Capturing Infrequent and Random Events Using Deep Memory Oscilloscopes

Application Note 1431

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Introduction

When evaluating the purchase of a new digital storage oscilloscope (DSO), the most obvious criteria that evaluators consider include bandwidth, sample rate, memory depth, and number of channels. An often-overlooked characteristic of an oscilloscope is the display/digitizing update rate.

Update rate should be an important consideration for two primary reasons. First, the digitizing update rate of an oscilloscope can greatly affect the usability of the instrument. Second, the oscilloscope's acquisition/waveform update rate can affect the statistical probability of capturing infrequent anomalies and glitches.

This application note discusses how today's deep memory oscilloscopes respond to the need for fast acquisition update rates. In particular, it considers two different approaches – using a Fast Acquisition operating mode or the MegaZoom deep memory technology from Agilent. These two approaches are examined in terms of their ability to capture infrequent events and, therefore, anomalies and glitches in a design. Whereas vendors of oscilloscopes using a Fast Acquisition mode claim to have faster acquisition rates, this specification probably applies to just a very narrow set of conditions. The real merit of a scope depends on specific applications, some of which will be considered here.

Update Rate Effect on Oscilloscope Usability

When DSOs first came on the market back in the 1980s, one of their major drawbacks as compared to analog oscilloscopes was their lack of responsiveness. It wasn't uncommon for digitizing oscilloscopes to have acquisition update rates in the range of just one or two waveforms per second...even with a shallow memory depth of just 1000 points.

This lack of responsiveness made DSOs much more difficult to use. When engineers and technicians used their oscilloscope to debug an electronic system, they often used the scope as a "browsing" tool, rapidly changing setup conditions such as V/div and timebase controls while viewing the waveforms on the oscilloscope's display. If the display update changed slowly while making these setup changes, it could become very frustrating and slow down the debugging process.

With advances in digital scope technology, most oscilloscope vendors have solved the problem of responsiveness in scopes with memory depths less than 100 K points. A good rule-of-thumb is if the oscilloscope can update the display with a new acquisition at least twenty times per second, the oscilloscope will feel responsive. Granted, this is still much slower than a typical analog oscilloscope's sweep rate, which can produce hundreds of thousands of sweeps per second, but to the human eye and hand twenty digitized updates per second is usually sufficient to give a DSO a "live" feel.

Unfortunately, as the demand for DSOs with much deeper memory (> 1 MB) increases, responsiveness in many oscilloscopes still suffers due to the time for processing digitized waveform records. For this reason, the default operation for many oscilloscopes with deep memory is a shallow memory mode (less than 50 K points, typically).

With shallow memory, the scope is responsive. If users require deeper memory for special applications, they can select one of the deeper memory modes, but then they must deal with the scope's unresponsive operation. Some scopes with very deep memory can take as long as 8 to 10 seconds for each screen update. To many users, this is unacceptable.

Fast acquisition operating mode

To solve the problem of update rates with deep memory, one scope vendor has implemented a special Fast Acquisition operating mode. In this mode of operation the scope can capture up to hundreds of thousands of waveform records per second. Problem solved? Yes and no.

Fast Acquisition definitely solves the update issue and makes the oscilloscope much more usable. However, Fast Acquisition is a special operating mode with some significant tradeoffs. While in this mode of operation, maximum sample rates and memory depths are limited to less than the scope's maximum specifications. In addition, post-capture zooming on long waveform records, automatic measurements, and waveform math are not permitted.

MegaZoom Deep Memory

Agilent Technologies has solved the deep memory responsiveness problem with a technology known as MegaZoom. With MegaZoom deep memory, digitized update rates can exceed tens of thousands of waveforms per second, even when processing very deep waveform records. MegaZoom is not a special operating mode. It is a standard operating mode of the oscilloscope with full user access to memory records using the scope's zoom capability. And with maximum acquisition updates in this range, the scope's responsiveness truly feels "live".

But isn't capturing hundreds of thousands of waveforms per second with a Fast Acquisition mode superior to capturing just tens of thousands of waveforms per second with MegaZoom? As far as overall usability is concerned, no. The actual display refresh rate for raster-scan CRTs on all DSOs ranges from just 30 to 60 Hz. Increasing the waveform capture rate beyond the scope's display refresh rate does not enhance the usability of the scope. There are many factors that contribute to a scope's usability, with display update being just one of them. The fact that Fast Acquisition limits the use of many functions – including zoom capability, measurement, and waveform math – is another factor to consider with respect to usability. The bottom line is the only way to evaluate the usability of an oscilloscope is to try it for yourself.

Effect of update rate on capturing infrequent anomalies

When it comes to capturing infrequent events, digitizing update rates can have a tremendous impact on the probability of capturing anomalies and glitches. And you would intuitively think that a DSO with Fast Acquisition that specifies hundreds of thousands of waveform updates per second would be superior to a DSO with MegaZoom that captures tens of thousands of waveforms per second.

But this is not necessarily the case. First of all, multiple factors can affect an oscilloscope's digitizing update rate. And when you see a specification that claims hundreds of thousands of waveforms per second, this specification probably applies to just a very narrow set of conditions. For instance, specifications for Fast Acquisition that specify hundreds of thousands of waveforms per second apply to only the fastest sweep speed settings (40 ns/div and faster) and under limited sample rate (1.25 GSa/s max) and memory depth (500 points) conditions. In addition, a key contributor to digitizing update rate is the input signal's trigger rate. If the input signal's trigger rate is less than the maximum digitizing update rate of the scope, the maximum digitizing update rate will always be limited by the trigger rate.

For the sake of argument, assume for the moment that the input trigger rate does not limit the maximum digitizing update rate. Is a specification that indicates the maximum number of waveforms per second a good measure of a scope's ability to capture infrequent events? If all the conditions are just right, it may be. Digitized waveforms per second is a good indication of the merit of a scope's dead time. Dead time is the period of time between acquisitions, when a scope is processing digitized information and re-arming itself for the next acquisition, as shown in Figure 1.

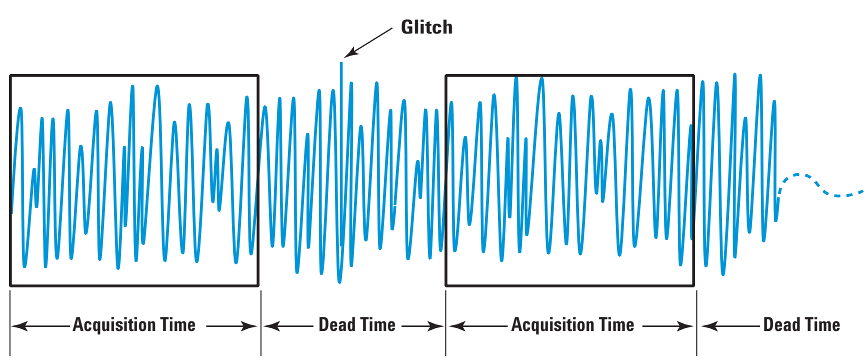
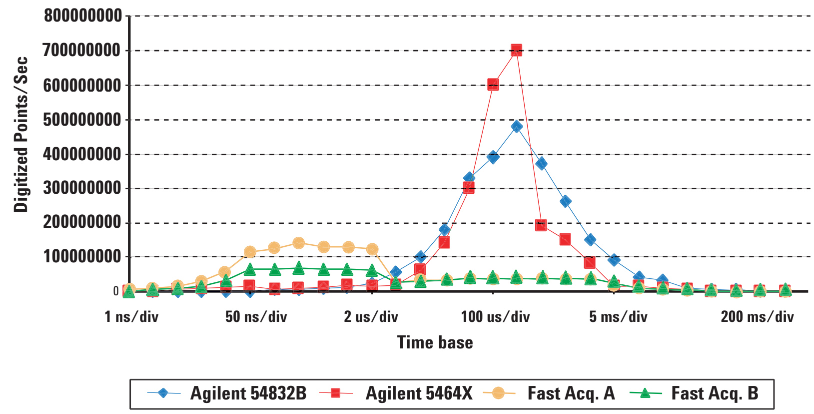


Figure 1. Digitizing oscilloscope acquisition time versus dead time

MegaZoom Deep Memory (continued)

If an infrequent event is truly random, it could occur at any time, including during dead time. Minimizing dead time may increase the probability of capturing an event. However, if dead time is minimized at the cost of limiting digitizing performance during acquisition time, the overall probability of capturing infrequent events may be reduced as compared to scopes with longer dead-time performance. Reducing sample rate and memory depth in a scope with a Fast Acquisition mode may indeed improve dead-time performance, but it can greatly reduce the probability of capturing narrow events during the acquisition time.



Note: Measurement conditions: Realtime sampling, 1 channel acquisition, sinx/x interpolation OFF, markers OFF, math OFF,connect dots ON, stats OFF, sinewave input with ~5 cycles per screen, number of digitized points based on "on-screen" viewable points only.

Figure 2. Comparing digitized points per second for Fast Acquisition mode versus MegaZoom

A better measure of merit under most conditions would be to specify the number of digitized points over a long period of time (digitized points per second). Before getting into a discussion on why this specification is a better measure of merit, the reader should be cautioned that digitized points per second is NOT the same as sample rate. Sample rate, which is always specified in samples per second, specifies the digitizing rate only during the acquisition time. The sample rate during the scope's dead time is always zero. Whereas specifying the total number of digitized points over an entire second (or more) gives an indication of the number of points collected over the long haul, which includes points digitized during both the acquisition time and dead time. You could also think of it as an average digitizing rate over a long period of time that includes both acquisition time (maximum sample rate) and dead time (zero sample rate).

By specifying the number of digitized points per period of time, the scope user has a better idea of the statistical probability of capturing an infrequent event, whether it occurred during either the acquisition time or the dead time. Unfortunately, this is NOT a common specification found in the data sheets and manuals of most scope manufacturers. The primary reason it is not specified is because there are too many variables to consider, such as sweep speed, number of channels, memory depth, etc.

However for the purpose of comparing Fast Acquisition mode versus MegaZoom, Figure 2 shows the performance of four 500 MHz to 1 GHz oscilloscopes (two with Fast Acquisition and two with MegaZoom). The data for these graphs have been collected under near-optimal conditions (single channel operation, real-time sampling, no measurements or math functions) over a broad range of sweep-speed settings. In addition, only "on-screen" digitized points have been considered in this characterization. For instance, when a digitizing oscilloscope is set up to display waveform information on very fast timebase settings, many off-screen digitized points may exist. But since this analysis is trying to show the probability of observing infrequent events, off-screen data points would be useless and have not been considered.

As you can see in Figure 2, neither Fast Acquisition nor MegaZoom is superior under all conditions. The number one variable that affects the number of digitized points per second is the scope's timebase setting. For sweep speed settings of 2 µs/div and faster, the oscilloscopes with Fast Acquisition mode appear to win because they minimize dead time. However, the reader must be cautioned that Fast Acquisition scopes limit their sampling rate. Even though the number of digitized points per second may be higher than the MegaZoom scopes at these faster sweep rates, if the sample rate is too slow to capture an infrequent event, the number of digitized points per second may be a mute point.

For sweep speed settings of 5 µs/div and slower, the MegaZoom scopes win because they maximize sample rate and memory depth during the acquisition time (more waveform information collected during the acquisition time). Which scope is better for capturing infrequent events? It depends! So let's look at two examples of capturing infrequent events.

If you are attempting to capture a metastable state on the output of a high-speed latch, the scopes with Fast Acquisition may do a better job. In this case, you would most likely set up the scope's timebase on a relatively fast sweep rate to see the details of the metastable state, as shown in Figure 3.

However even though the output of a latch may exhibit high-speed characteristics, such as a fast rise time, the actual switching rate may be well below the maximum specified digitizing update rate of the scope with Fast Acquisition. This would limit the trigger rate, which would be the driving factor in determining the digitizing rate. Hence, the dead time may not be determined by the minimum re-arm and processing time of the scope, but it may be determined simply by the trigger rate of the input signal. Under ideal conditions (not limited by trigger or sample rates), the scope with Fast Acquisition would do a superior job. But under most real-world conditions, the MegaZoom scope would probably do a superior job because of its higher sample rate and deeper memory.

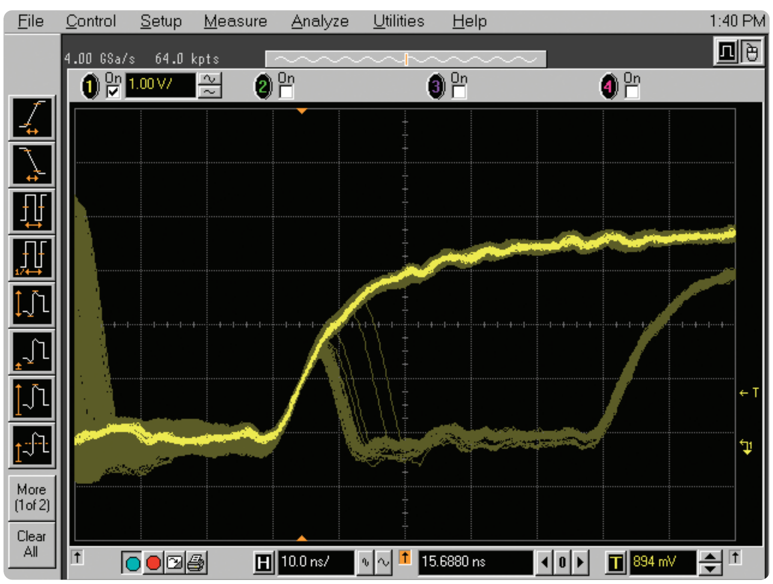


Figure 3. Capturing an infrequent metastable state

MegaZoom Deep Memory (continued)

If you are attempting to capture an inadvertently transmitted bit or packet of bits within a long serial data stream, as shown in Figures 4 and 5, the MegaZoom scopes would do a superior job of capturing the infrequent event. To capture this type of event, you would probably set up the scope on a timebase setting slower than 2 µs/div. Under these conditions, the MegaZoom scope always captures more information and at a higher sample rate and memory depth than a scope with Fast Acquisition. So, again, it depends on your particular application.

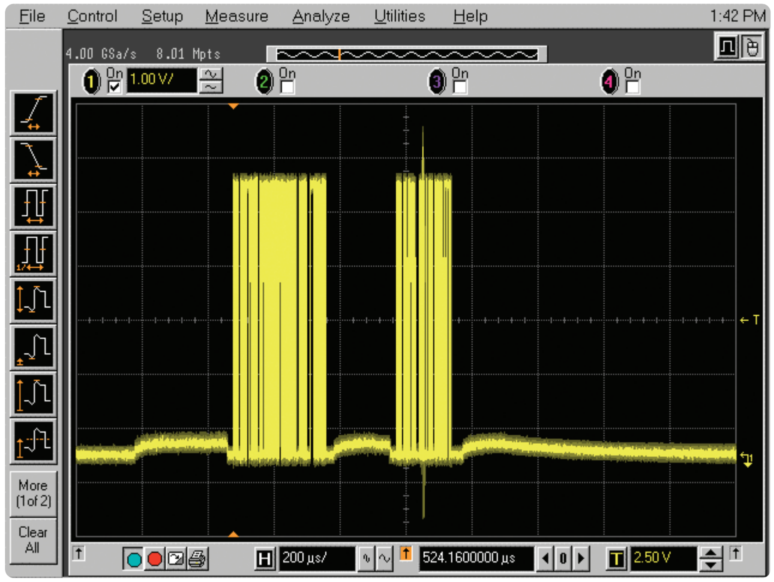


Figure 4. Capturing an infrequent glitch

Figure 5. Zoomed-in view of glitch

Summary

As you can see from the graph of Figure 2, across the broad range of sweep speeds the MegaZoom scopes from Agilent Technologies have the absolute highest number of digitized points per time period. So why doesn't Agilent specify the most digitized points per given period of time over other vendors' scopes? After all, other vendors' scopes with Fast Acquisition mode specify their maximum waveform update in the hundreds of thousands of waveforms per second range (but under non-specified limited conditions). Agilent could claim to digitize as many as 700 million points per second in a MegaZoom scope, which is 5X better than the fastest competitor's scope with Fast Acquisition. But this specification would be for a specific timebase setting under specific conditions.

One last thing to consider is "special mode" versus "standard-operating" mode. As mentioned before, the Fast Acquisition mode of some oscilloscopes is a special mode of operation. You might only use this mode of operation if you already suspect a special need to do so. If you are operating in the normal acquisition mode, you may never suspect that you needed to select the Fast Acquisition mode to look for anomalies.

MegaZoom from Agilent is a normal/default operating mode. Update rates with deep memory are always optimized without going into a special operating mode. In addition, digitizing performance, measurements, and post-acquisition zoom analysis are not sacrificed.

Glossary

Acquisition time The period of time that a scope is continuously digitizing a signal, equal to (memory depth)/(sample rate)

Dead time The period of time between acquisitions when a scope is processing digitized information and re-arming itself for the next acquisition

Digitized points per second The total number of points digitized over a continuous period of one second

DSO Digital storage oscilloscope

Fast Acquisition A special repetitive display mode that greatly improves acquisition update rates, but at the cost of reduced sample rate, memory depth, and functionality

MegaZoom Digitizing scope technology that provides fast update rates when using deep memory

Metastable state An unstable output condition of a digital circuit usually exhibited as a glitch and caused by a setup and/or hold time violation on the inputs

Related Literature

Publication Title	Publication Type	Publication Number
Agilent Infiniium 54800 Series Oscilloscope Brochure	Data Sheet	5988-3788EN/EUS
Agilent 54600 Series Oscilloscopes Data Sheet	Data Sheet	5968-8152EN/EUS
Finding Hidden Problems Using Agilent's Deep Memory Oscilloscope: How IBM Solved a Mystery	Application Note	5988-5655EN
Spectral Analysis Using a Deep Memory Oscilloscope FFT	Application Note	5988-4368EN
Deep Memory Oscilloscopes Illuminate Hard-to-Find Problems	Application Note	5988-4538EN

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