Improve Margins for Your 6-Gbps Storage Design by Choosing the Right Oscilloscope

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If you design storage devices, your job is about to get considerably more complicated.

Two standards bodies that oversee storage interconnect technology -- the Serial ATA International Organizations (SATA-IO) and International Committee for Information Technology Standards (INCITS) T10 Technical Committee on SCSI Storage Interfaces -- have released specifications to support 6 Gbps data transfer rates on the communication link between chips and storage devices. With the storage industry migrating from conventional mechanical drives to solid-state drives (SSDs), the need for increasingly faster transfer rates is readily apparent. With SSDs, data transfer performance is not limited by the rotational disk arrays found in a conventional drive, which capped the transfer rate to about 3 Gbps. In the near future, the standards bodies are planning to push the data transfer rate even faster, probably to 12 Gbps or higher.

It sounds good on paper, but it is easier said than done. Doubling the data rate just from 3 Gbps to 6 Gbps is a huge challenge by itself. The level of difficulty in ensuring designs and products operate correctly does not just double, it increases dramatically. At 6 Gbps, the unit interval of the bit becomes so small that noise in the system, crosstalk from adjacent electrical signals or even electromagnetic interference could easily distort the signal integrity. In addition, channel skin effects and a lossy signal path can degrade the signal integrity further, which can lead to an increased bit error rate (BER) at the device receiver. These phenomena will reduce the reliability and robustness of the storage system.

Your team is likely to invest a great deal of engineering effort in overcoming these design challenges. As you work on increasing your design margins and system reliability, don't overlook an important factor: the performance of signal measuring devices you use to validate and characterize signal performance. Without adequate performance accuracy, the effectiveness of the design improvements you make may be diminished if the design's true performance is limited by the test instruments you use.

One of the most common instruments engineers use to validate and characterize their designs is an oscilloscope. With the decreased signal margin at 6 Gbps data rate, the error introduced by an oscilloscope makes a huge impact on your design. For instance, the noise and jitter of the oscilloscope could make a huge difference in your measurement, which could lead to reduced margin even though the design could perform better. This article offers insight into how you can get more design margin back from an oscilloscope, quickly demonstrate design compliance, and reduce manufacturing costs.

Boost Bandwidth and Lower the Noise Floor for Higher Accuracy
Engineers have a tendency to look first for more bandwidth when accuracy is at stake, but bandwidth is only part of the story. An oscilloscope’s noise floor performance is also critical. Without sufficiently low noise floor performance, you cannot reap the benefit of additional bandwidth. Having more bandwidth in a scope with poor noise floor performance will just increase your uncertainty and decrease your measurement accuracy, which could lead to reduced design margins.

In the top screenshot in Figure 1, you can see the signal frequency spectrum of a 6-Gbps time-domain signal measured with a spectrum analyzer. The signal content is represented as odd harmonics in the spectrum domain. To be able to capture the digital signal accurately, it would be ideal for the oscilloscope to capture as much signal content as possible on the vertical scale as well as on the horizontal scale (sometimes up to the 5th harmonic content of the signal) to properly represent the signal in the time domain. In the bottom two screenshots in Figure 1, we are comparing the signal content captured using a lower-noise-floor oscilloscope and a higher-noise-floor scope. It is evident that the lower-noise-floor oscilloscope allows you to capture more signal content both vertically and horizontally, so it is able to represent the signal better. Even with more bandwidth, a higher-noise-floor oscilloscope will not be able to measure the 5th harmonic because it is totally buried beneath the noise floor of the oscilloscope. The benefit of having more bandwidth is rendered useless.

Here is a tip to choosing a lower-noise-floor oscilloscope: An oscilloscope that achieves its bandwidth rating through its normal analog filter capability usually has a lower noise floor than a scope that uses artificial bandwidth manipulation such as digital signal processing (DSP) boosting or digital bandwidth interleaving (DBI).

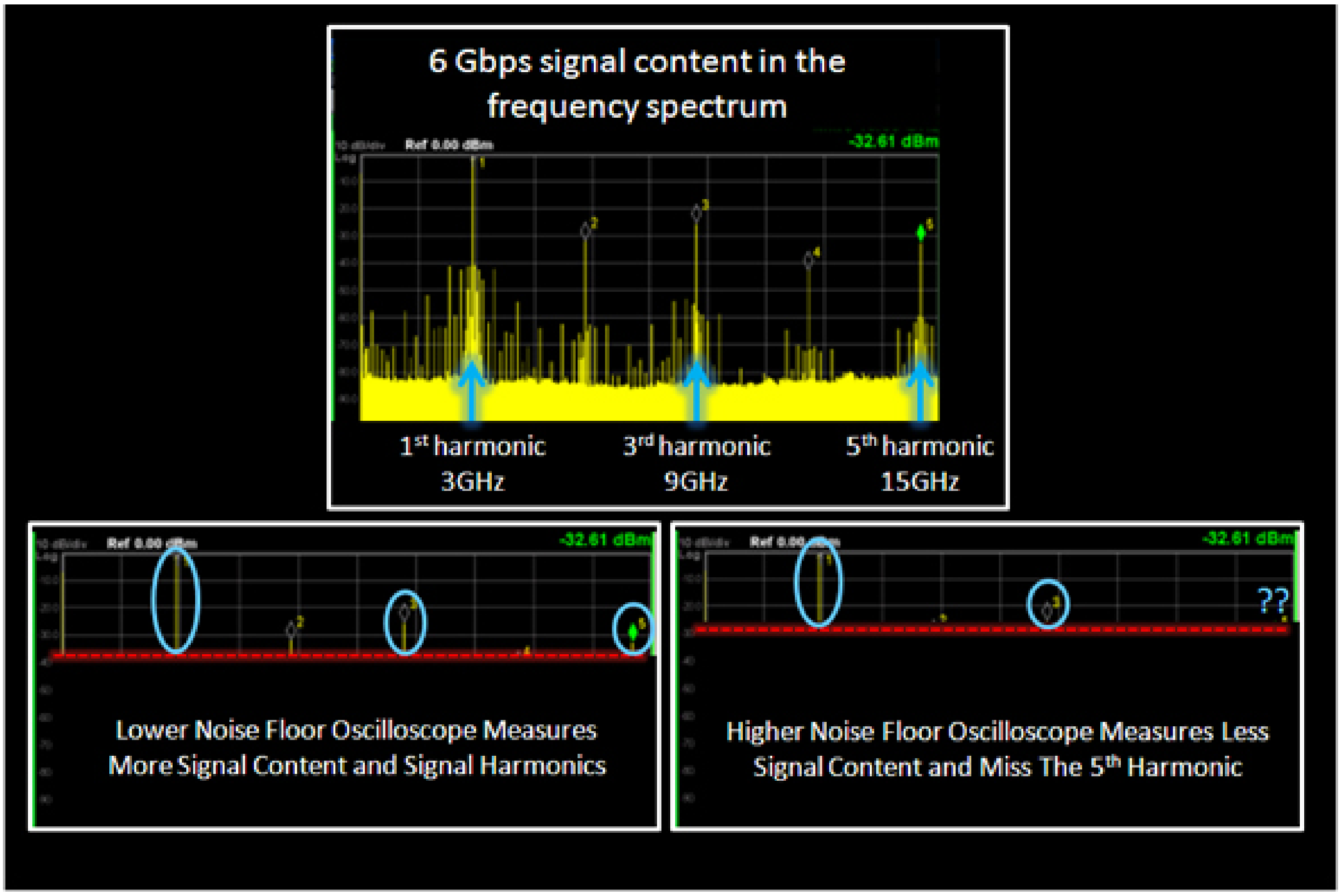

Figure 1. The signal content of a 6-Gbps signal in the frequency spectrum. See what you have been missing with a lower-noise-floor oscilloscope.

The bandwidth and noise floor performance will definitely impact measurements such as unit interval, amplitude, common mode voltage, rise time and fall time measurements of your 6-Gbps signal. With less signal content captured from the digital waveform, the signal might appear to be distorted from the real signal. For instance, your signal could have a slower rise time because some of the higher harmonics are missing. Thus, when you are validating your design, your design could appear to be failing because of the limitation of your oscilloscope. In another example, the high noise floor of an oscilloscope contributes to the common mode voltage measurement on the oscilloscope. Although your design could resist noise from coupling into the signal path, it could again be failing due to the noise contributed by the scope. Regardless, a higher-noise-floor oscilloscope could cause you to over design your product, increasing costs and delaying the schedule of the product release even though the true performance meets the design requirement.

For Better Jitter Results, Look for a Scope with Lower Intrinsic Jitter
One of the main nemeses to reliable high-speed signal transfer is a system's total jitter (TJ). Jitter is defined as the deviation of a signal transition from its ideal time. It affects the ability of a 6-Gbps receiver to properly recover the clock and sample the incoming data, causing system error. The faster the data transfer rate, the less tolerant the receiver is to jitter.

Jitter is statistical in nature, and it can be broken down into two main categories:

deterministic jitter (DJ) and random jitter (RJ). DJ is correlated and bounded, usually represented as DJ peak-to-peak (DJp-p). It can be caused by intersymbol interference, crosstalk, subharmonic distortion and other spurious events such as power-supply switching. On the other hand, RJ is an uncorrelated and unbounded jitter caused by thermal or other physical, random processes; the shape of the RJ distribution is Gaussian. The width of the distribution is known as RJ peak-to-peak (RJp-p), and it can be estimated statistically using the sigma of the RJ distribution (RJrms). Because RJ is unbounded, the more unit intervals you measure, the larger RJp-p gets, even though RJrms stays constant. For instance, RJp-p measured with 1012 unit intervals is larger than RJp-p with 106 unit intervals. Because RJp-p has a huge effect on the system’s TJ, it is important to have an oscilloscope that can measure RJ accurately.

In Figure 2, you can observe the RJrms performance of oscilloscopes with higher and lower intrinsic jitter and see how it affects the TJ result. At 1012 unit intervals, RJrms is multiplied with the constant 14.1 to get the RJp-p value. RJp-p and DJp-p are then summed to obtain the TJ number. In the example, the TJ measured by the scope with lower intrinsic jitter is 27% lower because the oscilloscope’s lower intrinsic jitter returns a smaller RJrms of an ideal signal without the oscilloscope’s performance getting in the way. Using a scope with lower intrinsic jitter will return more jitter margin to your design.

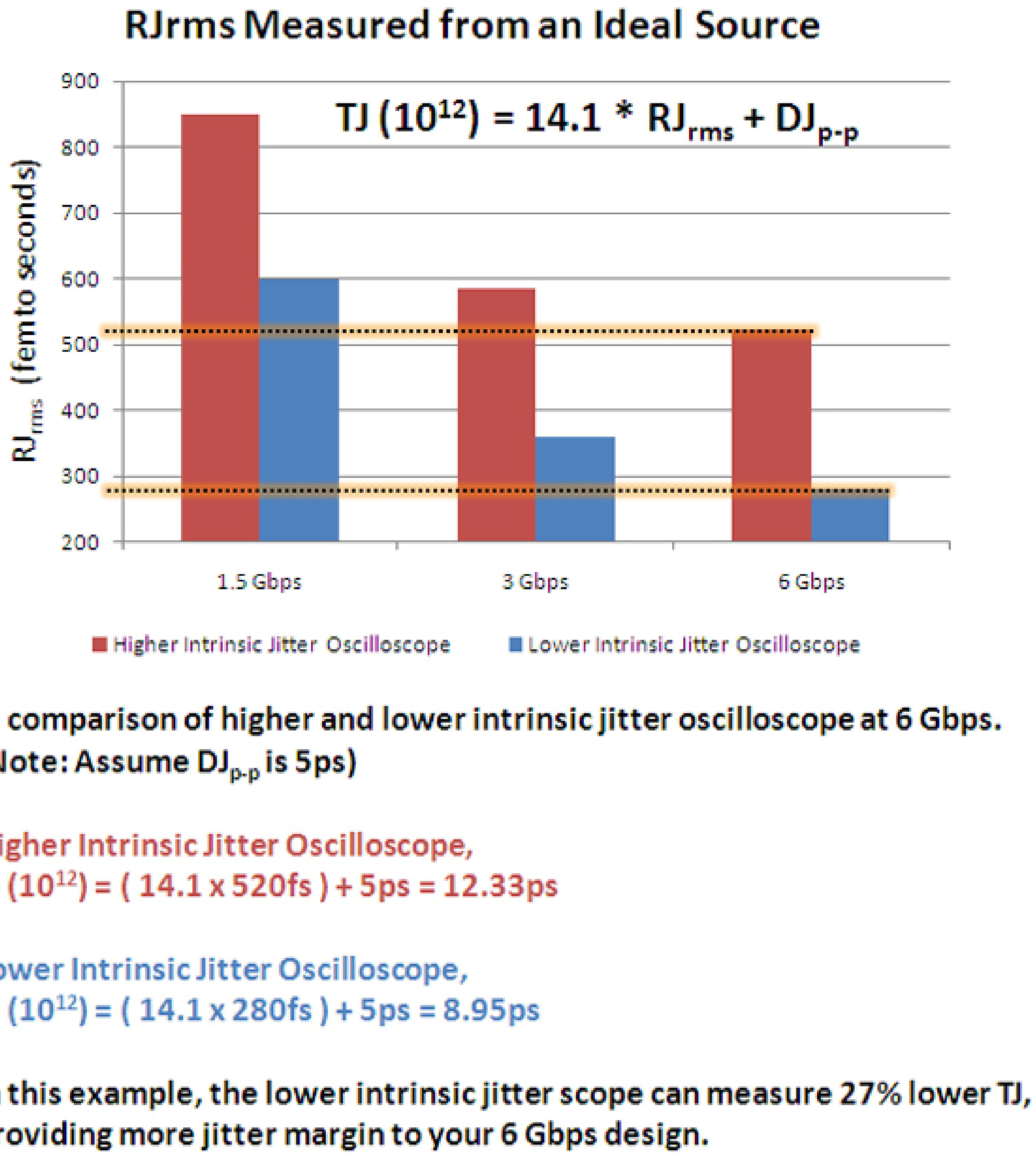

Figure 2. In the example above, the scope with lower intrinsic jitter shows a 27% lower TJ result, which provides more jitter margin to your 6-Gbps design.

Remove Unwanted Loss on Measurement Paths

In a common test setup, the design measurement path usually consists of traces on a test fixture and connectors and cables that degrade the signal integrity when the signal travels to the oscilloscope. If you want to access the signal at a desired test point, the signal loss is unavoidable in many circumstances. It can be frustrating because your measurement results include the loss of these components in the measurement path that make the measurement result worse than the real performance at the desired test point.

One way to overcome this problem is to remove the effects of the unwanted components mathematically on the oscilloscope. Removing the unwanted effect enables the oscilloscope to recover the original signal. Using the loss profiles of those unwanted components, an overall system loss response can be generated. Subsequently, a gain response of the system loss response can be calculated and applied to the degraded signal to recover the original signal. Some oscilloscopes can compensate for the insertion loss as well as the reflection characteristics of the components to provide a more accurate answer.

In Figure 3, you can observe the huge eye opening of the 6-Gbps signal at the transmitter with plenty of design margin. The signal then travels through a series of connectors and channels to reach the oscilloscope. While going through connector 1, the test-fixture channel and connector 2, you can see the eye begins to close due to the loss introduced at each component. As it reaches the oscilloscope, the eye is closed entirely due to significant degradation. There is no way for the oscilloscope to properly characterize the true performance of the transmitter without measuring the effect of these components. However, if the loss profiles of the connectors and channel are available, they can be combined to generate the equivalent system loss response by the oscilloscope. Then, the oscilloscope’s de-embedding feature can calculate the system gain response to compensate for the loss. The yellow response at the bottom of Figure 3 shows the system gain response over the signal spectrum to recover the original signal. Using this technique, you can compensate for any loss introduced by the test fixture, connectors or cables that is affecting the measurement, thus increase your design margin.

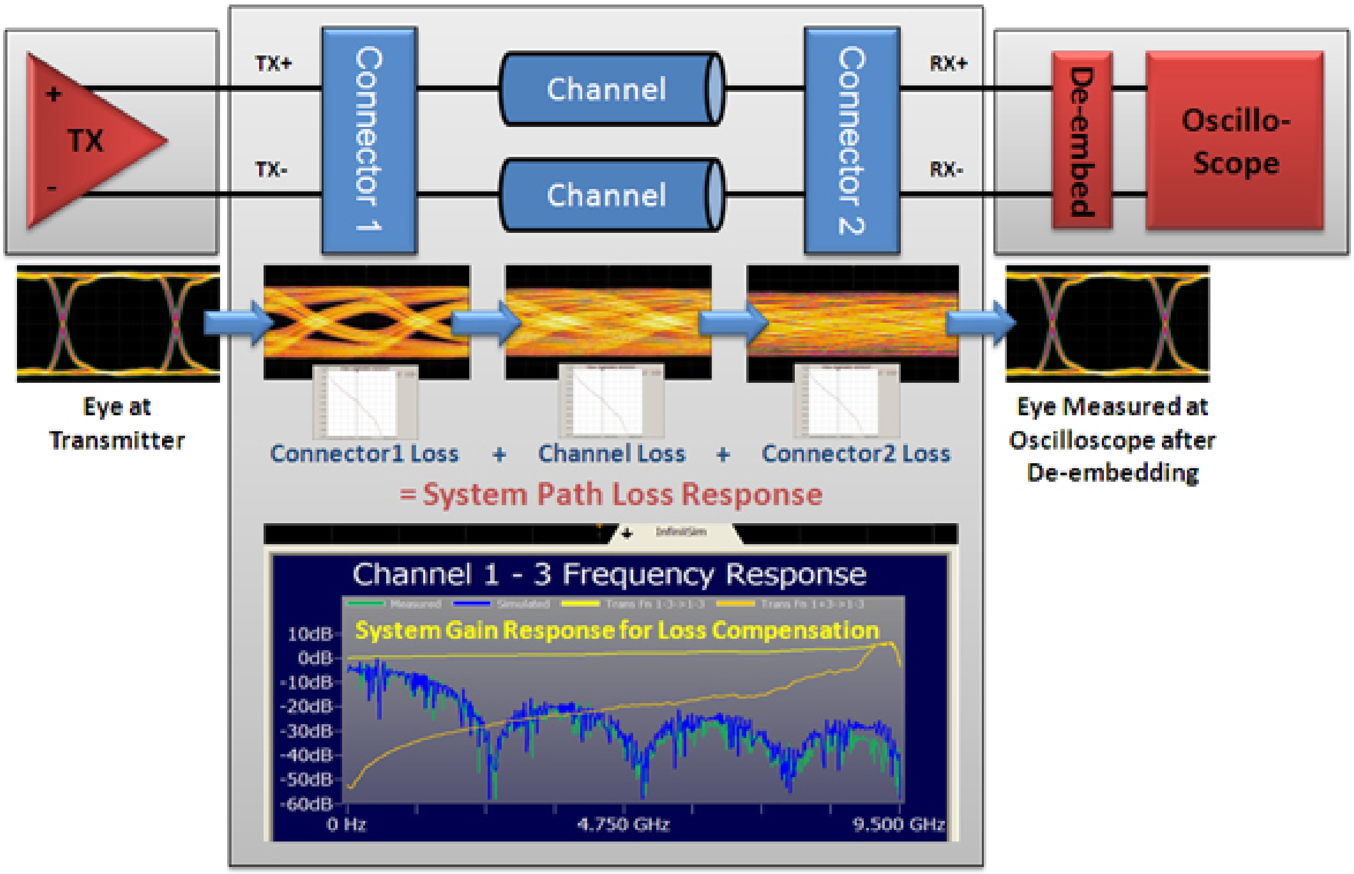

Figure 3. Degradation of the 6 Gbps signal eye opening transmitted along the measurement path due to signal loss introduced by connectors and channels. The oscilloscope has the ability to compensate (de-embed) the system loss response to recover the original signal.

Summary
As the data transfer rate on the storage interface reaches 6 Gbps and beyond, the signal amplitude and unit interval become so small that you cannot ignore the impact of your measurement devices. Instrument performance can affect measurement results, especially at the borderline of passing and failing the design, which can have huge implications for project cost and schedule. Thus, choosing a high-performance oscilloscope with the highest bandwidth, lowest noise floor and lowest jitter measurement floor can ensure higher design margins and faster design compliance. Also, capability such as loss compensation on the oscilloscope can remove unwanted measurement effects, providing more accurate results. Using scopes with the lowest noise floor and lowest jitter measurement floor has been proven to reduce costs by saving engineering time and by allowing the use of parts with looser tolerances. The investment will eventually be paid off by generating better quality products and getting them to market faster.