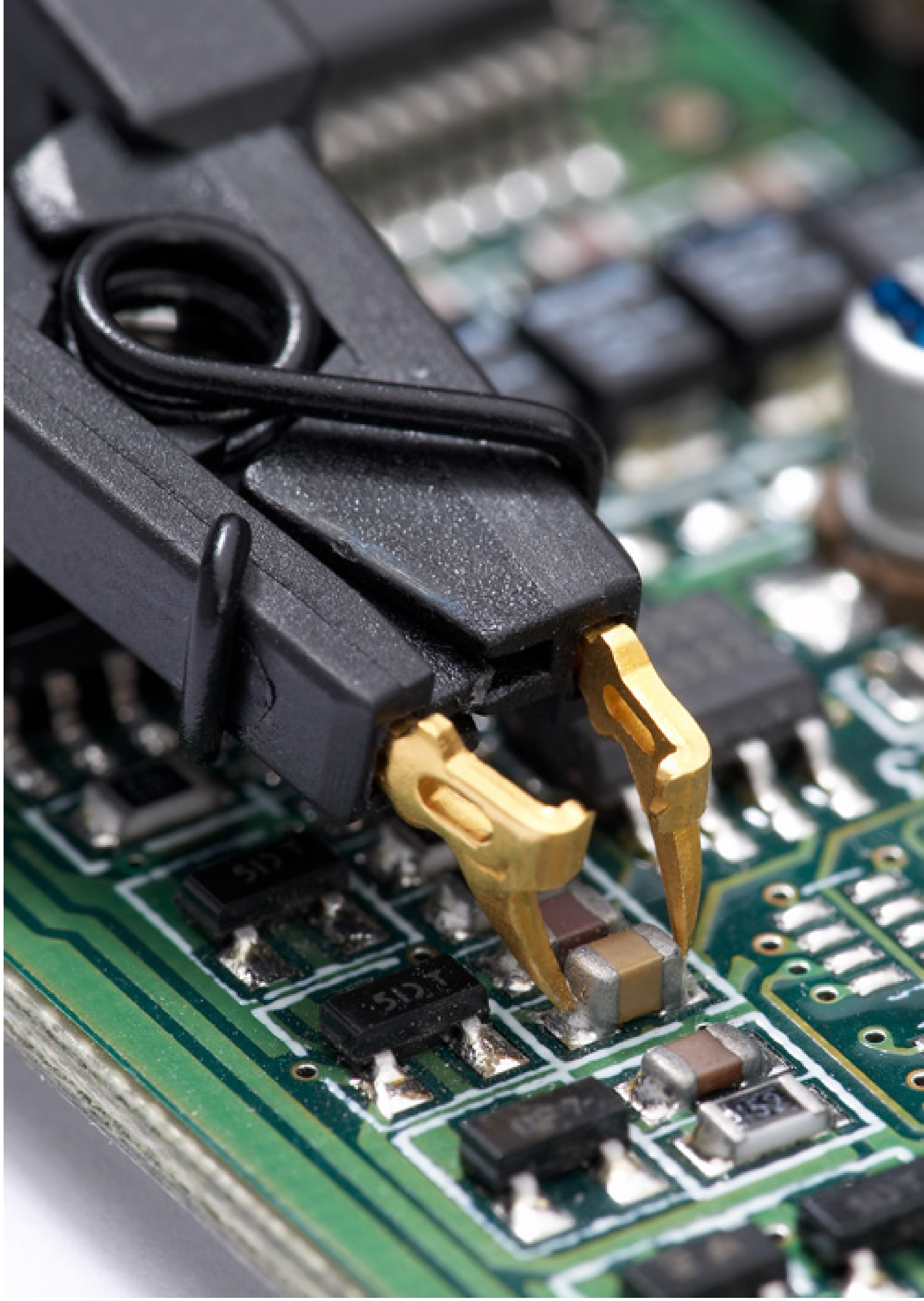
PITFALL 3

# Not Fully Utilizing Your Differential Probe

Many people think differential probes are made to only probe differential signals. Did you know you can also probe single-ended signals with your differential probe? This will save you both time and money and increase the accuracy of your measurements. Maximize the usage of your differential probe, and get the best signal fidelity possible.

Differential probes can make the same measurements as single-ended probes, and due to the common mode rejection on both inputs of the differential probe, the differential measurements can have significantly less noise. This allows you to see a better representation of your DUT's signals and not be misled by random noise that is added by probing.

You can see the single-ended-measured signal in blue in Figure 6 and the differential-measured signal in red in Figure 7 on the next page. The single-ended measurement in blue has much more noise than the differential measurement in red due to less common mode correction by the single-ended probe.



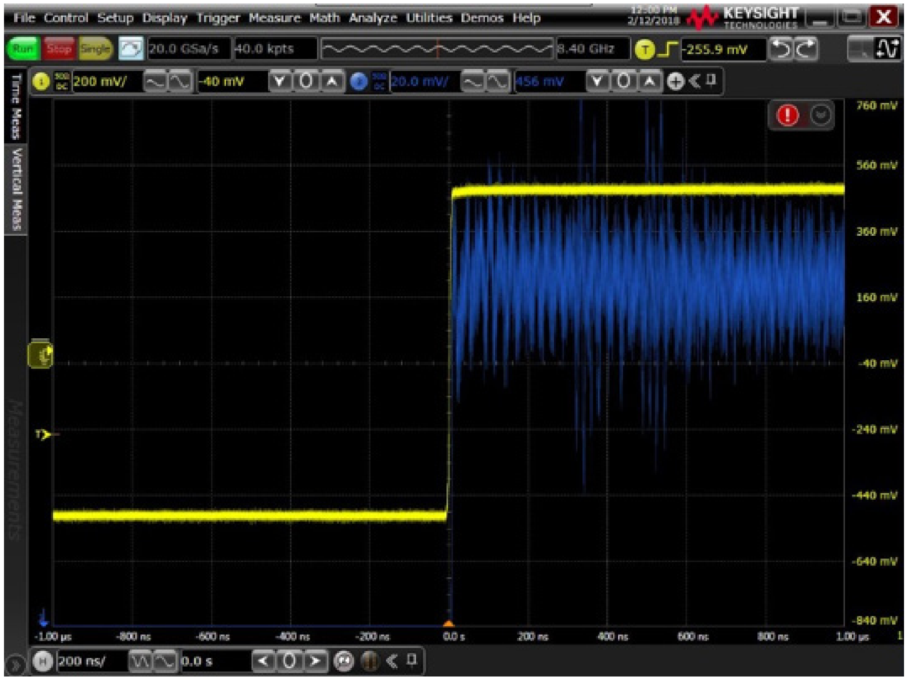



Figure 6. Single-ended measurement.

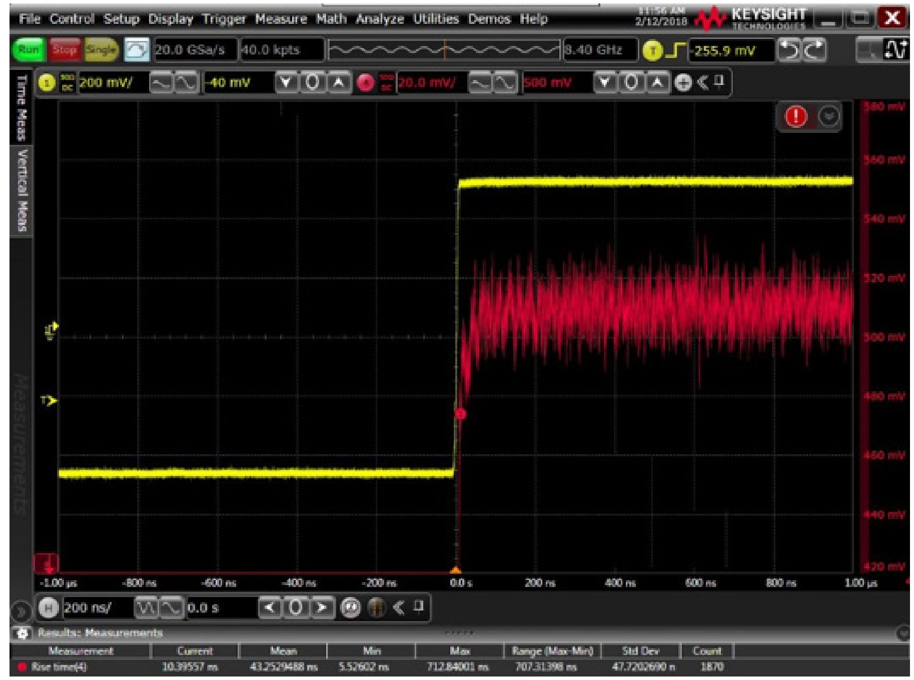



Figure 7. Differential measurement.

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

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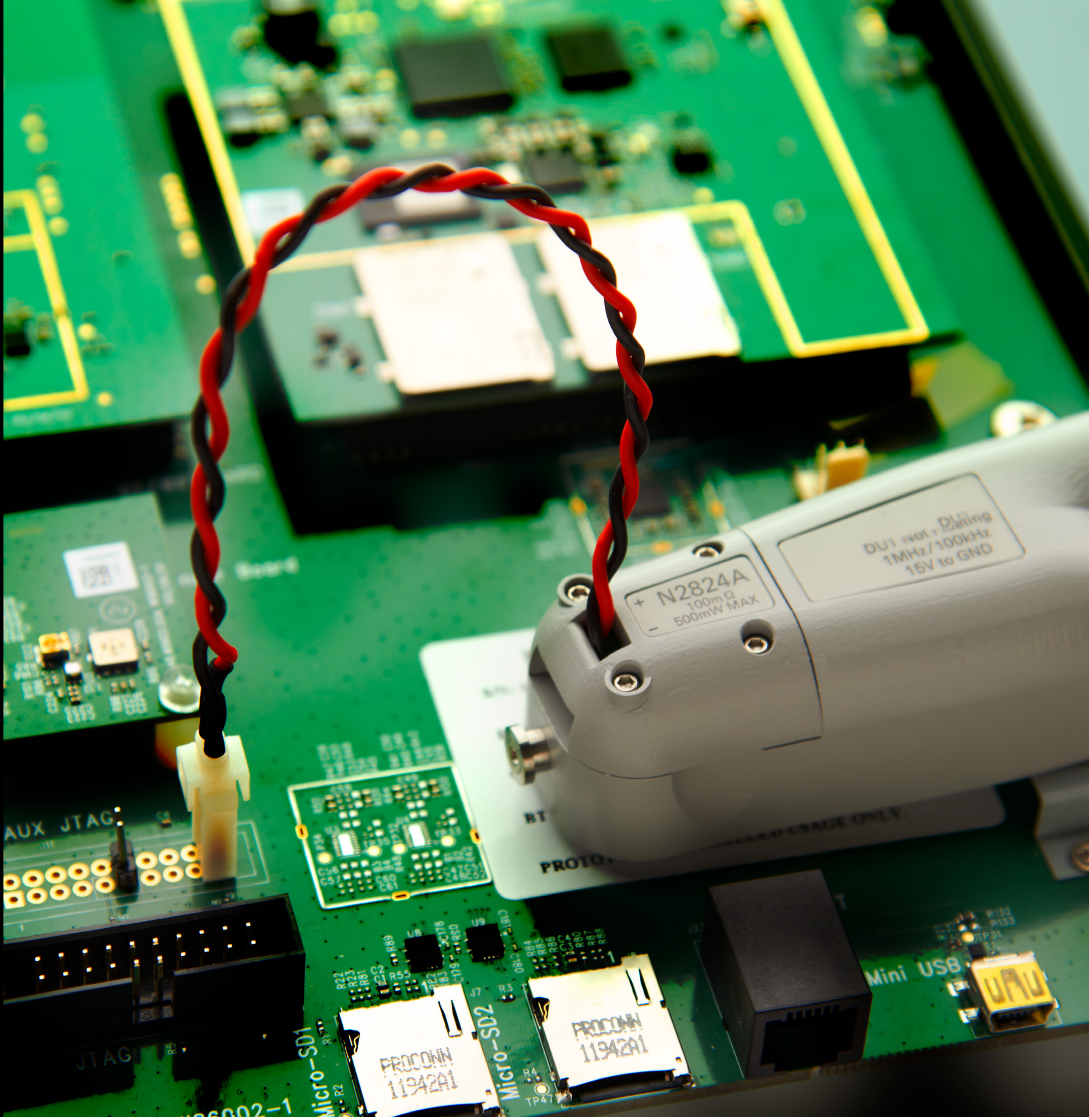
Video: Single-ended or Differential Probe?

PITFALL 4

# Selecting the Wrong Current Probe



# Selecting the Wrong Current Probe

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

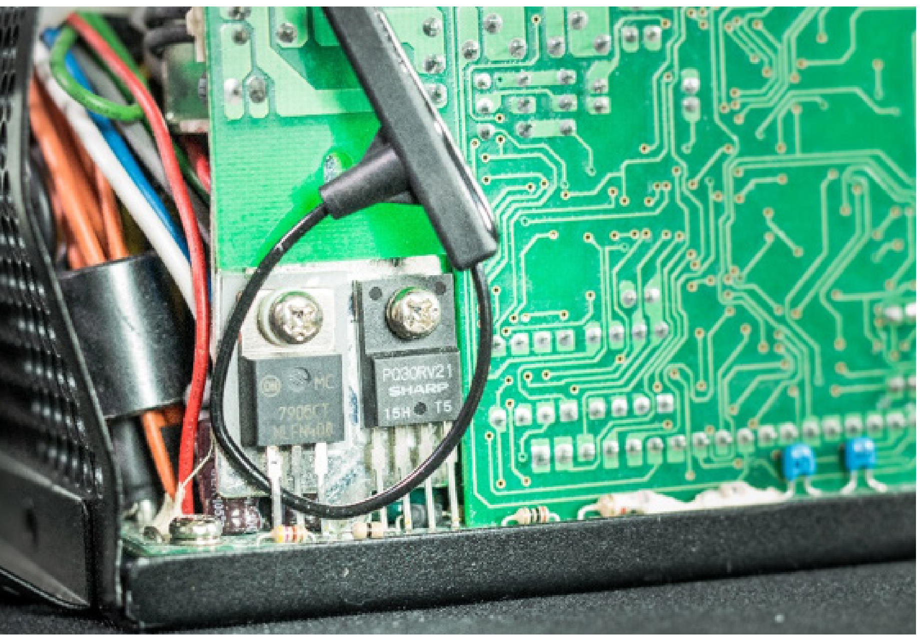


Figure 8. A Rogowski probe tip wrapped around a component.

## High current measurements

If you are using a clamp-on probe to measure high current (10A – 3000A), only do so if your device is small enough to fit in the original clamp. Engineers with this probe type will get creative and add additional wires to their probe clamp to measure devices that can't 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 that has a flexible loop probe head. You can wrap this flexible loop around any device. This type of probe is called a Rogowski coil. It allows you to probe your device without adding components with unknown behaviors, maintaining high signal integrity for your measurement. They also enable you to measure large currents from mA to hundreds of kA. Just be aware that they measure AC current only, so the DC components are blocked. They also have a lower sensitivity than some current probes. This generally isn't a problem for high current measurements. Sensitivity and viewing the DC component becomes more of a concern when you're 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, and your measurement will be distorted and invalid.

Choose a current probe that is not only able to measure a wide range from uAmps to Amps, but also one with multiple amplifiers to view both large and small current deviations at once. Two variable gain amplifiers in a probe allow 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 9).

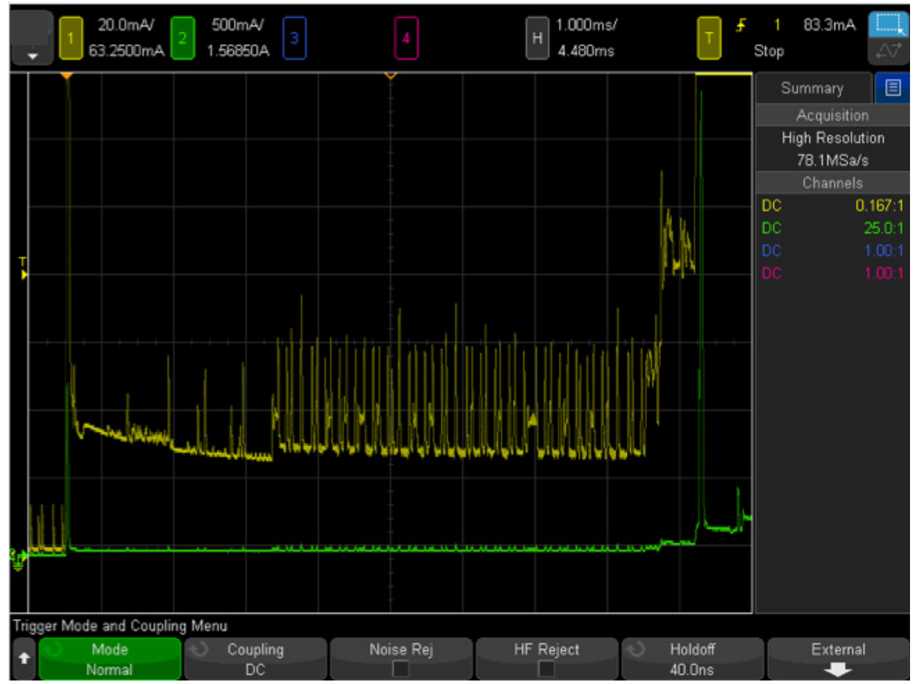



Figure 9. Current probes with two variable gain amplifiers allow you to view both large and small current deviations at once. This example shows Keysight's N2820A/21A high-sensitivity current probes.

LEARN MORE

Video: How to Measure Current with an Oscilloscope?

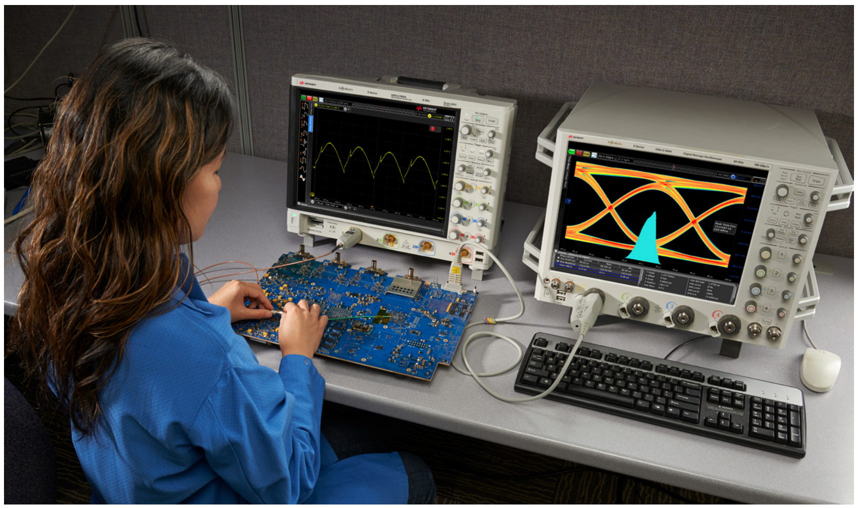
**Use a low current probe with enough sensitivity and dynamic range** to capture all aspects and details of your signal.

**PITFALL 5**

# Mishandling DC Offset During Ripple and Noise Measurements

PITFALL 5

# Mishandling DC Offset During Ripple and Noise Measurements



Ripple and noise on a DC supply are made up of small AC signals on top of a relatively large DC signal.  With 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 sensitivity of the measurement and increases noise compared to the small AC signal. This means 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'll 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 large offset capability to center the waveform on screen without removing the DC offset. This allows you to keep the entire waveform on screen while keeping the vertical scale small and zoomed-in. With these setting you can view transients, ripple, and noise in detail.

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

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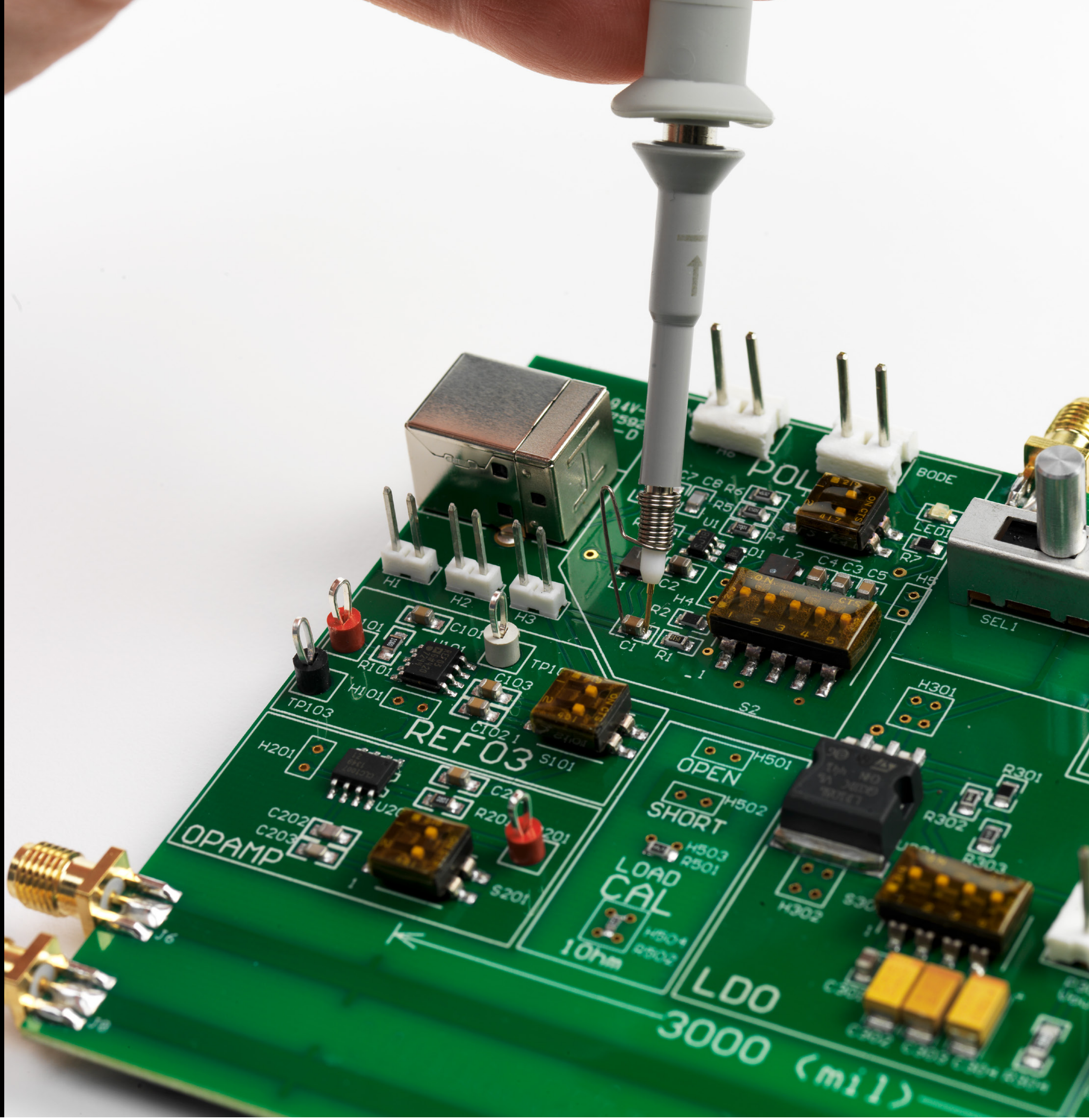
Video: Power and Current Probe Measurements

PITFALL 6

# Unknown Bandwidth Constraints



PITFALL 6

# 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: 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. The formula for calculating your system bandwidth is shown below.

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

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 that the system bandwidth is degraded greatly from the two individual bandwidth specifications of the probe and the oscilloscope.

Now, if probe bandwidth is only 300 MHz and the oscilloscope bandwidth is still 500 MHz, the system bandwidth is now further reduced to 257 MHz.

## LEARN MORE

Video: Selecting the Right Probe Bandwidth

**The probe and oscilloscope are a "system"** and combined impact your bandwidth more than they would individually.

**PITFALL 7**

# Hidden Noise Impacts

PITFALL 7

# Hidden Noise Impacts

Your DUT noise can be exaggerated by probe and oscilloscope noise levels. Selecting the correct probe for your application with the correct attenuation ratio will lower the probe and oscilloscope added noise. 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 (EIN) and will be listed in volts rms. Higher attenuation ratios allow you to measure larger signals but the down side is that the oscilloscope will sense these ratios and amplify both your signal and its noise. To see this effect in action, Figure 10 shows the overstated noise using the 10:1 probe on the green trace.

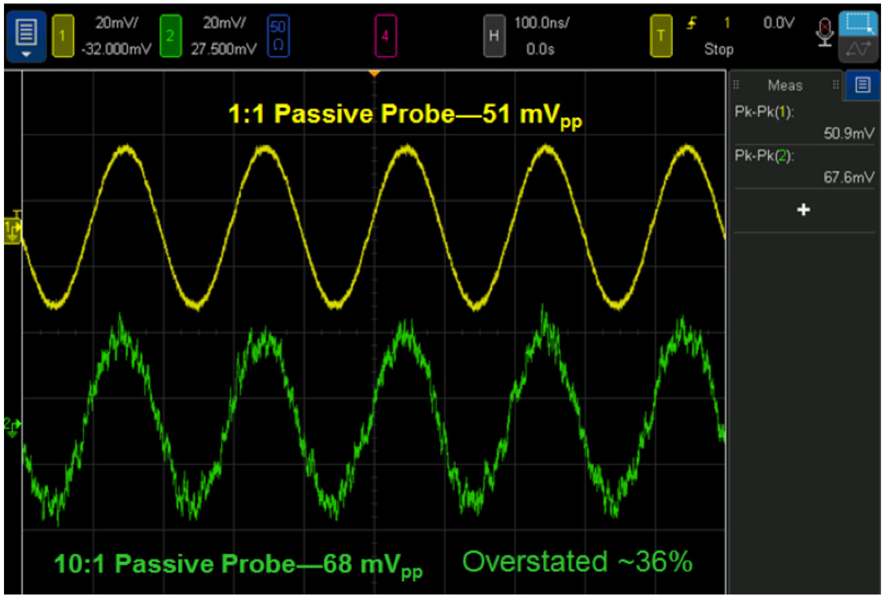



Figure 10. A 50 mVp-p sinewave measured with bot 1:1 and 10:1 probes.

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

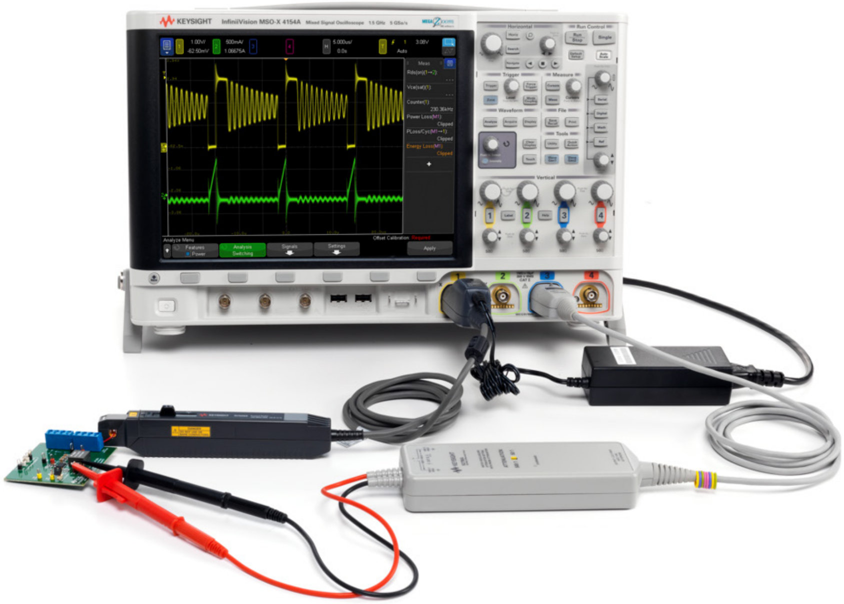
LEARN MORE

Video: Decrease Noise with Good Probing

# Keysight Probing Solutions

Find the best probing solution for your application with a variety of online tools. Whether you need a Passive, Active, Differential, Current, or High Voltage, Keysight can provide the correct probing technology. Keysight probes continue to provide superior signal access with the best measurement accuracy across multiple industries.

- Find out which Keysight oscilloscope probe is right for you with the Oscilloscope Probes Selection Guide.
- Download Keysight's Probe Resource Center (PRC) application to easily access Keysight oscilloscope probe manuals, data sheets, SPICE models, application notes, and more.



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