Mega*Zoom*® vs. FastAcq®

Agilent Technologies

Capturing Infrequent and Random Events Using Deep Memory Oscilloscopes

22 May 2002

Accelerating Innovation

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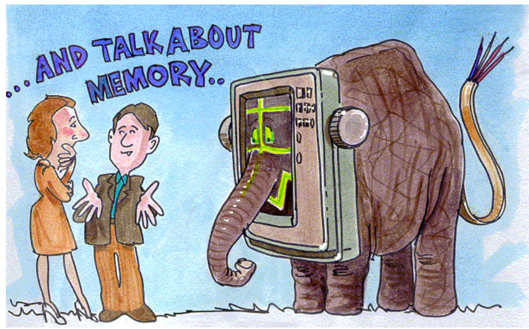
Capturing Infrequent and Random Events Using Deep Memory Oscilloscopes

Agenda

- Why Deep Memory?
- Frustrations with 1st Generation Deep Memory
- Mega*Zoom* vs. FastAcq Mode



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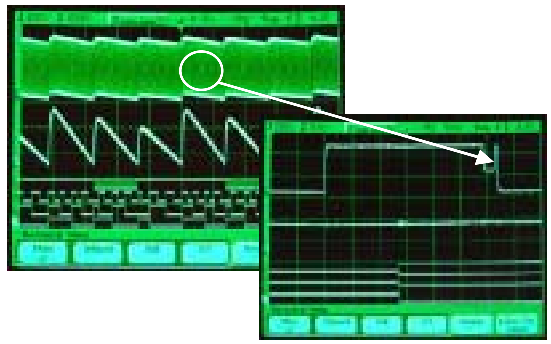
Agenda

Welcome to Agilent Technologies seminar on “Capturing Infrequent and Random Events Using Mega*Zoom* Deep Memory Oscilloscopes”. Some of the needs/applications for deep memory in digital storage oscilloscopes are pretty obvious. They allow you to capture long waveform records with sufficiently high enough sample rate to not only capture complex signals, but also capture infrequent and random events that may occur within long data streams. However, deep memory in oscilloscopes does not come without a few tradeoffs. During today’s seminar, we will discuss these tradeoffs and show some typical applications of capturing long waveforms with anomalies. In addition, we will compare two very popular deep memory technologies that overcome some of the tradeoffs. These technologies are called Mega*Zoom* and FastAcq.

Q: Why Deep Memory?

- Enables capture of long serial data streams
- Enhances capture of infrequent events/glitches
- Discover anomalies in the absence of a good trigger event
- Correlate high-speed digital signals with slower analog signals

Allows for sustained sample rates!



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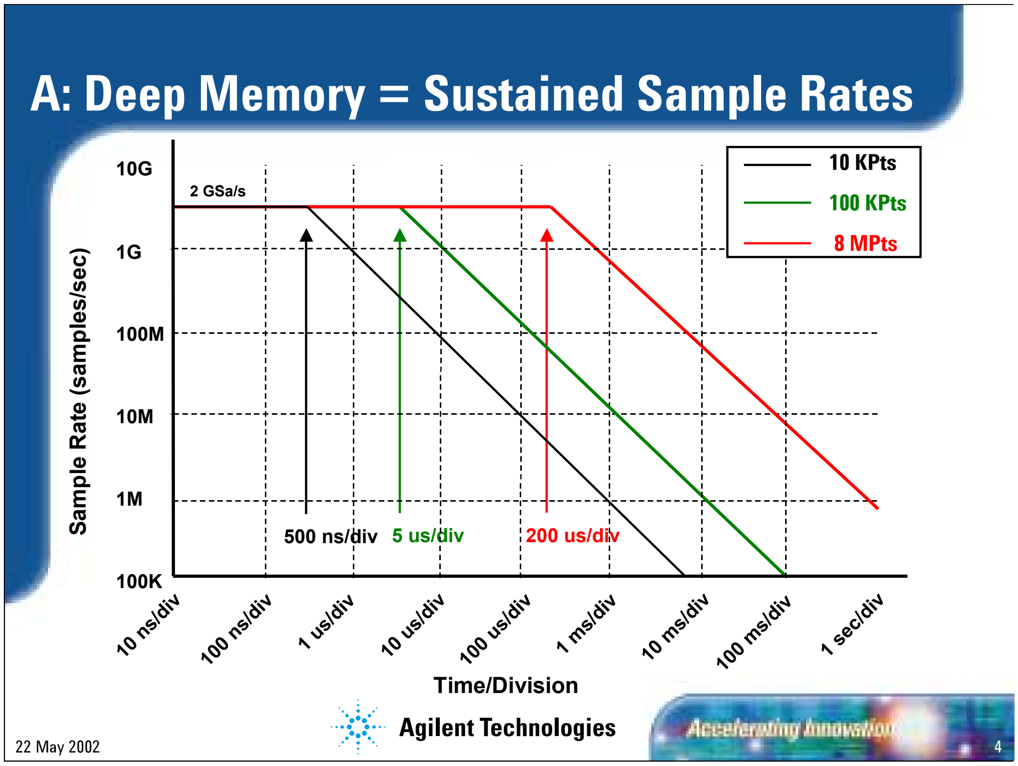
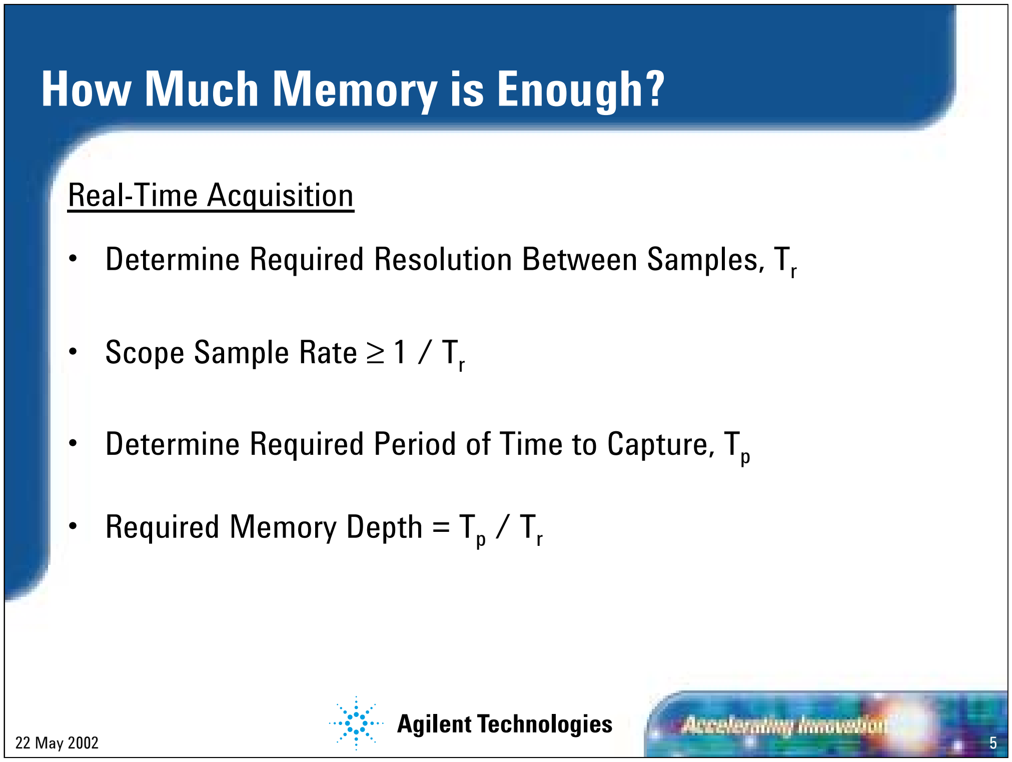
Why Deep Memory?

What are some of the reasons engineers want to have deep memory in their digital storage oscilloscopes? The most obvious application is for capturing long complex waveforms such a serial data streams. Secondly, deep memory can enhance the probability of capturing infrequent events such as glitches. Deep memory will allow you to capture anomalous events in the absence of a known trigger event. Also, deep memory is essential when evaluating analog and digital signals simultaneously in a mixed signal design. Lastly, deep memory oscilloscopes allow for sustained sample rates on slower sweep settings in order to capture waveforms with higher timing resolution and accuracy. Actually, sustained sample rate is the fundamental result of deep memory that allows the oscilloscope to capture long waveforms with sufficient digitizing resolution to also capture waveform details, including anomalies and glitches. So, let’s get a better understanding of what we mean by sustained sample rates.



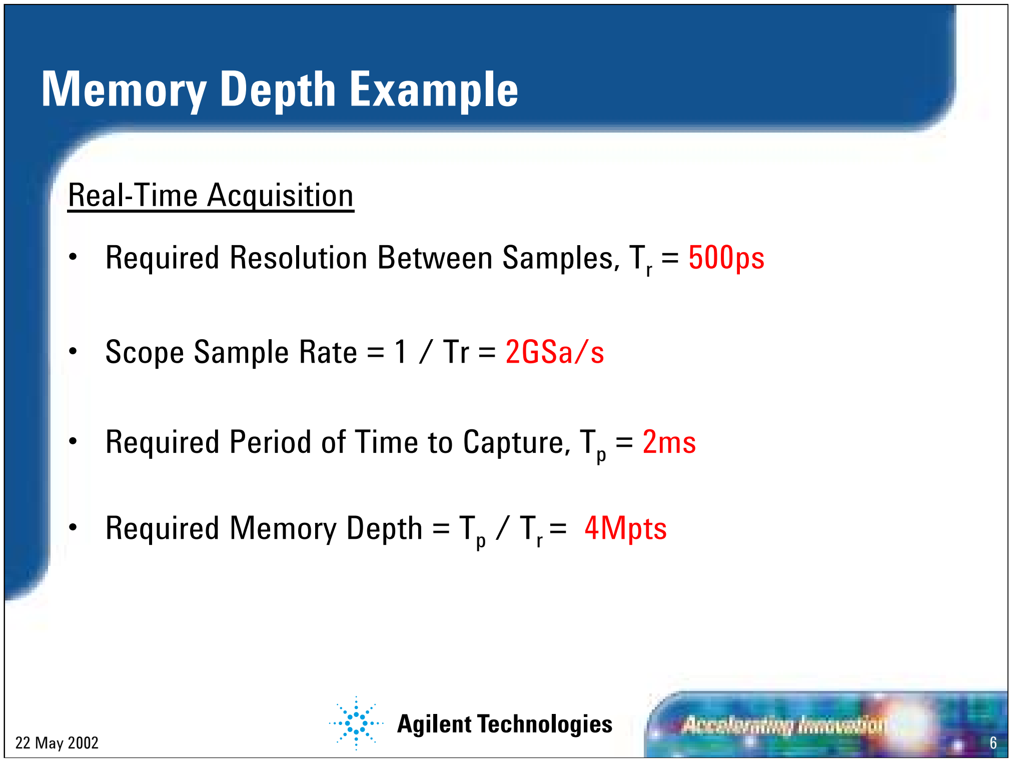
A: Deep Memory = Sustained Sample Rates

Many scopes are capable of sampling incoming signals at rates that are 10 or more times faster than the maximum bandwidth of the scope's attenuator. This extreme oversampling is unnecessary, and cannot be sustained in shallow memory scopes. All scopes will eventually reduce their sample rate because of memory depth limitations. You can see that with a scope that has 2GSa/s and only 10KB of memory, the sample rate can only be sustained at the lowest few time/division settings, thus only short windows of data can be captured for analysis at this sample rate (black curve). With deeper memory available, you can see that the scope is able to maintain its maximum sample rate through many more time/division settings, thus maintaining an adequate sample rate to reproduce the incoming signal, and reduce the likelihood of aliasing. For example, if you were analyzing a 50MHz clock, you would need to maintain at least a 200MSa/s data capture rate in order to accurately reproduce the signal. The 10KB scope with 2GSa/s can only capture this signal at time/division settings of 500ns, which equates to 5us of data, with the maximum sample rate. With the 8MB scope, we see that we can capture this signal out to time/division settings of 200us/div, which equates to 2ms of data, with the maximum sample rate. We are now going to look at the way to calculate the required memory depth that we need for making our measurements.



How Much Memory is Enough?

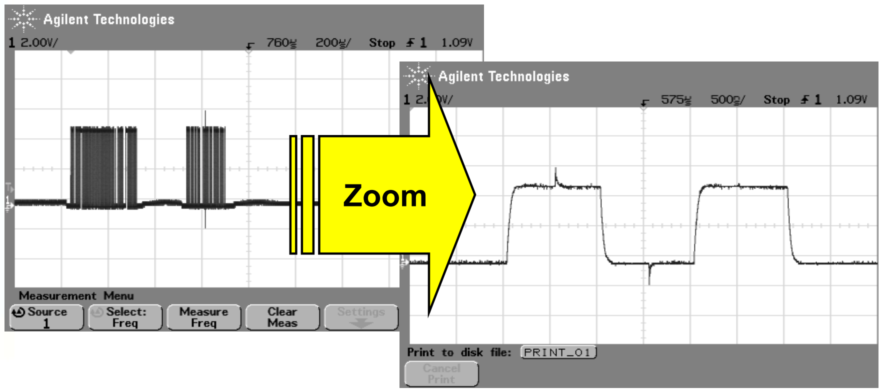
When making single-shot measurements with an oscilloscope, we are capturing data with a real-time acquisition system. We must first determine how frequently we want to sample our incoming signal, or the resolution between samples. A good rule-of-thumb is to divide our fastest signal edge speed by four to reduce the risk of aliasing. (Most digitizing scopes will use a sinx/x filter to provide additional points between samples with high statistical probability. If your scope does not have a sinx/x display filter, then divide your fastest signal edge speed by 10 to find the required resolution.) We then compute the required sample rate of the oscilloscope by calculating the inverse of the sampling resolution. Now we can see that the amount of memory necessary to maintain our required sample rate is directly dependent on the amount of time that we want to capture. If we do not have enough memory in our oscilloscope, then we have to trade record length for sampling resolution, and vice versa.



Memory Depth Example

In this example, we are measuring a signal with a 2 ns edge, and that we require a sampling resolution of no greater than 500ps between points to accurately capture the signal edges. This resolution corresponds to a 2GSa/s sample rate. We want to acquire 2ms of data, then check our setup and hold times to find any slow pulses. We see that in order to capture this long data record, we need to have at least 4Mpts of memory!!! Now, let’s look at two measurements made on a signal with an intermittent glitch. One measurement is made with a deep memory scope, the other with a shallow memory scope.

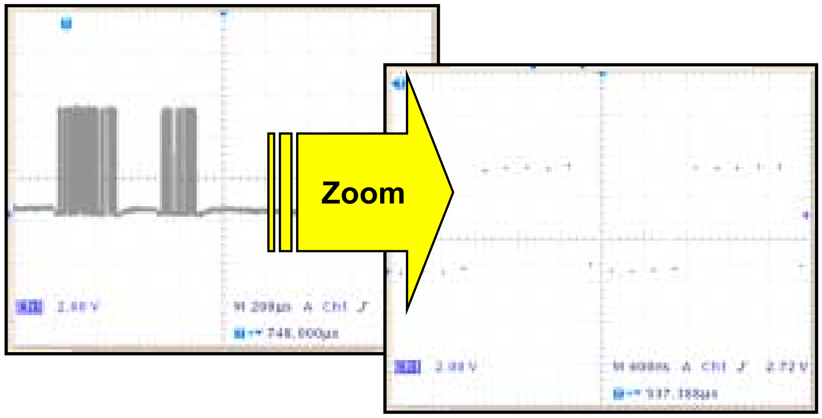
Memory Example #1:
Tp = 2ms with scope at 2GSa/s & 4MB



Memory Example #1

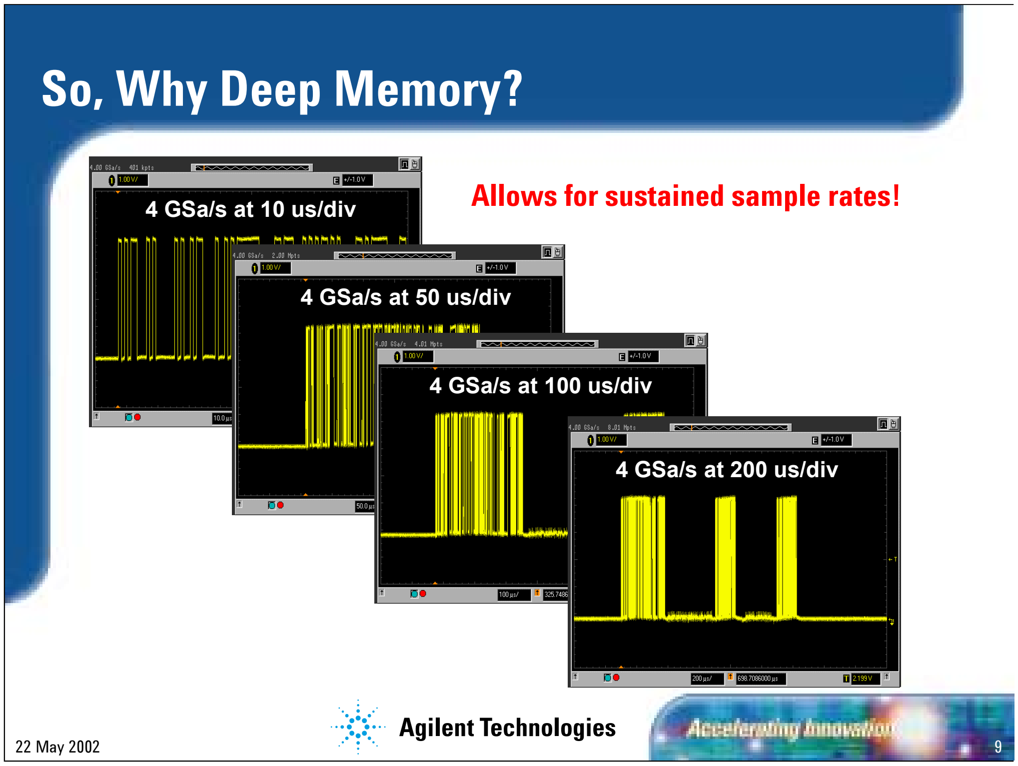
In this case, we have captured 2ms of data with our oscilloscope. With 4MB of memory available, we are able to sample the signal at 2GSa/s. We then notice that we have a glitch on the top and bottom of our waveform, and we can zoom in to look at the characteristics of these glitches. Deep memory has allowed us to capture a long data record, quickly scan it for obvious anomalies, then zoom in and observe these anomalies with maximum resolution. Now let’s look at the same signal measurement with shallow memory.

Memory Example #2:
Tp = 2ms with scope at 5MSa/s & 10KB



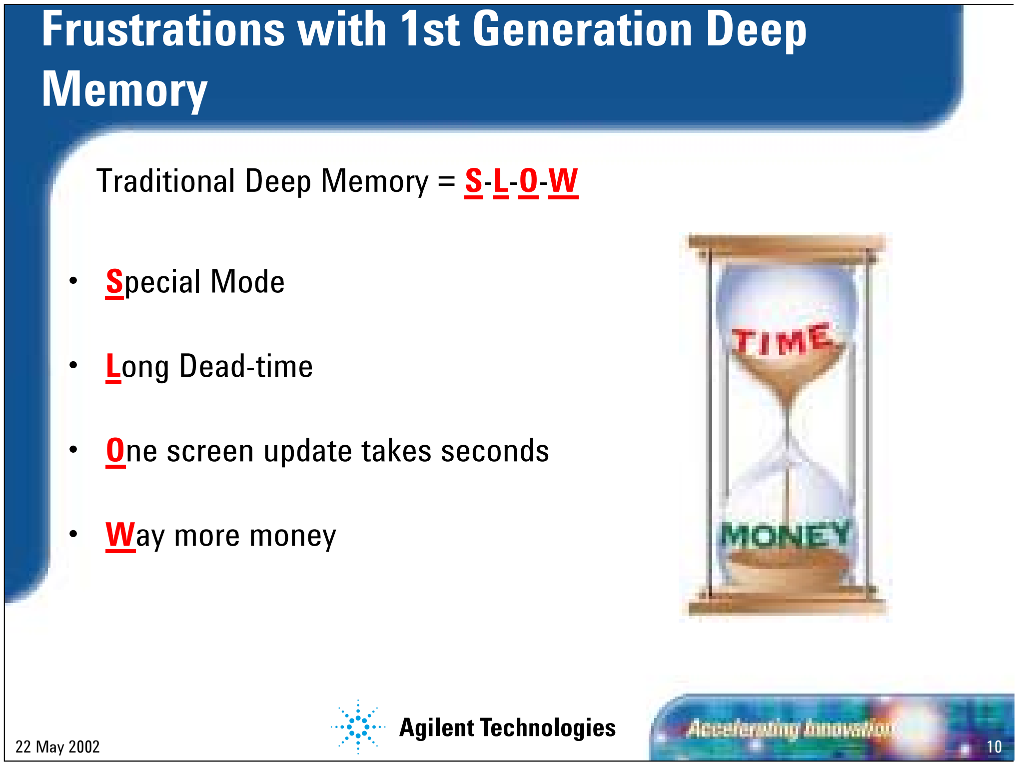
Memory Example #2

In this case, our oscilloscope only has 10KB of memory available. We capture the same 2ms pulse train, and we observe that we can no longer see the glitch. Because these measurements were made from the same signal source, we know that the glitch exists, and the screen on the left appears nearly identical to the same screen in the previous example. But…when we zoom in to look at our signal, we can now see that our signal is severely undersampled, and that aliasing has occurred. Because we were limited to a shallow memory, our sample rate was decimated at the slower sweep speed, and our scope was not able to capture any points on the edge transition. (Now, most scopes have a sinx/x reconstruction filter that we mentioned before, but in this case we do not have enough samples on the signal edge for the sinx/x filter to provide accurate intermediate points.) So, we revisit the question: Why Deep Memory?



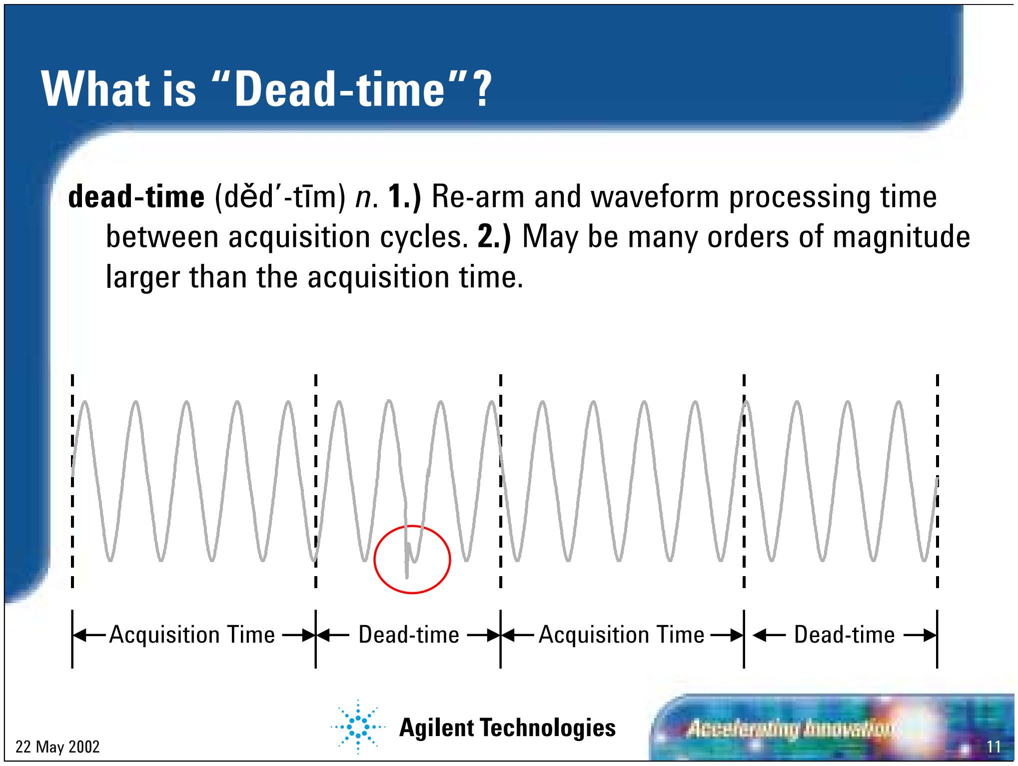
So, Why Deep Memory?

We can see that deep memory allows us to maintain our maximum sample rate out to slower sweep speeds which, in turn, allows us to capture long data records without trading in our sample rate. We can now quickly observe many packets of captured data, or a long time event, and then quickly zoom in to see the details. Now, let's look at some of the frustrations with traditional deep memory implementations.



Frustrations with 1st Generation Deep Memory

More is better, right? Possibly. However, there could be some negative implications of using a deep memory oscilloscope. If the scope must process more digitized information, the scope's display refresh rate may slow down significantly, which would degrade the scope's usability. To overcome the update rate problem, the scope may employ user-selectable memory depths. In this case, you would have to decide whether to use the scope in shallow memory mode with fast update rates, or a deep memory mode with slow update rate. Related to slow update rates would be longer dead-time. If the scope has a longer dead-time, then this could degrade the probability of capturing infrequent events. And lastly, deep memory oscilloscopes usually cost more than standard low memory scopes. Let's now take a closer look at each of these issues.



What is "Dead-time"?

As just mentioned, scopes with faster acquisition update rates will have less dead-time. Actually, the key to increasing update rates is to minimize dead-time. So, what is dead-time? Dead-time is the oscilloscope's re-arm and waveform processing time between acquisition cycles. This time may be many orders of magnitude greater than acquisition time at fast time per division settings.

So, why is it important to minimize dead-time? If you are attempting to capture an infrequent and random glitch, this glitch can happen at any time. If it happens during the dead-time, then it will be missed by the oscilloscope. By minimizing the dead-time, the probability of capturing it during the acquisition time can be improved.

Waveform Update Rate

•**Tek Normal Acq =**	**130 max**	TDS 5000/7000 Series
•**Tek Fast Acq =**	**100,000 max**	TDS 5000-Series
	200,000 max	TDS 7054/7104
	400,000 max	TDS 7154/7254/7404
•**Agilent Mega*Zoom* =**	**7,800 max**	54830B/31B/32B
	64,000 max	54641A/41D/42A/42D

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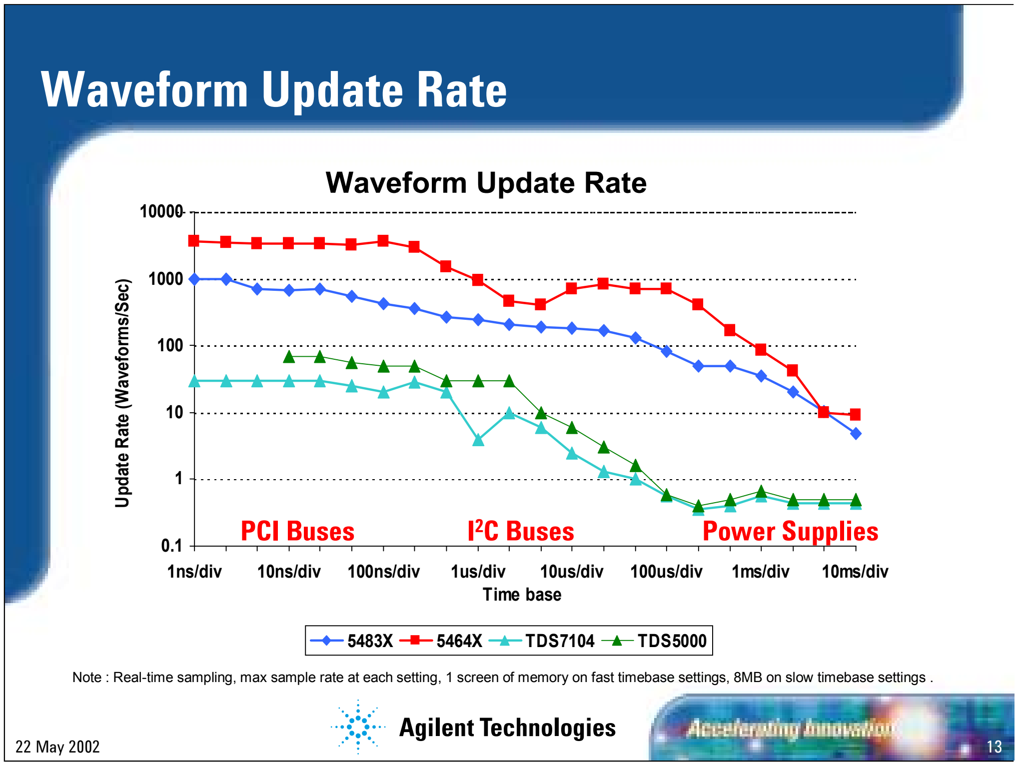
Waveform Update Rate

With the FastAcq mode, maximum acquisition update rates of 100,000 to 400,000 waveforms per second can be achieved, depending upon the oscilloscope family.

Mega*Zoom* technology can deliver a maximum update rate of 7,800 waveforms per second in the Infiniium 54830 Series oscilloscopes. In the 54640-series, the update rate is maximum at 64,000 waveforms/second. Now that we have seen the fastest waveform captures available on these scopes, let's look at the display update rate, and compare the speed at which these scopes can convey information about your signal to the display and, ultimately, to you.



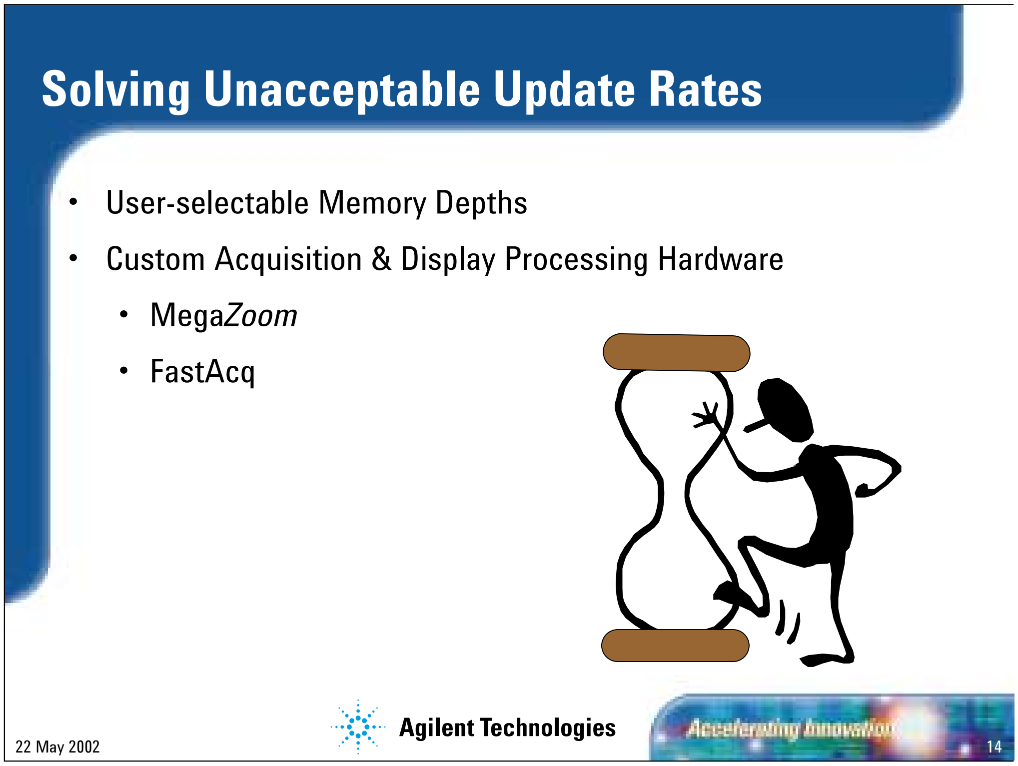
Waveform Update Rate

These measurements were made with all scopes forced to REALTIME acqusition mode, and optimized memory depths and acquisition speeds, to provide the fastest possible waveform update rates.

In this graph we show display update rates for two different vendors' deep memory oscilloscopes with optimum sample rates and enough memory to fill one display screen. You can see that the Agilent 5483X and 5464X scopes with Mega*Zoom* technology can realize much faster update rates at the maximum sample rates.

(On the slower timebase settings, all of the scopes slow down their update rates. But at these timebase settings, this is not related to processing the deep memory acquisitions, but is a function of capturing longer time spans. For instance, if you set your scope's timebase to 100ms/div, the time span of capture would be 1 second. The best you could hope for would be just one update every second, regardless of the memory depth of the scope.)

Note: The TDS5000 series curve stops at 10ns/div because the scope cannot be setup to acquire data in a REALTIME acquisition below this time per division setting.



Solving Unacceptable Update Rates

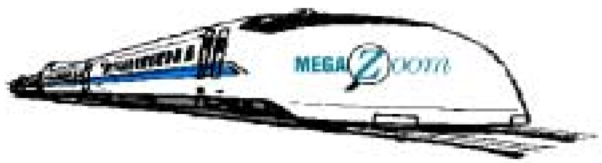
The most obvious solution is to allow the user to choose between using deep memory for special applications, but deal with the slow update rate, or choose to use the scope in a shallow memory mode with a usable update rate.

A better solution from a vendors’ perspective is to fix the deep memory acquisition processing time problem. Today, two oscilloscope vendors have adopted two different technologies that address the acquisition update problem. Agilent Technologies employs an acquisition processing technology known as Mega*Zoom*. Another vendor uses a technology known as FastAcq. Let’s take a closer look at the performance and benefits of each of these technologies.

What is Mega*Zoom*?

<u>Mega*Zoom* is a Memory Management Tool</u>

- Custom ASIC designed into acquisition system
- Ping-Pong Acquisition Memory
- Preprocessing of Data in Hardware
- No Special Modes--Always On and Always Fast



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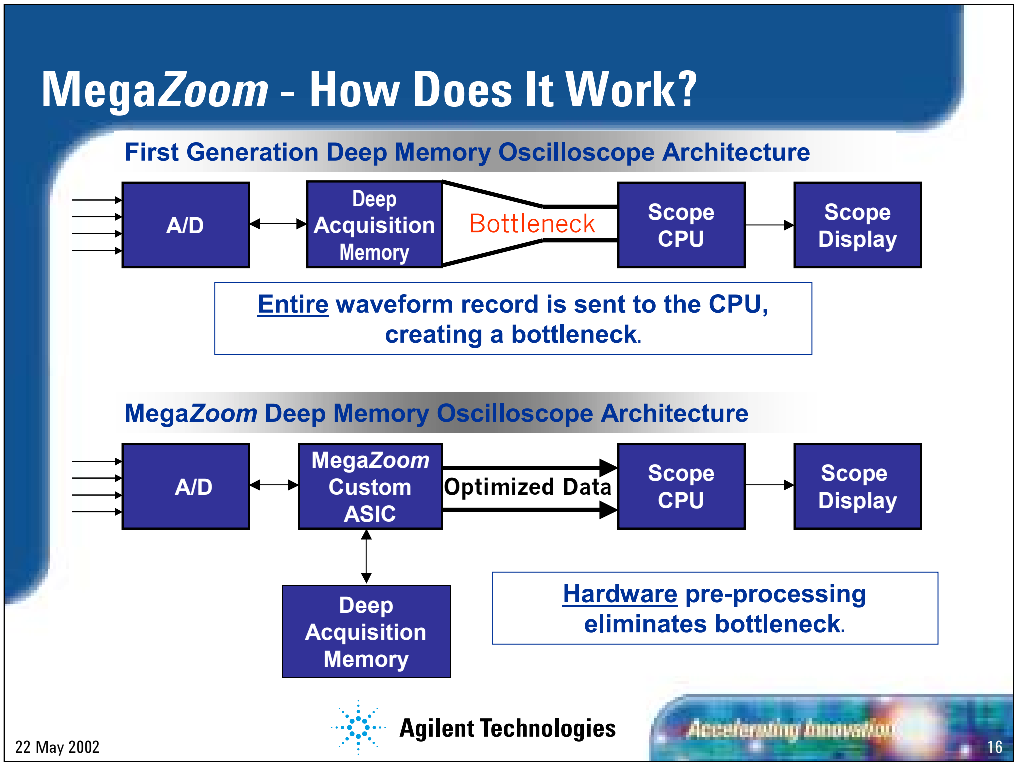
What is MegaZoom?

Mega*Zoom* is a memory management tool that allows the oscilloscope's user to enjoy a lively display update rate that is always fast. Mega*Zoom* is a custom ASIC, designed and patented by Agilent Technologies, that allows the acquisition system to concurrently store and display waveform data using a "ping-pong" memory storage technique. The captured data is then pre-processed in the ASIC hardware before being sent over the CPU bus to the display. Mega*Zoom* is not a special mode, but instead, it is a normal operating characteristic of the deep memory scopes. The benefits of Mega*Zoom* is that it is always on, and always fast.



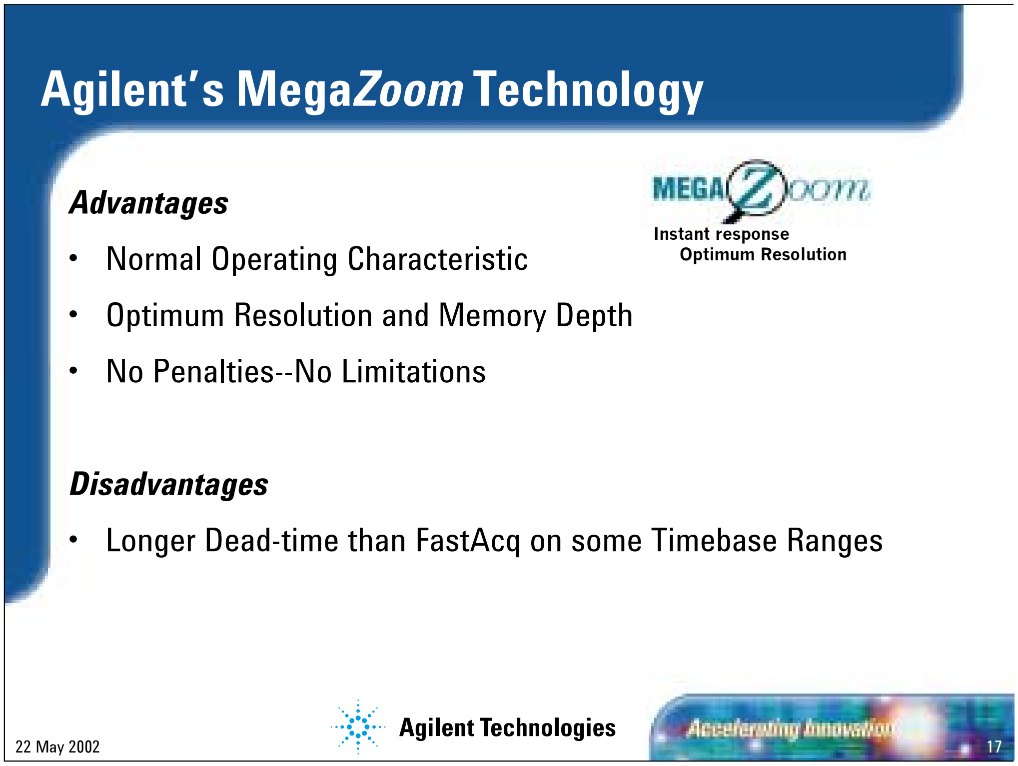
MegaZoom-How Does It Work?

With 1st generation deep memory, the scope CPU must perform many tasks including processing the samples from the A/D to their storage in the acquisition memory, also drawing the waveforms on the display and also monitoring the front panel button presses. This is all done in software which really slows things down. Also the entire waveform record is sent to the CPU creating a bottleneck which slows down the display update rate causing large dead times which could cause you to miss important details.

Next generation deep memory architecture:

We designed Mega*Zoom* deep memory differently than our competitors' deep memory and it shows. The Mega*Zoom* architecture utilizes a "Mega*Zoom* custom ASIC" to capture data into acquisition memory and quickly post-process it in the hardware for display and measurements. So only "on-screen" data is sent to the CPU to be displayed. "Off-screen" data is stored in acquisition memory and is called upon when needed. This reduces the post processing tasks of the CPU.

The result is that Mega*Zoom* greatly increases the waveform update rate and front panel responsiveness even with the deepest memory turned on.



Agilent's MegaZoom Technology

Let's now take a look at the advantages and disadvantages of Agilent Technologies Mega*Zoom* technology. The biggest advantage is that Mega*Zoom* is the normal operating mode of the scope. MegaZoom is always ON and running. The user can't even disable it. And since MegaZoom is the normal operating mode, there are no tradeoffs in functionality and features.

The biggest disadvantage is that Mega*Zoom* update rates are not as fast as other vendor's FastAcq mode on some of the fastest timebase ranges. In other words, Mega*Zoom* scopes have longer dead-times than FastAcq scopes on some timebase ranges. This means than Mega*Zoom* scopes may have more difficulty in capturing infrequent/random events. But, this may not always be the case. We will address this issue and explain why a little later. But first, let's look at how Mega*Zoom* works compared to conventional deep memory acquisitions.

FastAcq Mode

Advantages

- Minimum Dead-time
- Can improve probability of capturing infrequent, random events at a few timebase settings

Disadvantages

- Max sample rate = 1.25 GSa/s at 5KB or less
- Max memory = 1MB at 50MSa/s or slower
- No Zoom, No waveform math, No measurements, No peak detect

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FastAcq Mode

With the FastAcq mode of technology, hundreds of thousands of waveform acquisitions per second can be achieved. This means that the oscilloscope's dead-time is minimized as compared to oscilloscopes with slower update rates. And by minimizing the scope's dead-time, the probability of capturing infrequent/random events, such as a glitch, can be significantly improved. We will explain and address the dead-time issue in just a few minutes.

So, what are the tradeoffs? First of all, the hundreds of thousands of waveform acquisition updates specification only applies to a narrow set of timebase ranges and the capture of just 500 points per acquisition. At timebase settings slower than 40ns/div, the memory depth increases beyond 500 points, but the update rate decreases significantly. Secondly, the FastAcq mode is a special operating mode that must be selected by the user. Much of the functionality of the oscilloscope is limited when operating in this special mode. Even though the scope may specify a maximum sample rate in the multi-gigasamples per second range, while operating in the FastAcq mode, the maximum sample rate is limited to 1.25GSa/s. This will effectively limit the realtime bandwidth of the scope to approximately 350MHz. In addition, the maximum memory depth is limited to 1MB and post acquisition analysis is not available. This means that you cannot zoom-in on waveform details, you can't perform waveform math or waveform measurements, and the peak detect mode is disabled. Hence, a special operating mode.

Best Metric for Capturing Infrequent Events

Sample Rate

- Indicates Acquisition Performance
- Does not reflect dead-time characteristics

Waveform Update Rate

- Indicates Dead-time Characteristics and Display Responsiveness
- Does not reflect acquisition performance

Digitized Points per Second (over long period of time)

- Indicates Acquisition AND Dead-time Characteristics
- Best measure for Capturing Infrequent Events

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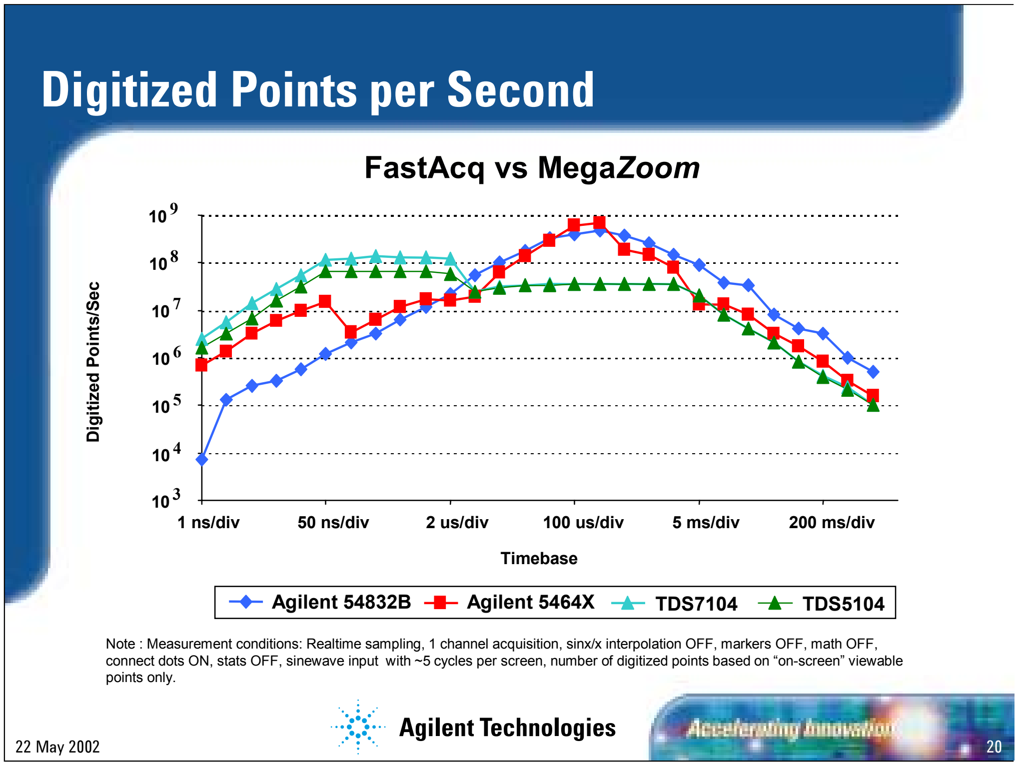
Best Metric for Capturing Infrequent Events

Acquisition/display update rates can be either characterized as “sample rate”, “waveform update rate” or “digitized points per second”. Sample rate is a good metric for evaluating a scope’s acquisition performance during the acquisition time. However, sample rate does not give any indication of the dead-time associated with the scope’s data processing and trigger re-arm time.

Update rate specified as waveforms per second gives a good indication of the oscilloscope’s dead-time, as well as the scope’s display responsiveness. If the scope’s waveform update rate is high, then this is a good indication that the dead-time is low. If the dead-time is low, then this will improve the probability that a random glitch will fall within the acquisition time, rather than the dead-time. However, it does not indicate the quality of capture during the acquisition time. For instance, if maximum sample rate is sacrificed to improve (lessen) dead-time, then even if a random glitch does occur during the acquisition time, the probability of capturing it with high fidelity may be decreased.

A better measure of merit of capturing random events would be evaluate the total number of digitized points over a long period of time, such as an entire second. The total number of digitized points per second (for an entire second) could be thought of as an average digitizing rate that includes both dead-time and acquisition time. It should be noted that this is NOT the same as sample rate, which is the digitizing rate only during the acquisition time.



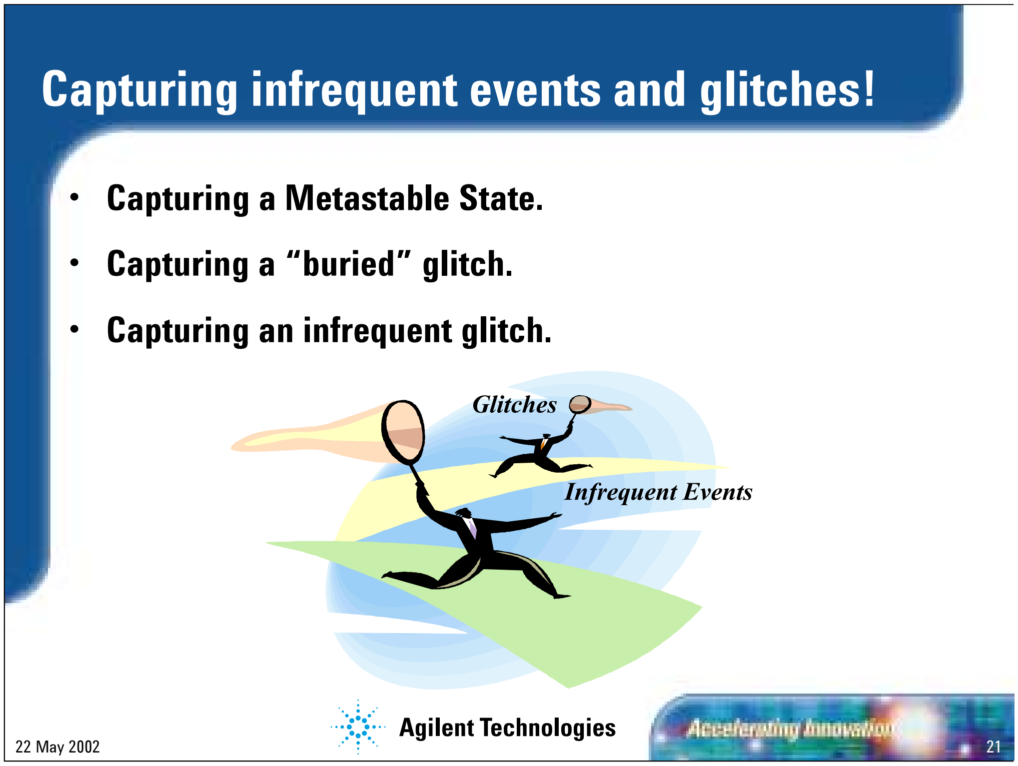
Digitized Points in Comparison

This chart shows a plot of digitized points per second for four deep memory oscilloscopes; two from Agilent that have Mega*Zoom* technology, and two from another oscilloscope vendor with FastAcq and deep memory.

Note that at timebase settings of 2µs/div and faster, the scopes with FastAcq hardware are able to capture more digitized points per second. The TDS7104 is able to capture up to 140,000,000 digitized points per second at 400ns/div. At these faster timebase settings, the scopes with the FastAcq mode may have a higher probability of capturing infrequent random events. However, if the limited sample rate of 1.25GSa/s is too slow to capture a narrow event, it may be a mute point.

At timebase settings slower than 2µs/div, the Mega*Zoom* scopes are able to digitize more points per second. At 200µs/div, the Agilent 5464X scope captures 700,000,000 points per second, and the Agilent 5483X Mega*Zoom* scope captures nearly 200,000,000 points per second. The Agilent scopes are able to capture more points at the slower sweep setting because they maximize both sample rate and memory depth during the acquisition time.

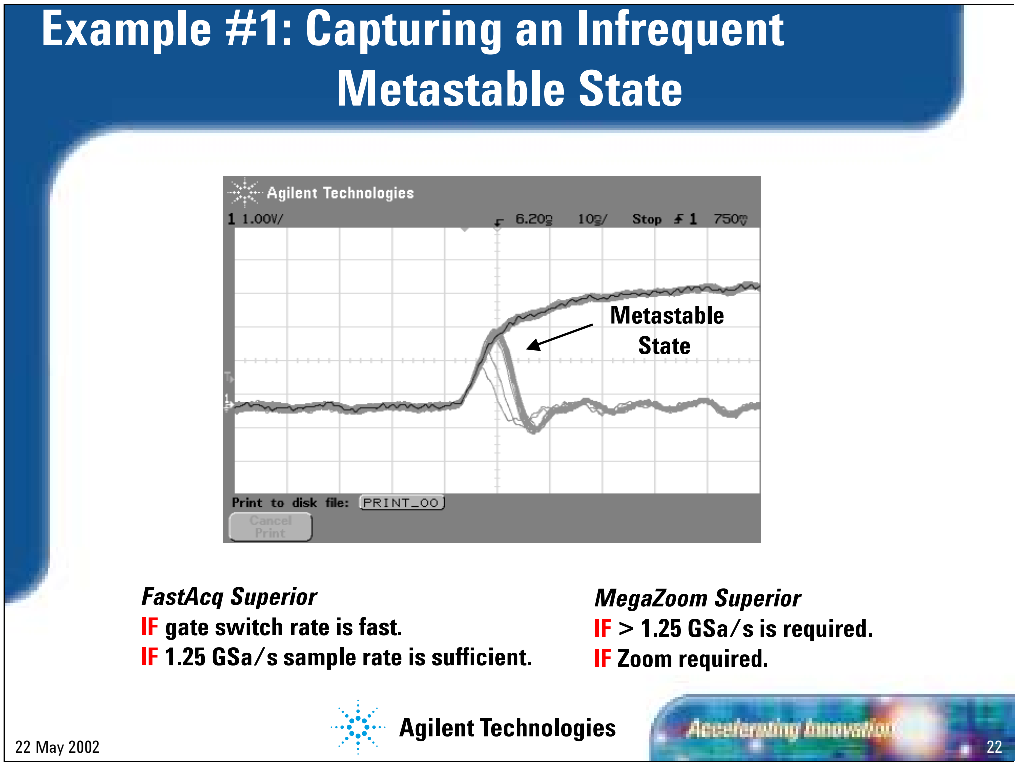
So, which technology (FastAcq or Mega*Zoom*) is superior at capturing infrequent events. It depends on the particular application. Let's look at a few examples.



Capturing infrequent events and glitches!

In the real-world of digital design, we understand that the outputs of our gates exhibit analog characteristics. This means that our setup and hold times are not infinitesimal, and that our clock timing is critical. For example, if the input of a flip-flop goes HIGH just before the clock signal arrives, the output will go HIGH. Similarly, if the input of a flip-flop goes HIGH just after the clock signal arrives, the output will go LOW. But, if the input goes HIGH at just the right time, the output of the flip-flop may hang while determining which way to go. This results in what is called a metastable state, or a narrow "runt" pulse at the output of our flip-flop. This "runt" pulse may cause our device to transition into an unwanted state and crash the system. Because of the intermittence and narrow pulse widths of these metastable states they are often difficult to catch, but crucial to the debug of digital systems.

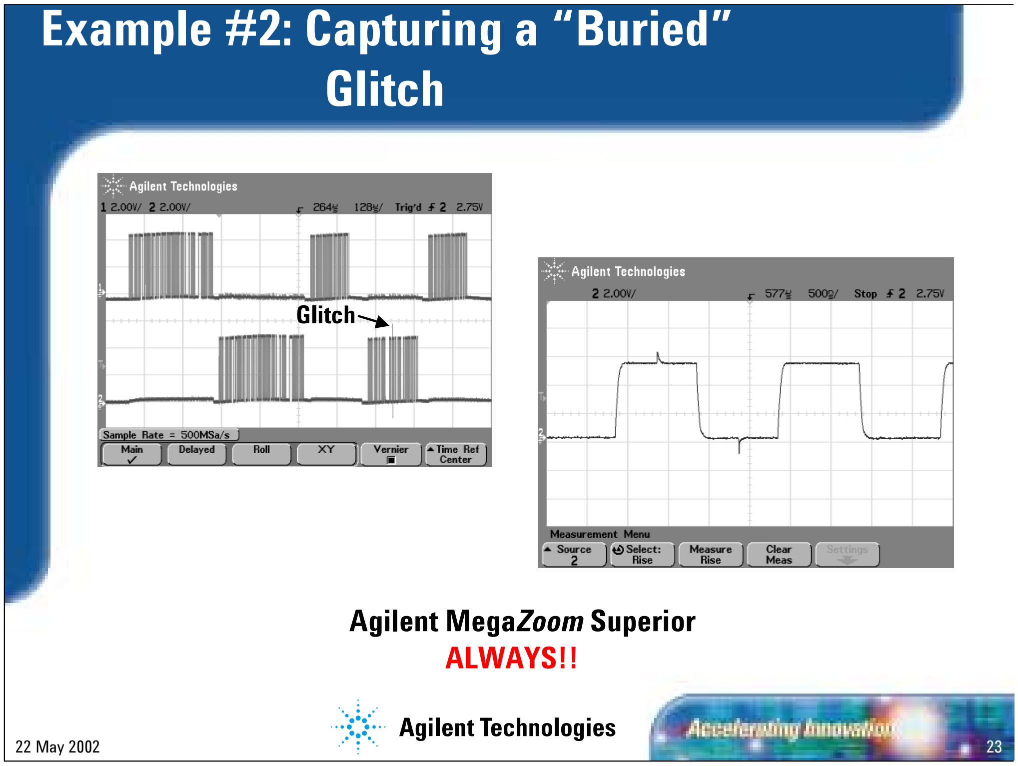
Another troublesome debug challenge is the elusive glitch. A glitch is any narrow pulse caused by an unforeseen event on a digital (or analog) line. Glitches may be a product of nearby EMI coupling, failing component connections, or reflections from a mismatched termination. Capturing these glitches is important, and at slower sweep speeds we need to employ a technology called "peak detect" to find these glitches in our system.



Example #1: Capturing an Infrequent Metastable State

A metastable state can occur if the setup & hold time of a latch/gate/memory device is violated, but is borderline. In this case, the output may attempt to switch to a different state, but then change its' mind. If you were attempting to capture an event such as an infrequent metastable state, you would probably set up the scope's timebase on a relatively fast setting. In this case, the scopes with the FastAcq mode of operation would improve the probability that the metastable state occurs during the acquisition time. But if the metastable state is very narrow (1ns), and very non-repeatable, then the limited sample rate of 1.25GSa/s may be insufficient to capture the state with sufficient resolution. The Mega*Zoom* scopes may have less probability of capturing it during an acquisition cycle, but would be able to digitize it with full sample rate resolution if it did occur during the acquisition cycle.

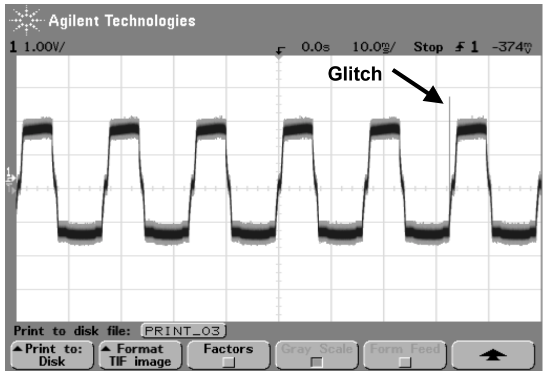
Another issue to consider is the signal's trigger rate. Even though the scope may be setup on a fast timebase range, the actual repetitive rate and trigger rate of the signal may be very slow. For instance, if the average switching rate of the output of the gate is just 5000 times per second, and you've setup the scope to trigger on a transition of the output, then the maximum acquisition rate would be limited to the trigger/switching rate of the signal under test. In this case, the dead-time of both types of scopes would be exactly the same. If the dead-time is determined by the trigger rate, then the Mega*Zoom* scopes would always have a higher probability of capturing the metastable state. Even though a scope with the FastAcq mode may be capable of capturing hundreds of thousands of waveforms per second on the faster timebase settings, this assumes that the trigger rate is at least that fast.



Example #2: Capturing a "Buried" Glitch

If you are looking for anomalies buried within a long serial data stream, you would probably setup your scope's timebase on a long sweep setting to capture an entire signal transmission, such as a packet or multiple packets of data. In this case, the Mega*Zoom* scopes from Agilent would always have a higher probability of capturing infrequent events buried in the packets of data as shown in this illustration. At these slower timebase settings (5µs/div and slower), the dead-time in both the Mega*Zoom* and FastAcq mode scopes is primarily determined by the timebase setting and trigger rate. However, the actual digitizing rate of the Mega*Zoom* scopes would always be higher than the scopes with the FastAcq mode because they do not limit their memory depth and sample rate.

Example #3: Capturing a VERY Infrequent & Random Glitch



Agilent Mega*Zoom* with Peak Detect never misses!

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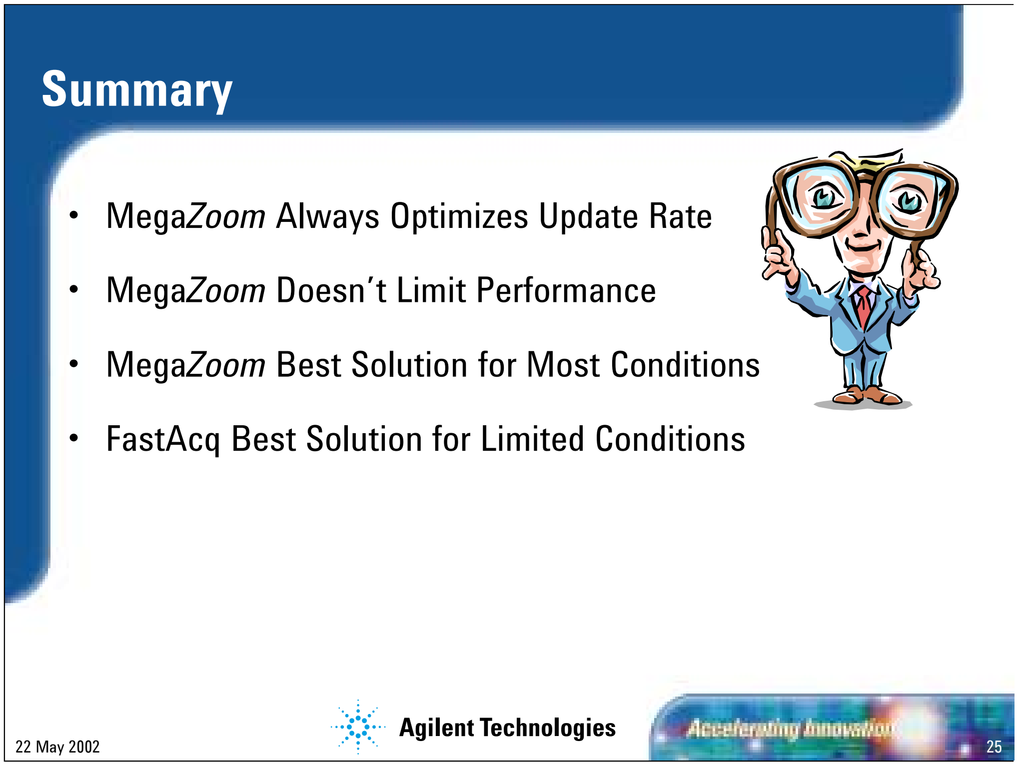
Example #3: Capturing a VERY Infrequent Glitch

Many times, glitches are non-repetitive and difficult to capture, especially when they are many orders of magnitude narrower than the fundamental signal. In fact, when looking at signals with very long repetitive rates, you might set your scope at a slower time per division setting that allow you to see many cycles of your waveform. We saw earlier that even the deepest memory scopes will sacrifice sample rate to capture longer time records of data. Such is the case here, where we are capturing 100ms of data with a 4MPt memory record. Our sample rate has been reduced to 40MSa/s, which equates to a sampling resolution of 25ns per point. If the glitch that is causing your design problems is less than 25ns per point, your scope can only capture one point on the glitch and may not capture the glitch at all. Capturing infrequent and random glitches at time per division settings greater than 1ms requires a hardware peak-detect capability to identify maximum and minimum points coming into the acquisition system. Without peak-detect, the acquisition system would simply ignore these points and continue to capture every Nth point at the current sample rate. Agilent Mega*Zoom* Oscilloscopes are equipped with peak-detect hardware that allows you to see infrequent and random glitches when using your scope at slower timebase ranges.

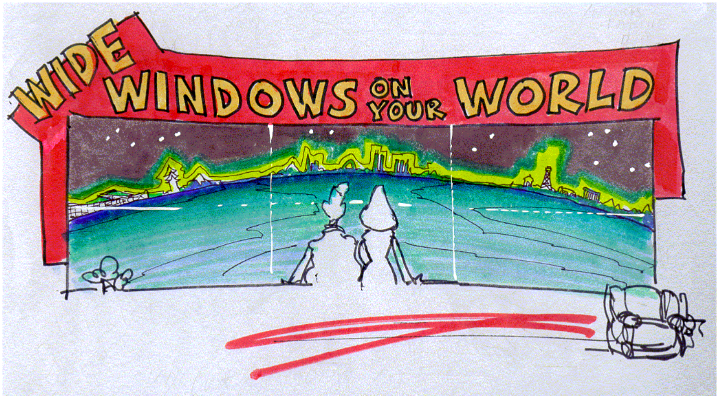


Summary

Agilent oscilloscopes with Mega*Zoom* deep memory technology provide fast updates without sacrificing digitizing performance. This not only enhances usability of the scope, but also improves probability of capturing infrequent/random events. Mega*Zoom* is NOT a special mode of operation. It is always on and is the best solution for capturing random/infrequent events under most conditions.

Scopes with the FastAcq mode of operation may be able to improve the probability of capturing infrequent/random events under special conditions. First of all, you would have to know that you needed to use this special mode of operation. Secondly, probability of improving capture of these types of events only applies when the scope is setup on a limited set of timebase ranges. And lastly, you must realize that digitizing performance and scope functionality is degraded when operating in this mode. If you wanted to zoom-in on a glitch after capturing it with FastAcq, you could not do so. You would have to switch back to a normal acquisition mode, in which case the scope's update rate could be reduced to as slow as one acquisition every eight seconds. If the event is very infrequent and random, you may never be able to recapture the event in the normal acquisition mode in order to zoom-in on it.

Thank you for Attending Today's Seminar on Deep Memory Applications



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