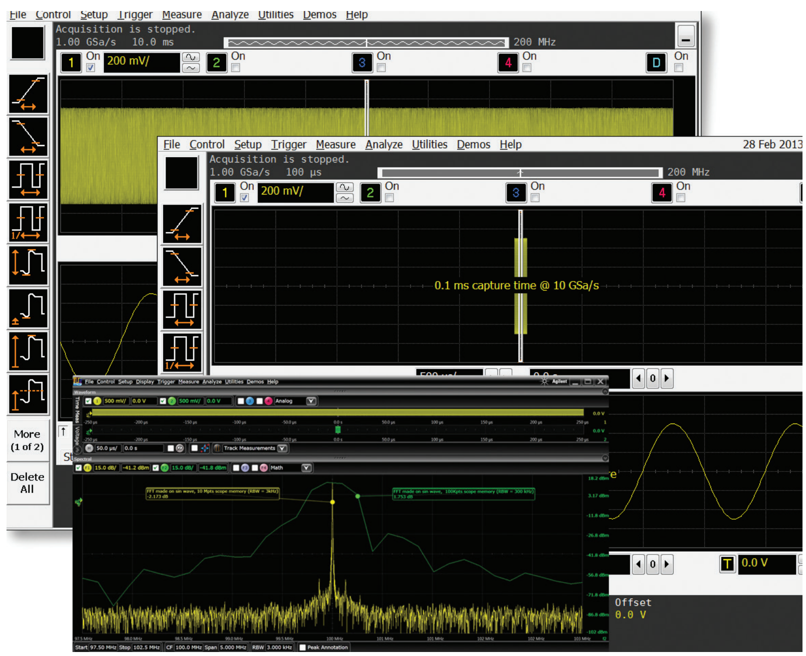
Keysight Technologies
Three Compelling Reasons for Deep Acquisition Memory

Application Note



Introduction

Oscilloscope vendors specify memory depth as a primary attribute for specific oscilloscope models. This value equals the number of samples that are stored with each acquisition. Memory depth is typically specified as a per-channel value. Some oscilloscopes have interleaved memory architectures. For example, memory may have a specific value when all channels are turned on and double the value when only half of the channels are enabled.

In addition to standard acquisition memory specified, most oscilloscopes have additional memory loaded on the acquisition board with this additional depth licensed separately. While acquisition memory depth is often used as a primary purchase consideration, the associated benefits and tradeoffs of deep memory require additional thought to fully appreciate. Here are three areas where deep memory adds value.

1. Capture Longer Period of Time

The most obvious benefit of deep acquisition memory is the capture of longer periods of time at a fixed sample rate. Deep memory helps in instances where the cause and effect may be separated by a significant time period and plays a key role in viewing events that simply take longer time to transpire.

Acquisition Time Window = Memory Depth / Sample Rate. As shown in Figure 1, with 1 Mpts (mega points) per channel an oscilloscope can capture .1 ms of time with 10 GSa/s sample rate. As shown in Figure 2, if the same oscilloscope instead had 100 Mpts per channel, it could capture on 10 ms of time at the same sample rate. There are wide varieties of applications and tests that benefit from longer time captures. Having deep memory provides more flexibility for engineers when they encounter

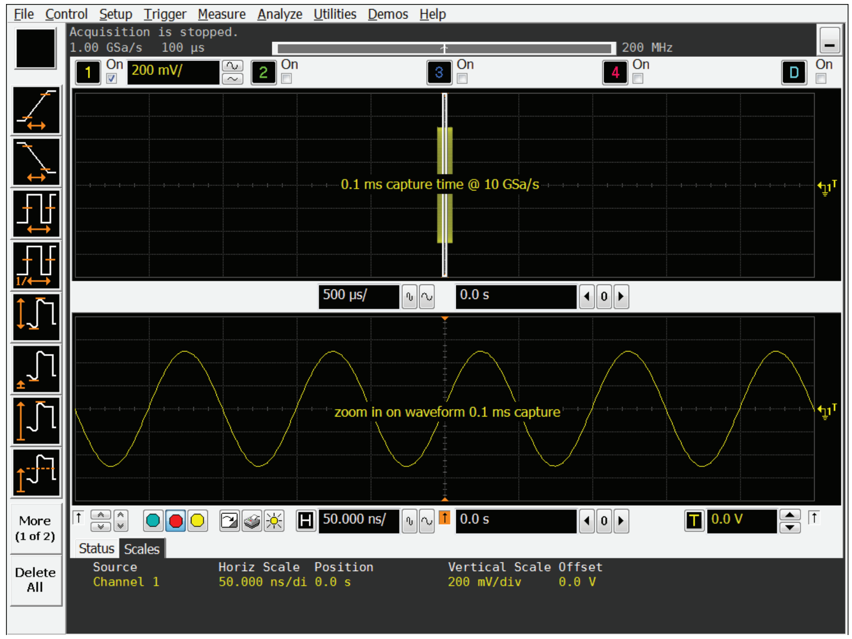


Figure 1. Acquisition Time Window = Memory Depth/Sample Rate. With 1 Mpts (mega points) per channel an oscilloscope can capture .1 ms of time with 10 GSa/s sample rate. To capture longer periods of time, sample rate is decreased.

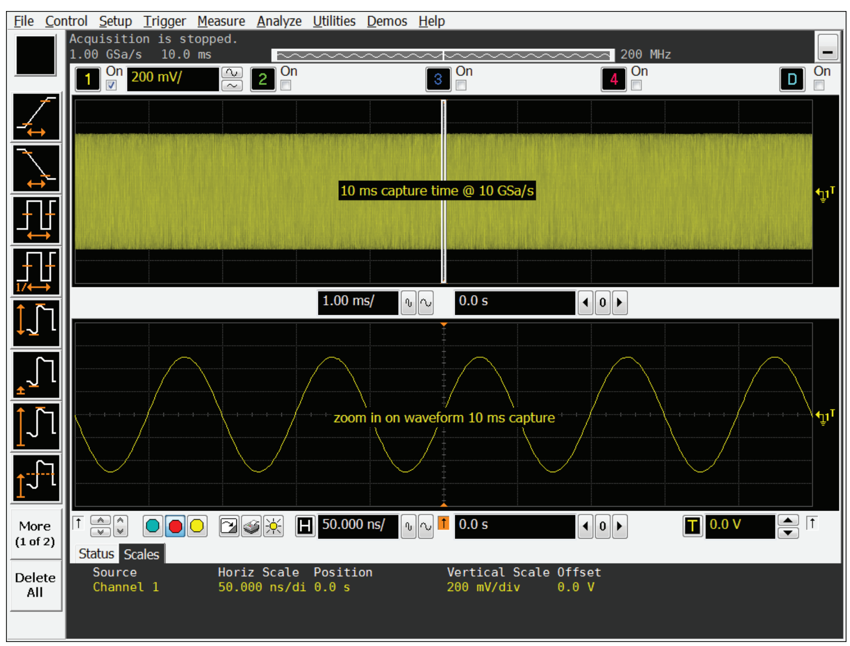
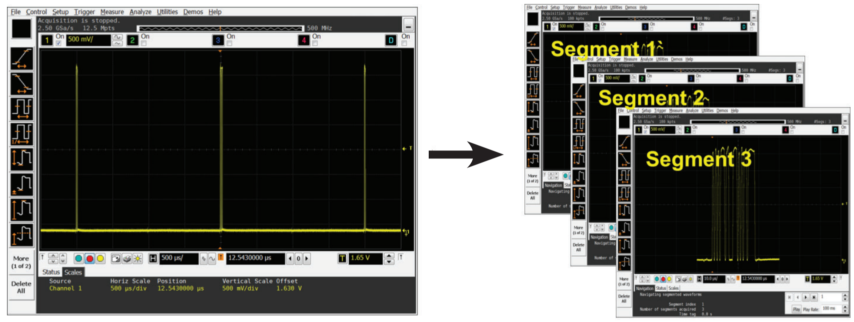


Figure 2. Time Window = Memory Depth / Sample Rate. An oscilloscope with 100 Mpts per channel can capture on 10 ms of time at 10 GSa/s. Additional depth provides more time capture at a fast sample rate.

All advanced oscilloscopes from major vendors include a mode that allows memory to be partitioned into smaller segments. The Keysight Technologies, Inc. oscilloscopes refer to this as segmented memory. The user specifies how many segments the memory should be divided into with each segment having equal length. When the oscilloscope sees the first trigger event, it stores sample points until the first segment of acquisition memory is full. It then looks for the next occurrence of the trigger event. When this trigger event occurs, it stores samples to the next segment of memory. The process repeats until all the segments are full or until the user tells the oscilloscope to stop looking for additional trigger events. Segmented mode is particularly useful for capturing bursts of activity surrounded by long periods of dead time. Many serial busses, optics, and communication signals fit in this category. By using segmented memory, oscilloscopes can maintain fast sample rates, capturing time windows that span seconds, hours, or even days.

How does deep memory enhance segmented memory? First, users can choose to use the additional memory to capture an incremental number of segments. For example, on Keysight's Infiniium oscilloscopes, users can specify that the memory be divided into up to 131K segments. That is a lot of segments. Second, for a given number of segments, users can increase the memory depth of each segment, providing the ability to see more signal activity around each trigger point. With 1 Gpts of memory per channel and 1000 segments, each segment can be 1 Mpts of acquisition memory. That is a decent amount of memory and time capture per segment.



12.5 Mpts to capture 3 pulses

300 Kpts to capture 3 pulses

Figure 3. In this example, capturing three consecutive pulses requires 12.5 Mpts memory in real-time mode. The oscilloscope can capture all three segments in segmented mode using just 300 Kpts memory. Each trigger point creates a trigger point. The oscilloscope stores memory around each trigger point and uses a time tag to keep track of how much time occurs between segments.

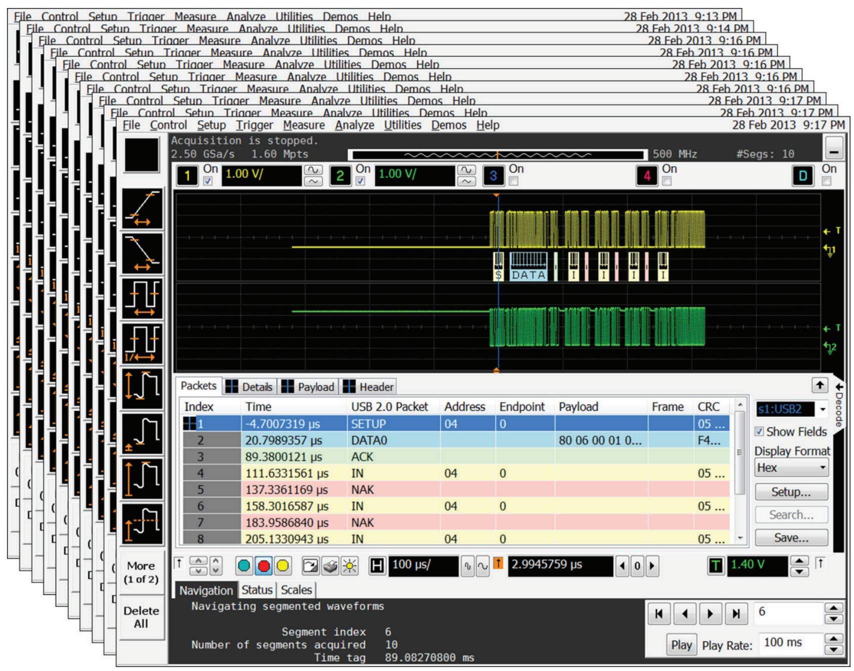


Figure 4. Using segmented memory with a USB 2.0 bus, the oscilloscope can be made to track the entire enumeration process using just a few segments. The oscilloscope triggers each segment acquisition on a setup packet that signals the enumeration process is ongoing. In this example, the oscilloscope captured the entire 90 ms of enumeration using 10 segments each with 1.6 Mpts of memory for a total memory of 16 Mpts. Without segmented memory, capturing the enumeration process would have required 225 Mpts, or 14X more memory, at the same sample rate.

2. Maintain Faster Sample Rate (over a constant period of captured time)

The second primary advantage of deep acquisition memory is the ability to maintain a fast sample rate over a larger number of timebase settings. Engineers tend to think of oscilloscope specifications as values that remain constant independent of how oscilloscope controls are set. Unfortunately, this isn't the case. Let's take a quick look at how memory depth can impact the sample rate and overall bandwidth of an oscilloscope as the user changes the horizontal timebase. Most oscilloscope users don't think about this aspect of acquisition memory. However, it makes a huge difference in the oscilloscope's ability to maintain its other key specifications, sample rate and bandwidth.

Deep memory, full scope bandwidth

Shallow memory can reducte scope bandwidth

Figure 5. An oscilloscope with adequate memory can retain full bandwidth at slower horizontal settings as shown in the right-hand image. An oscilloscope with shallow memory will reduce sample rate, limiting overall oscilloscope bandwidth and incorrectly displaying signals as shown on the right hand display.

Here's an example to illustrate the point. An engineer chooses a 4 GHz bandwidth oscilloscope equipped standard with 10 Mpts of memory per channel and a maximum sample rate of 10 GSa/s. These specifications appear bullet-proof, and the engineer begins using the oscilloscope. The engineer chooses a fast 10 ns/div timebase setting. The oscilloscope samples at 10 GSa/s and uses just 1 Kpts of memory. The entire 4 GHz of effective bandwidth is preserved as the engineer anticipates.

Remember the formula, (Acquisition Time Window) = (Memory Depth)/(Sample Rate).

The engineer needs to see more time on screen and thus turns the horizontal timebase knob to slower settings; the engineer chooses 200 us/div. To fill 10 horizontal divisions sampling at 10 GSa/s, the oscilloscope needs 20 Mpts of memory. Since only 10 Mpts are available, the oscilloscope compensates by dropping the sample rate by a factor of two to 5 GSa/s. The oscilloscope can now acquire 10 Mpts of samples and fill all 10 horizontal divisions. The engineer needs to see a bigger time window and changes the oscilloscope's timebase to 1 ms/div. As the oscilloscope has just 10 Mpts of acquisition memory, to capture 10 ms of activity, the oscilloscope must drop its sample rate again, this time to 1 GSa/s. When the user changed the timebase setting, the memory limitation slowed the oscilloscope's sample rate and overall bandwidth.

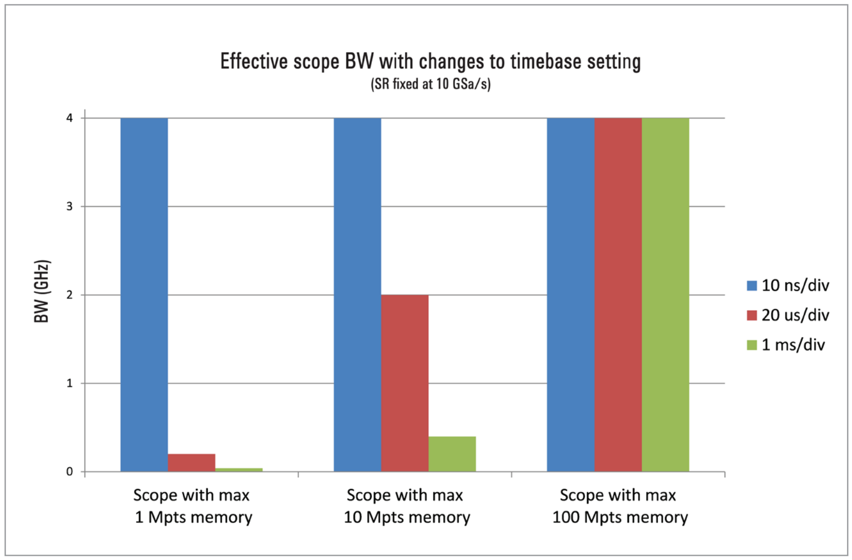


Figure 6. Sample Rate = Memory Depth / Time Window Captured. Having deeper memory enables the oscilloscope to retain a faster sample rate and full bandwidth as the user adjusts the timebase control to slower settings.

By changing the horizontal time-base control with a fixed amount of memory, their oscilloscope compensated by decreasing sample rate as well as the oscilloscope's overall effective bandwidth. The front end of the oscilloscope was still letting frequencies up to 4 GHz pass through. However, the oscilloscope with slower sampling is now subject to aliasing issues, as it is no longer sampling fast enough to support the frequencies passed through the front end. The user reduced effective bandwidth from 4 GHz to 400 MHz by changing the timebase setting. This measurement error was facilitated by the oscilloscope having only 10 Mpts of maximum memory.

What if the oscilloscope had 1 Gpts memory instead of 10 Mpts? At the slower timebase setting of 10 ns/div, the oscilloscope would retain the maximum sample rate of 10 GSa/s and hence would not alias signals up to the oscilloscope's rated 4 GHz bandwidth. At the slower sweep speed of 1 ms/div even up to 5 ms/div, the oscilloscope can still acquire at 10 GSa/s and hence will accurately represent signals up to the oscilloscope's full 4 GHz bandwidth. Surprisingly, memory depth is indeed linked with effective oscilloscope bandwidth when horizontal timebase settings are changed. Oscillocopes with deeper memory depth preserve high sample rate and the ability to use its full-rated bandwidth over a larger range of timebase settings.

3. Get Better Measurement and Analysis Results

The third primary value of deep memory is quality of measurements. Have you ever considered if taking rise time measurements on 1,000 acquisitions each with 1K memory yields better results than taking rise time measurements on a single acquisition of 1 Mpt (1K and 1000)? Ever wonder how an FFT with 10 Kpts of memory differed from one with 10 Mpts? Ever considered how deep versus shallow memory impacts jitter characterization? These are great questions, and deep memory has an impact on all of them.

How much memory the oscilloscope uses for analysis is a balance. If memory depth is set too low, the oscilloscope will have difficulty providing meaningful analysis. For example, when doing eye recovery and jitter, if the memory is set too low the oscilloscope can't do PLL clock recovery because it won't see enough edges. Also, shallow memory inhibits statistically valid analysis such as FFTs and histograms because the functions won't have enough points on which to operate. If the memory is set too high, the tradeoff is that the oscilloscope's responsiveness suffers as processing times for analysis increase significantly.

What's the downside of having deep memory all of the time? Deep memory decreases update rate because the oscilloscope must process additional information before rending the result on the display. Deep memory slows this task, resulting in bigger delays between when the oscilloscope can trigger; sluggish user control; and inability to show subtle signal detail. Update rate with deep memory varies dramatically by oscilloscope vendor as shown in Figure 8.

Figure 7. FFTs and other functions yield better results when more points are used. For FFTs, Resolution Bandwidth = Sample Rate / Points in FFT. So, to achieve more precise resolution bandwidth, the oscilloscope must acquire and process more samples. This screen shot shows the difference between an FFT made on a 100 kpts acquisition and one made on a 10 Mpts acquisition of the exact same signal.

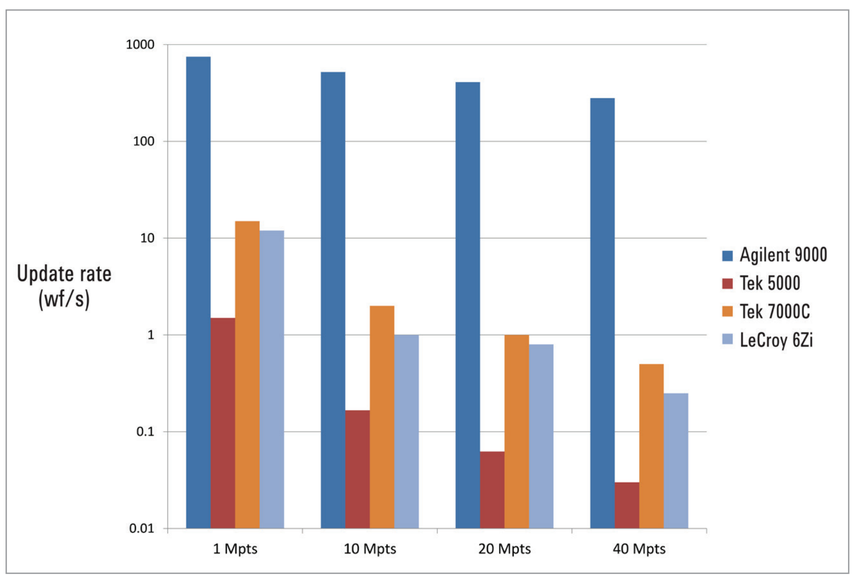


Figure 8. An oscilloscope's architecture determines how responsive it is when deep memory is enabled. Update rate, how many waveforms per second an oscilloscope can capture and process per second, is a good measure objective measure of how well the oscilloscope handles deep memory. As noted in the graphic with update rates shown on a log scale, there is a huge variation in update rate between oscilloscopes when deep memory is turned on.

Summary

When choosing an oscilloscope, pick one that has sufficient memory to cover your future needs. While you may not want to have deep memory turned on all the time, having the additional memory available on your oscilloscope is a huge benefit for times you need it for debug and testing. The additional memory can be enabled when you run into situations where it is needed. The benefits you will derive from the additional memory include capturing longer time windows with a given sample rate and retaining a faster sample rate and oscilloscope bandwidth when capturing longer time windows. Also, deeper memory can help your oscilloscope achieve better measurement and analysis results. Segmented memory enables a oscilloscope to better utilize acquisition memory and is effective for signals that have long dead times between periods of activity. The primary downside to deep memory is a slowing update rate. Oscilloscope update rate performance varies dramatically between vendors when deep memory is enabled.

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