Low Noise Improves Measurement Accuracy

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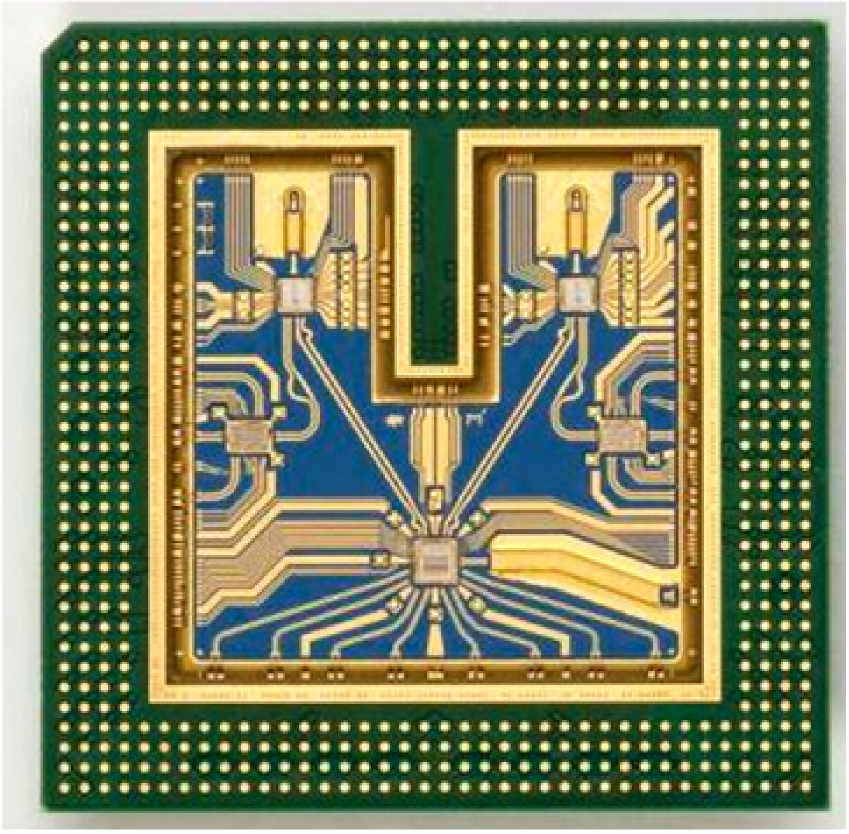
Engineers instinctively trust oscilloscopes and rely on a scope’s measurement accuracy as the ultimate authority for problem resolution. Choosing which oscilloscope to use often comes down to basic specification such as bandwidth, sample rate, and memory depth. Another key oscilloscope attribute that is often overlooked, but should be considered, is vertical noise. The front end and digitizing circuitry of all digital oscilloscopes generate noise, and this undesirable characteristic degrades a scope’s measurement accuracy. How can you measure how much noise is produced by your scope and what can be done to reduce noise generated from the oscilloscope to make the best measurements.

Vertical noise creates amplitude measurement errors. Scope vendors publish noise noise characteristics in their datasheets. If you can’t find this information, characterizing noise is straightforward and can be done quickly. Noise can be characterized by disconnecting all signal inputs, setting the input termination to 50 Ohms, setting memory depth to a specific value, and running the oscilloscope for a few seconds. The resulting flat-line waveform shows the noise floor of the oscilloscope at a particular V/div setting. The noise floor will change at each V/div setting, so a scope’s noise floor should be characterized across multiple V/div settings. Characterizing a scope’s noise floor can be done in 10 minutes or less. RMS voltage measurements provide good noise characterization as the noise is random in nature.

Evaluate a scope's noise floor by disconnecting all inputs and measuring the RMS value of the waveform.

Given that all oscilloscopes have noise, what is the most effective way to reduce noise? The best way to reduce noise is obvious; compare oscilloscopes and choose the one with the lowest noise floor. Noise varies from vendor to vendor and model to model.

An oscilloscope's architecture directly impacts how much system noise is produced. Let's take for example the front-end of the oscilloscope. This circuitry contains attenuators and amplifiers to condition the incoming signal before it reaches the analog-to-digital converter. The hardware technology employed in this front-end makes a huge difference in how much noise the oscilloscope produces. The front-end design may consist of tens of discrete components, may be a multi-chip module, or some combination of the two. Typically, higher-levels of integration in the front-end produce oscilloscopes with lower noise. For higher-bandwidth oscilloscopes, maintaining signal integrity while minimizing the introduction of noise is the design goal of the front end and results in multi-chip modules that look more like RF design than analog design.

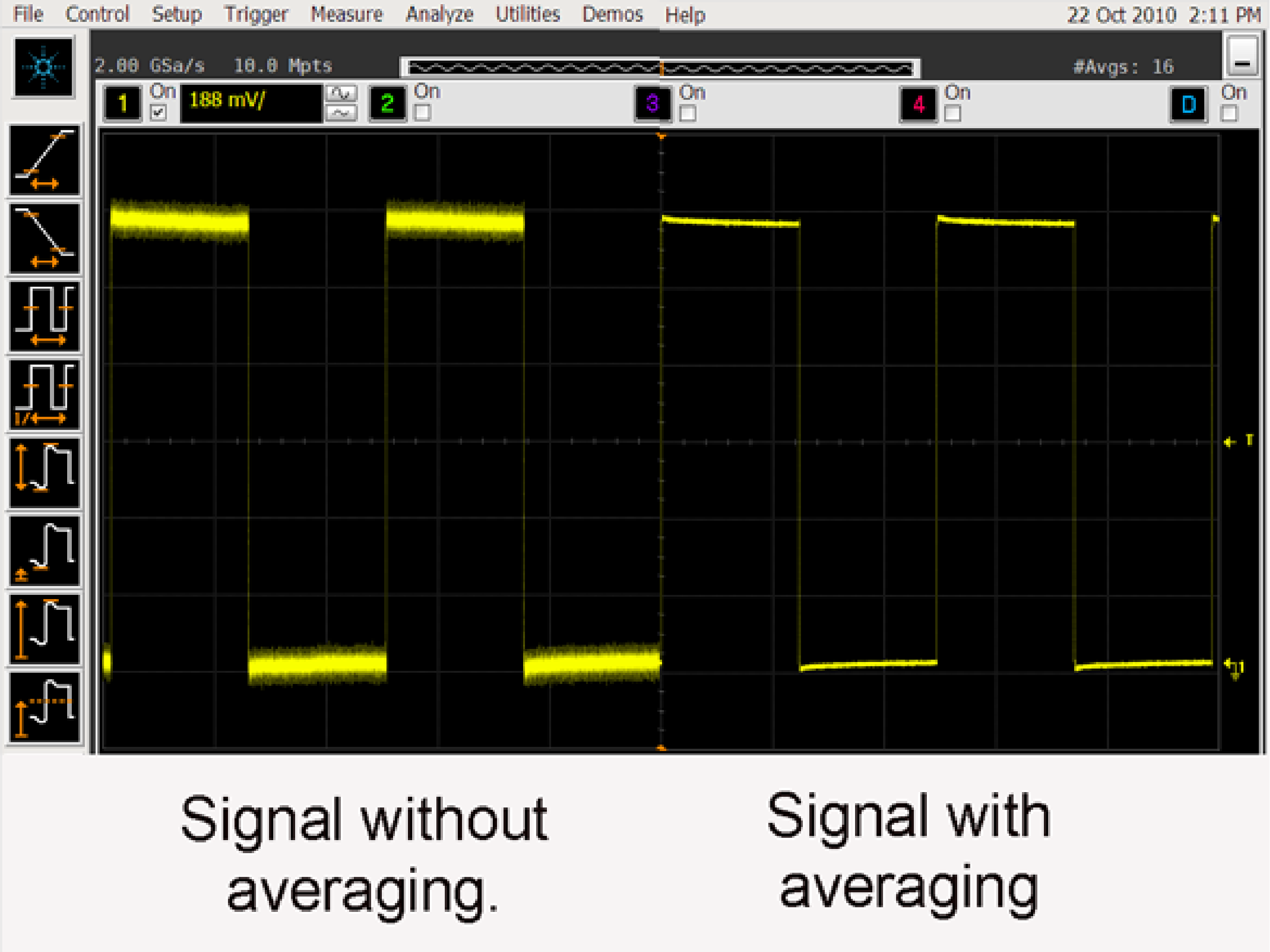


Examples of front-end technologies that produce the industry's lowest noise floor can be found in the multi-chip modules used in Agilent's Infiniium oscilloscope lineup.

Scopes are broadband instruments, and higher bandwidths generally result in higher noise floors. So, an oscilloscope with 8 GHz bandwidth is expected to produce more noise than a scope with 1 GHz bandwidth at the same V/div settings. In order to minimize broadband noise, the most accurate vertical measurements should be made by using a scope with bandwidth that is just one Hertz higher than the measurement need. As it is not practical to have a large number of scopes each with its own unique bandwidth, higher-end scopes typically offer bandwidth-reduction features. The user can selectively specify how much bandwidth the scope allows. Bandwidth reduction can be implemented in either hardware or software and typically comes with a tradeoff of reducing a scope's update rate. By picking the lowest possible bandwidth for a specific measurement, noise is minimized.

The impact of noise is more pronounced when measuring low-level signals that require small V/div settings. Some scope models automatically employ bandwidth reductions when they are used at the most sensitive V/div settings. So, if you compare noise floor characteristics at each scope's most sensitive V/div setting, you may be comparing a lower-bandwidth scope against a higher-bandwidth scope. This is not a valid comparison.

If the signals being measured are repetitive, turning on averaging mode will enable the scope to take multiple acquisitions and display the resulting average. Increasing the number of averages reduces random noise effect on the measured signal. For single shot measurements, most scope vendors offer a high-res mode that averages adjacent sample points to reduce the impact of noise and increase vertical resolution beyond eight bits. The tradeoff is that this technique reduces bandwidth.



The opposite of bandwidth reduction, DSP-boosting is offered on some scope models to artificially increase the scope's natural 3db roll-off point. DSP algorithms magnify the higher frequencies that are just beyond the 3 db point. These frequencies have been attenuated by the scope's front-end low-pass filter and are closer in magnitude to the scope's noise floor than lower-frequency signals that pass through the scope's front end. For this reason, DSP boosting inherently produces more noise and users should be aware that additional frequency comes at the expense of additional noise.

Some oscilloscopes tend to show fat waveforms while other scopes measuring the same signal show a thinner line. While a user might initially expect that the thinner signal is a result of using an oscilloscope with lower noise, this isn't necessarily true. The waveform difference may be a result of update rate instead of noise floor differences. A scope with a fast update rate will show target signal variations more quickly than a scope with slower update rate thereby displaying a fatter signal. If infinite persistence mode is enabled on both scopes, they may show the same fat waveform over time. The scope with faster update rate just showed it more rapidly.

For applications that require accurate measurements, evaluate the scope's noise floor when choosing which scope to use. If comparing multiple scopes, make sure each has the same V/div setting, memory depth, and interpolation settings to get consistent comparisons. Consider using averaging or high-res modes, and bandwidth reduction to minimize noise impact on your scope measurements.