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Evaluating oscilloscopes: Dig deeper

Read between the lines of banner specifications—bandwidth, sample rate, and record length—to do the nuances and less glamorous features that affect efficiency and even the validity of your design.

By Colin Shepard, Tektronix Inc -- EDN, 8/19/2004

For years, electronic-system performance increased in step with steadily increasing semiconductor and functions, simulation-model improvements, architectural changes, and more. Through all these interdevice-signaling speeds and techniques did not change significantly, because the I/O-signaling architectures were doing an adequate job, and the underlying technologies for change were not in

In the past half-decade or so, engineers have focused more on LVDS (low-voltage differential signaling) to achieve dramatic increases in system performance. Data rates have increased by an order of magnitude with the wider adoption of complex serial protocols for communication among devices. These protocols include SATA Express, InfiniBand, and XAUI (10-Gigabit attachment-unit interface). These environments encompass a wide range of data rates and transmission architectures, but all of them share a need for rigorous design and development practices.

This need has made test equipment, such as oscilloscopes, more important than ever. Engineers turn to oscilloscopes to analyze the performance of their serial-device designs and to support verification and debugging work. Their tasks include precise parametric measurements, troubleshooting, and signal analysis. Later in the development process, they turn to oscilloscopes to produce eye-diagram compliance testing.


Too often, an engineer choosing an oscilloscope considers only the specifications that appear in the product brochures and magazine ads. The best known of these banner specs are bandwidth, sample rate, and record length. Though important, these dimensions of oscilloscope performance provide an incomplete picture of the instrument's effectiveness in daily real-world use. The bandwidth figure, for example, states only the instrument's gross frequency range; it says little about the instrument's ability to reliably detect signal anomalies.


Consequently, it is important to read between the lines of the banner specifications when evaluating an oscilloscope. This advice actually has two contexts. First, it is a caveat to drill down to the nuances of the heavily promoted specifications. Second, it is a reminder to study the features that, though less glamorous, can substantially impact the efficiency and even the validity of the designer's work.


Define and redefine bandwidth

Bandwidth specifications are legitimately important. To a designer pushing the limits of high-speed architecture, pure bandwidth is at the top of the shopping list for oscilloscope features. But bandwidth is not simply a specification describing the frequency response of the instrument, the frequency at which the response rolls off by -3 dB. Two oscilloscopes having the same bandwidth rating can have different rise time

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disparate responses to complex wave shapes. Is there a between-the-lines specification or feature better inform the purchaser's decision? There are two facets to the answer to this question. One is oscilloscope's true rise-time performance. The other is the instrument's behavior in its DSP modes.

The analog rise time is a function of the oscilloscope's bandwidth. It is tempting to simply calculate from the bandwidth using a textbook formula, and this calculation is the basis of some published rise-time specifications. An objectively measured rise time is a better foundation for measurements, either with or without DSP enhancement. Every engineer understands the importance of rise-time response. Weighing the difference between measured and calculated rise times is an example of reading between the lines.

You can use DSP filtering to extend the oscilloscope's net bandwidth, flatten its frequency response, and better match between channels. These capabilities are key when the device under test employs a serial transmission environment. But DSPs can introduce errors that tend to increase in proportion to the frequency extension beyond the true analog bandwidth.

You should use DSP when measuring less-than-200-psec rise times or eye diagrams ([Figure 1](#)). In such cases, it's essential to extract the maximum bandwidth from the oscilloscope. Clearly, this need favors the approach of using DSP. The fastest measurements almost always demand the highest bandwidth. But it is some times to have a way to bypass the DSP extensions and make measurements using only the instrument's bandwidth and rise time. For example, some researchers use application-specific DSP algorithms to work with raw data from the oscilloscope. In such cases, a DSP-bypass feature is important. This kind of specification may not make headlines, but it is a factor in choosing a high-performance oscilloscope.

Signal complexity, not just speed

The phrase "high-speed measurement" has all kinds of implications about less-than-1-nsec edges and fast clock rates. Designers sometimes overlook the fact that these high-speed measurements are complex complexity measurements. Capturing one symbol in a data stream can involve judgment, luck, and a little guesswork, or the right choice of triggering features.

Oscilloscope triggering—just as much as the bandwidth and sample rate—determines what you can see, and measure with the instrument, just as much as the bandwidth and sample rate do. The trigger has its own set of specifications. The trigger path is typically a tributary of the main input-signal path and embody many of the same environmental attributes: sensitivity, jitter, and more. Another dimension of performance is the range of trigger types—the conditions that you can impose to define when a trigger occurs.

Of course, the trigger system has its own banner specs. A designer choosing an oscilloscope to measure serial signals might assume the trigger path has the same bandwidth as the instrument's specified bandwidth. In truth, the term of interest is "trigger sensitivity." This specification embodies one simple question: What amplitude requirements when capturing signals near the top of the frequency range? In many cases, trigger sensitivity does not match the analog-acquisition bandwidth.

Even though the normal content of a signal may be comfortably within the trigger's performance specifications, you might not detect narrow glitches or truncated pulses if the trigger sensitivity at high speed is inadequate. Fortunately, innovations such as SiGe (silicon-germanium) trigger-circuit topologies have begun to overcome this limitation. Engineers commonly regard the oscilloscope's triggering features as a given and assume that edge and glitch triggers they've always used will suffice. In truth, triggering flexibility stands alongside an instrument's top banner specs when it comes to doing real work.

Every oscilloscope has edge triggering, and most higher end instruments have "advanced" triggers. Edge triggering detects a simple voltage-threshold crossing, and advanced triggering applies many qualifications pertaining to voltage, timing or logic conditions, and more. Advanced triggers are becoming increasingly important in serially transmitted digital signals.

In some cases, an advanced trigger setup may be the only way to trigger on the signal of interest. For example, working with a multilane InfiniBand device, for example, must ensure that the lanes are time-aligned to specific tolerances—that is, they must not only comply with the standard, but also function properly.

The normal way to approach this measurement challenge is to trigger on a single character in one lane and measure the skew, or time shift, among the lanes. The measurement results summarize the skew at one instant. The results are often good for the time being but insufficient for predicting stable operation long run.

Recently, oscilloscopes with full-featured dual triggering have dramatically simplified the complex task of observing these skew changes over time. You can define two advanced triggers from the full menu conditions. After the data character fires the first trigger, a secondary trigger can look for skew error of time or rearm the first trigger to start the search again ([Figure 2](#)). The setup can wait for days, if for an error combination to occur.

Trigger specifications are rarely the first order of business when evaluating an oscilloscope. But the system is a full partner in detecting and capturing complex or intermittent events. The time you save with unattended long-term skew measurement more than makes up for the time you spend reading between the trigger specifications.

More "secondary" specifications

The banner specs of bandwidth, sample rate, and the like have overshadowed the specifications thus far discussed. These "secondary" specs are not alone in this respect. Designers often treat many parameters as secondary issues during the oscilloscope evaluation, but these issues can potentially make or break an urgent engineering deadline.

Embedded clock recovery is the foundation of oscilloscope-eye-diagram analysis for many serial standards and also supports measurements such as the CDR (clock-data recovery, [Figure 3](#)). The designer working with embedded clock signals needs to look beyond banner specs and ponder what the oscilloscope can do to recover clock recovery faster, easier, more flexible, and more repeatable.

As always, the needs of the application guide the designer's choice. You need to ask whether you need an oscilloscope for troubleshooting or for compliance measurements, what clock-recovery mechanism is available, and whether the oscilloscope can recover the clock in real time, enabling it to display eye diagram behavior.

Most high-end oscilloscopes offer either software- or hardware-based clock recovery. You can produce an eye diagram from clock recovery from stored acquisition data. The software approach is a well-accepted tool for configuration testing using applications such as Tektronix's TDSRT (real-time)-Eye automated compliance and analysis software.

You can use PLL-based clock recovery to acquire real-time eye diagrams, but herein lies another big question: Does the PLL, which may be software- or hardware-recovered, adapt to the evolving clock frequencies in today's serial standards? Some do; some don't. It pays—literally—to understand the

Eye-diagram measurements exemplify some of the most complex procedures that a design engineer must perform with an oscilloscope; another example is jitter measurements. In both cases, the designer relies on the domain expertise of application software running on the oscilloscope. The software tools not only shorten the learning curve and dramatically reduce setup, measurement, and analysis time ([Figure 3](#)). Yet, they never appear on a list of banner specs. You must do your homework, look beyond the glamorous top of the list, and make sure the right tools are available.

Beyond probe banners

Probing opens yet another spec discussion. All of the acquisition and analysis features that this article has explained depend on faithful transmission of the signal between the device under test and the oscilloscope. Many new high-speed-interface standards use differential signaling rather than the more familiar single-ended communication.

Although probing approaches have banner specs of their own, especially in bandwidth and loading, it is important to understand the implications of the oscilloscope and the probe working together as a system. Do the oscilloscope system offer true differential-probing tools? If it does not use these tools, you need to use single-ended probes and onboard math, precluding certain types of measurements. Moreover, issues such as common-mode rejection, sensitivity, response accuracy, and noise floor all affect the probe's impact on the signal. Small differences in these parameters can cause large probe-load distortions when you're probing today's high-speed signals.

Probe-attachment methods rarely get top-tier visibility among an oscilloscope's banner specs, but they are critically important in every measurement. Some vendors fit devices under test with SMA test points; others require access to individual pins on tiny surface-mount devices. Determine whether the oscilloscope

family of probes embraces all these needs.

In short, banner specs remain the accepted standard of comparison among oscilloscopes. But savvy readers read between the lines to scrutinize the underlying performance that affects everyday tasks. If you read the whole, some less prominent specs in acquisition, triggering, analysis tools, and probing can be just as important as the big numbers describing bandwidth, sample rate, and record length. It's all about details and even the humblest specification can sometimes make the difference between success and failure.

Author Information

Colin Shepard is product-line manager of the performance-oscilloscopes product line at Tektronix Inc.

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