Evaluating oscilloscopes: Dig deeper

Read between the lines of banner specifications—bandwidth, sample rate, and record length—to d 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 signa achieve dramatic increases in system performance. Data rates have increased by an order of magn wider adoption of complex serial protocols for communication among devices. These protocols incl Express, InfiniBand, and XAUI (10-Gigabit attachment-unit interface). These environments encomp of data rates and transmission architectures, but all of them share a need for rigorous design and v practices.

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

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

Consequently, it is important to read between the lines of the banner specifications when evaluating oscilloscope. This advice actually has two contexts. First, it is a caveat to drill down to the nuances heavily promoted specifications. Second, it is a reminder to study the features that, though less gla vendors most often tout in the market, can substantially impact the efficiency and even the validity 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 bandwic simply a specification describing the frequency response of the instrument, the frequency at which rolls off by –3 dB. Two oscilloscopes having the same bandwidth rating can have different rise time 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 ris specifications. An objectively measured rise time is a better foundation for measurements, either wi DSP enhancement. Every engineer understands the importance of rise-time response. Weighing th 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 better matching between channels. These capabilities are key when the device under test employs speed, multilane, serial-transmission environment. But DSPs can introduce errors that tend to incre 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**). Ir it's essential to extract the maximum bandwidth from the oscilloscope. Clearly, this need favors the approach. The fastest measurements almost always demand the highest bandwidth. But it is some 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 a work with raw data from the oscilloscope. In such cases, a DSP-bypass feature is important. This k 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 a fast clock rates. Designers sometimes overlook the fact that these high-speed measurements are c complexity measurements. Capturing one symbol in a data stream can involve judgment, luck, esti guesswork, or the right choice of triggering features.

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

Of course, the trigger system has its own banner specs. A designer choosing an oscilloscope to me serial signals might assume the trigger path has the same bandwidth as the instrument's specified I truth, the term of interest is "trigger sensitivity." This specification embodies one simple question: W amplitude requirements when capturing signals near the top of the frequency range? In many oscill 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 sp you might not detect narrow glitches or truncated pulses if the trigger sensitivity at high speed is ina Fortunately, innovations such as SiGe (silicon-germanium) trigger-circuit topologies have begun to this limitation. Engineers commonly regard the oscilloscope's triggering features as a given and ass edge and glitch triggers they've always used will suffice. In truth, triggering flexibility stands alongsi 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 bec 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. A working with a multilane InfiniBand device, for example, must ensure that the lanes are time-aligned 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 and measure the skew, or time shift, among the lanes. The measurement results summarize the sk one instant. The results are often good for the time being but insufficient for predicting stable opera long run.

Recently, oscilloscopes with full-featured dual triggering have dramatically simplified the complex ta
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 erro
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 sav
unattended long-term skew measurement more than makes up for the time you spend reading betw
of the trigger specifications.

More "secondary" specifications

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

Embedded clock recovery is the foundation of oscilloscope-eye-diagram analysis for many serial st
also supports measurements such as the CDR (clock-data recovery, **Figure 3**). The designer worki
embedded clock signals needs to look beyond banner specs and ponder what the oscilloscope can
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 w
oscilloscope for troubleshooting or for compliance measurements, what clock-recovery mechanism
available, and whether the oscilloscope can recover the clock in real time, enabling it to display dyr
diagram behavior.

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

You can use PLL-based clock recovery to acquire real-time eye diagrams, but herein lies another b
lines question: Does the PLL, which may be software- or hardware-recovered, adapt to the evolving
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 engine
perform with an oscilloscope; another example is jitter measurements. In both cases, the designer
from the domain expertise of application software running on the oscilloscope. The software tools n
learning curve and dramatically reduce setup, measurement, and analysis time (**Figure 3**). Yet, the
never appear on a list of banner specs. You must do your homework, look beyond the glamorous s
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 arti
explained depend on faithful transmission of the signal between the device under test and the oscil
Many new high-speed-interface standards use differential signaling rather than the more familiar si
communication.

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

Probe-attachment methods rarely get top-tier visibility among an oscilloscope's banner specs, but t
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 oscil

family of probes embraces all these needs.

In short, banner specs remain the accepted standard of comparison among oscilloscopes. But savv
read between the lines to scrutinize the underlying performance that affects everyday tasks. If you t
a whole, some less prominent specs in acquisition, triggering, analysis tools, and probing can be ju
important as the big numbers describing bandwidth, sample rate, and record length. It's all about de
and even the humblest specification can sometimes make the difference between success and failu

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