Evaluating Oscilloscopes for Best Signal Visibility

Application Note 1604

How to Increase Your Odds of Finding Infrequent Glitches

Agilent Technologies

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Introduction

Mixed signal oscilloscopes (MSOs) have become the tool-of-choice for many of today's designers of embedded devices. Agilent Technologies (formerly Hewlett-Packard) introduced the first MSO in 1996 and has recently introduced its third-generation MSO. All major scope vendors now offer mixed signal oscilloscopes in their portfolios. MSOs add sixteen or more logic analyzer acquisition channels — along with serial bus triggering and protocol decoding — to basic scope functionality, making it possible for R&D engineers and technicians to debug their mixed-signal designs faster. MSOs bridge the gap between conventional digital storage oscilloscopes (DSOs) and today's more complex logic analyzers and serial bus protocol analyzers. What tradeoffs do MSOs have relative to traditional DSOs? What are the differences between the vendors' MSOs?

All the major oscilloscope vendors today claim their MSOs perform just as well as DSOs of similar bandwidth. But this is not true. Although basic acquisition performance, such as bandwidth and sample rate, may not be degraded in today's MSOs relative to their DSO counterparts, there is one very important performance characteristic that is compromised in all vendor's MSOs — except Agilent's. And that is waveform and serial bus decode update rates.

There are three reasons why fast update rates are important for both MSOs and DSOs. First of all, if an oscilloscope updates waveforms very slowly, it can make using the oscilloscope very frustrating. If you rotate the timebase control, you expect the oscilloscope to respond immediately — not seconds later after the scope finishes processing data. Secondly, fast waveform update rates can improve oscilloscope display quality to show subtle waveform details such as noise and jitter with display intensity modulation. But most importantly, fast waveform update rates improve the scope's probability of capturing random and infrequent events that may be keeping you up late at night.

Agilent's InfiniiVision Series MSOs not only provide the fastest waveform update rates when you use just the scope channels (up to 100,000 waveforms per second when you use the default real-time sampling mode), but they also are the only MSOs in the industry that can maintain these fast update rates when you are using logic acquisition channels and/or serial bus decoding. Although other vendors may specify relatively fast banner waveform update rate specifications for their MSOs, when you use logic channels and/or serial bus decoding, these other scopes' update rates drop significantly.

This application note includes side-by-side measurement examples that compare the probabilities of capturing an anomalous event using various vendors' MSOs. But let's first review some of the factors that impact oscilloscope update rates, and then we will show you how to compute probabilities of capturing infrequent events.

Understanding oscilloscope dead time

When you debug new designs, waveform and decode update rates can be critical — especially when you are attempting to find and debug infrequent or intermittent problems. These are the toughest kinds of problems to solve. Faster waveform and decode update rates improve a scope’s probability of capturing elusive events. To understand why this is true, you must first understand what is known as oscilloscope “dead time.” All oscilloscopes have “dead time,” as shown in Figure 1. This is the time between oscilloscope acquisitions when a scope processes the previously acquired waveform to display on the scope’s display. During this processing or dead time, the scope is essentially “blind” to any signal activity that may be occurring within the mixed-signal design you are debugging.

Note the highlighted glitches shown in Figure 1 that occurred during the scope’s dead times. After two oscilloscope acquisition cycles, these glitches would not be shown on the scope’s display.

Don’t be confused about the difference between “real” and “effective” dead-time. Using an oscilloscope’s deep memory, scopes will often acquire more waveform data than is possible to show on the scope’s display, as defined by the timebase setting (sec/div). Although a scope may actually capture an anomaly, such as the second glitch shown here, if the glitch doesn’t occur within the scope’s display window, you would never know that it occurred when you are viewing repetitive acquisitions. For this reason, we consider off-screen acquisition time as a component of “effective” dead time. "

Determining an oscilloscope’s dead-time percentage is pretty simple once you know the instrument’s update rate. A scope’s dead-time percentage is based on the ratio of the scope’s acquisition cycle time minus the on-screen acquisition time, all divided by the scope’s acquisition cycle time. The scope’s acquisition cycle time is simply the inverse of the scope’s waveform update rate, which must be measured for the particular setup condition used. The following equation summarizes how to compute an oscilloscope’s dead-time percentage:

% DT = MSO’s dead-time percentage
= 100 x [(1/U) – W]/(1/U)
= 100 x (1 – UW)
where
U = MSO’s measured update rate
and
W = Display acquisition window = Timebase setting x 10

One ugly fact that most oscilloscope vendors won’t readily admit is that an oscilloscope’s dead-time is often orders-of-magnitude longer than its on-screen acquisition time — even in scopes that may specify remarkably fast update rates.

This means that capturing infrequent and elusive events on an oscilloscope is a gamble with odds or probabilities based on several different setup parameters. In fact, we can make a very close analogy between the probability of capturing random events on an oscilloscope to the probability of a specific side of a die landing up when rolling dice. Let’s first address die rolling probabilities and then see how this relates to oscilloscope capture probabilities.

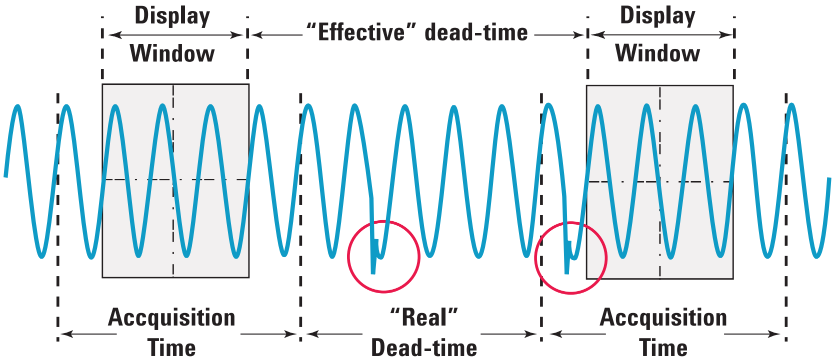


Figure 1. Oscilloscope dead-time versus display acquisition time.

Lessons in rolling a die

When you roll a single six-sided die one time, the probability of the die landing with a specific side up is one part in six. Pretty simple calculation! So what is the probability of obtaining a specific side up at least once if you roll the die two times? Intuitively, some might say two parts in six, or 33.3%, before completely thinking through this situation. But if this rationale were true, if you rolled the die 10 times you would have greater than a 100% probability of a specific side landing up at least once, which is not possible. The probability (P_N) in percent of a specific side of an “S” sided die landing up at least once after “N” rolls of the die is...

$$P_N = 100 \times (1 - [(S-1)/S]^N)$$

To understand this equation, it’s actually easier to think of computing the probability of *not* obtaining a specific side as opposed to computing the probability of obtaining a specific side. The probability of *not* obtaining a specific side after one roll of the die is based on the “**(S-1)/S**” factor. So for a 6-sided die this is 5/6. The more times the die is rolled (N), the odds of not obtaining a specific side at least once go down exponentially. This means that the odds of obtaining a specific side up at least once go up, but these odds will never reach or exceed 100% probability.

Figure 2. A multi-sided die with a “glitch” on just one side

For oscilloscope capture probabilities, “S” is the ratio of the average occurrence time of an anomalous event relative to the oscilloscope’s display window time. So for example, if a glitch occurs once every 10 ms (100 times per second) and you have the oscilloscope’s timebase set at 20 ns/div, then the on-screen acquisition time is 200 nanoseconds and S = 10 ms/200 ns, or 50,000.

In this example we effectively have a 50,000-sided die – as you might try to imagine by referring to the multi-sided die shown in Figure 2 – that has a waveform anomaly on just one side. The odds of capturing a glitch once after just one acquisition are just 1 part in 50,000, and the odds of *not* capturing the glitch are 49,999 parts in 50,000.

To improve the scope’s probability of capturing the infrequently occurring glitch during a fixed period of time requires that the scope try to acquire the signal multiple times – and as fast as possible. This is where the scope’s waveform update rate factors into the equation. “N,” which is now the number of oscilloscope acquisitions, is equal to the scope’s waveform update rate multiplied times a reasonable observation time. The observation time is the time that you might be willing to view a waveform on the scope’s display to determine if it is normal or not before moving your probe to another test point. So for an oscilloscope, the anomalous event capture probability equation reduces to...

$$P_t = 100 \times (1-[1-RW]^{(U \times t)})$$

where

P_t = Probability of capturing anomaly in “t” seconds
t = Observation time
U = Scope’s measured waveform update rate
R = Anomalous event occurrence rate
W = Display acquisition window = Timebase setting x 10

Mixed-signal measurement comparisons: Agilent InfiniiVision MSO7104A

Using the above probability equation we will make some measurement comparisons between MSOs of similar 1-GHz bandwidth performance from three different scope vendors. In addition to determining the probability of capturing an infrequent glitch, we also will determine each scope’s dead-time percentage for the measurement setup condition used.

Although there are many factors that determine a scope’s actual waveform update rate and dead time, we began our measurement comparison by initializing each MSO with a default setup configuration. At the timebase setting used for the measurement comparison (20 ns/div), the default configuration of each scope minimized acquisition memory while maximizing waveform update rate. Using the default real-time sampling mode, we probed two digital signals using two analog acquisition channels on each scope, while also probing five time-correlated digital signals using the MSOs' logic channels. No parametric measurements or waveform math functions were turned on. This step also helps to maximize update rates on most scopes.

The signal used as the trigger source (rising edge of the channel-1 input) included significant jitter on the falling edge along with an infrequent metastable state (glitch) coincident with the rising edge of the signal. We determined that the infrequent glitch occurred approximately 100 times per second on average. To determine the probability of capturing the glitch, we assumed that 5 seconds was a reasonable observation time for our calculations.

In Figure 3 you can see that Agilent’s MSO7104A reliably captured the random and infrequent metastable state (glitch) on channel 1 while also capturing several digital signals using the logic input channels of this MSO. With a measured waveform update rate of approximately 95,000 waveforms per second, the Agilent MSO easily showed this infrequent anomaly at the center-screen trigger point, along with jitter on the falling edge of the signal when viewing the waveforms for a 5-second observation time.

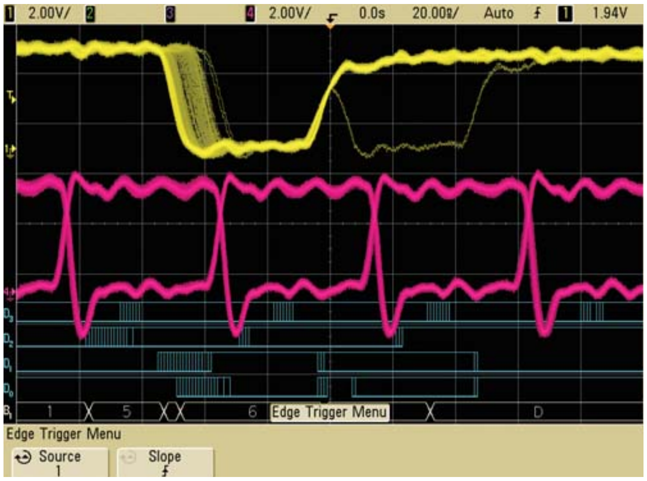


Figure 3. An Agilent MSO7104A quickly captures the infrequent metastable state on channel 1 while also using logic channels.

InfiniiVision scopes incorporate acquisition memory, waveform processing, and display memory in an advanced .13m ASIC. This patented 3rd generation technology, known as MegaZoom III, delivers up to 100,000 waveforms (acquisitions) per second with responsive deep memory always available.

Mixed-signal measurement comparisons: Tektronix MSO4104

With an acquisition display window of 200 ns (20 ns/div x 10 divisions), and an acquisition cycle time of 10.5 µs (1/95,000 waveforms/sec), dead-time percentage of this measurement was determined to be:

$$\% \text{ DT} = 100 \times (1 - (95{,}000/\text{s} \times 200 \text{ ns})) = 98.1\%$$

Even though the dead-time percentage of this MSO was approximately 98% with the timebase set at 20 ns/div – which intuitively may appear to be excessively long – the probability of capturing the glitch within 5 seconds was actually very high, as determined in the following probability calculation:

$$P_{(5s)} = 100 \times (1 - (1 - (100/\text{s} \times 200 \text{ ns}))^{(95{,}000/\text{s} \times 5\text{s})}) = 99.9925\%$$

Note that actual waveform update rates must be measured for each setup condition of each scope because waveform update rates vary greatly depending upon several different setup parameters. Don’t simply rely on each vendor’s banner waveform update rate specification. In Appendix A of this paper we have provided a table of update rates using several different setup conditions for comparison.

Using Tektronix’ MSO4104A mixed signal oscilloscope, the measurement results were significantly different, as shown in Figure 4. When logic channels of this MSO were turned on, the maximum waveform update rate dropped to just 125 waveforms per second. We failed to observe the metastable state on channel-1 after five seconds of observation time. Although 125 waveforms per second will produce a very responsive display that appears to be updated fast, statistically speaking this update rate is much too slow to reliably capture infrequent anomalies such as this metastable state that occurred just 100 times per second on average. This is because the scope’s dead-time at 125 waveforms per second when set up at 20 ns/div was extremely long.

$$\% \text{ DT} = 100 \times (1 - (125/\text{s} \times 200 \text{ ns})) = 99.998\%$$

Figure 4. The Tek MSO4104A fails to capture the infrequent metastable state after 5 seconds of observation time.

Mixed-signal measurement comparisons: LeCroy WaveRunner 104Xi with MSO 500

The reason we failed to see the infrequent metastable state after five seconds of observation time using the Tektronix MSO was because the probability of capturing the glitch was extremely low due to the long dead-time. If you suspect that your signals may have a problem, and if you are willing wait long enough, this scope will eventually capture the metastable state. Below is the probability calculation of capturing the glitch after a 5 second observation time using the Tek MSO.

$$P_{(5s)} = 100 \times (1 - (1 - (100/s \times 200\ \text{ns}))^{(125/s \times 5s)}) = 1.24\%$$

Figure 5 shows the same measurement using LeCroy's WaveRunner 104Xi with the external MS-500 MSO option. Even with minimum memory selected, this MSO's update rate was just 27 waveforms per second, and again, we failed to see the infrequent glitch and jitter on the channel-1 signal. At this slow update rate, the scope's display appeared to be less responsive than the previously tested MSOs, and dead-time increased significantly. The dead-time percentage for this scope using this measurement and setup condition was determined to be:

$$\%\ DT = 100 \times (1 - (27/s \times 200\ \text{ns})) = 99.9995\%$$

The probability of capturing the infrequent metastable state was extremely low using this vendor's MSO, as determined by the following equation:

$$P_{(5s)} = 100 \times (1 - (1 - (100/s \times 200\ \text{ns}))^{(27/s \times 5s)}) = 0.27\%$$

C1 DC1M 2.00 V/div 3.060 V ofst
C2 DC1M 2.00 V/div -1.940 V ofst
Digital1 2.00 GS/s 400 S
Digital2 2.00 GS/s 400 S
Timebase 0.0 ns 20.0 ns/div 1.00 kS 5.0 GS/s
Trigger C1 DC Normal 2.72 V Edge Positive
10/19/2007 4:18:58 PM

Figure 5. The LeCroy WaveRunner 104Xi – MS500 fails to capture the infrequent metastable state after 5 seconds of observation time.

Mixed-signal measurement probability comparisons

Table 1 below summarizes dead-time percentage and glitch capture probability of each MSO tested using four different timebase settings. In all cases, two analog channels plus five logic channels were turned on and memory depth was either automatically or manually optimized such that each scope sampled at its maximum specified rate to provide 1 GHz real-time bandwidth with the minimum amount of acquisition memory to support that sample rate. A glitch occurrence rate of 100 glitches/sec with an observation time of 5 seconds was used for these measurements and theoretical calculations.

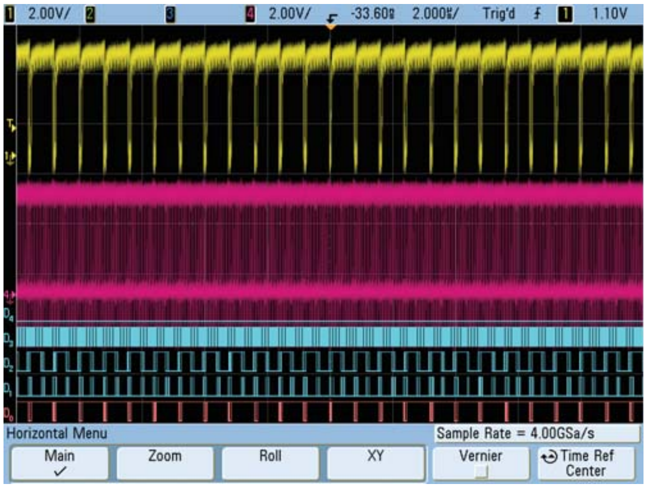
Table 1. MSO dead-time and glitch capture probability using analog and digital channels

	Agilent MSO7104A			Tek MSO4104A			LeCroy WR104Xi-MS500		
Timebase	Update rate	Dead time	Glitch capture probability	Update rate	Dead time	Glitch capture probability	Update rate	Dead time	Glitch capture probability
2 ns/div	74,000	99.85%	52.29%	130	99.999%	0.13%	27	99.999%	0.03%
20 ns/div	95,000	98.1%	99.993%	125	99.998%	1.24%	27	99.999%	0.27%
200 ns/div	63,000	87.4%	99.999..%	125	99.978%	11.75%	27	99.995%	2.66%
2 µs/div	8,000	84.0%	99.999..%	125	99.780%	71.39%	17	99.966%	15.65%

Viewing infrequent events with slow timebases

Slower update rates on slower timebase ranges is primary driven by longer display acquisition time.

The probability of capturing a waveform anomaly also improves on slower timebase ranges. This is primarily because the dead-time percentage is decreasing as you slow down the timebase setting. But don't be fooled into thinking that you are better off using slower timebase ranges to capture narrow glitches. Although the scope definitely has a better chance of capturing the narrow anomaly, assuming that the scope still samples at a sufficiently fast rate, you may not be able to visually spot the narrow anomaly on these slower timebase ranges. Figure 6 shows an example of capturing the same metastable state shown previously, but now with the scope's timebase set at 2 µs/div. The scope easily captures the 15-ns-wide glitch, but we can't see it at this timebase setting.



Sample Rate = 4.00GSa/s

Figure 6. Although scaling the timebase to a slower range improves the probability that the MSO can capture the glitch, we are unable to visually "spot" the glitch on-the-fly while repetitively acquiring waveforms.

Serial bus measurement comparisons: Agilent InfiniiVision MSO7104A

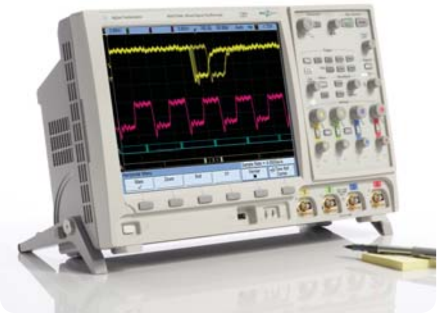
Most of today’s embedded designs include serial bus communication such I^{2}C, SPI, RS-232, CAN, and LIN. Oscilloscope users have traditionally performed visual bit-counting techniques to decode these serial buses to verify proper bus communications. But this technique of manually counting bits is tedious and prone to errors. Many of today’s DSOs and MSOs provide optional built-in serial bus triggering and protocol decoding that significantly improves a designer’s productivity.

However, when searching for infrequent serial bus errors, such as error frames and/or parity errors, most scopes with serial bus decoding capabilities employ software decoding techniques that further slow down oscilloscope update rates. Agilent’s InfiniiVision DSOs and MSOs are the only scopes that utilize hardware-based serial bus decoding. With hardware-based decoding, update rates can be maintained at the scope’s maximum rate — without tradeoffs.

Figure 7 shows an example of debugging a CAN serial bus with Agilent’s MSO7104A. With the scope’s main timebase set at 1 ms/div, Agilent’s MegaZoom III technology automatically increases and optimizes its acquisition memory depth in order to also maximize its sample rate. In this measurement example, the scope was set up to trigger on data frame 07F$_{\text{HEX}}$. With an error frame rate of approximately 2%, we quickly see a red error frame message flashing on-screen when the scope randomly captures the error frame — without actually triggering on an error frame condition. The probability of capturing the error frames in this example is 99.77%. Also note that the MSO7104A provides a real-time totalizer that counts all error frames received with zero dead time. Even if oscilloscope acquisitions have been stopped, the totalize counter continues to counts error frames along with the occurrence rate.

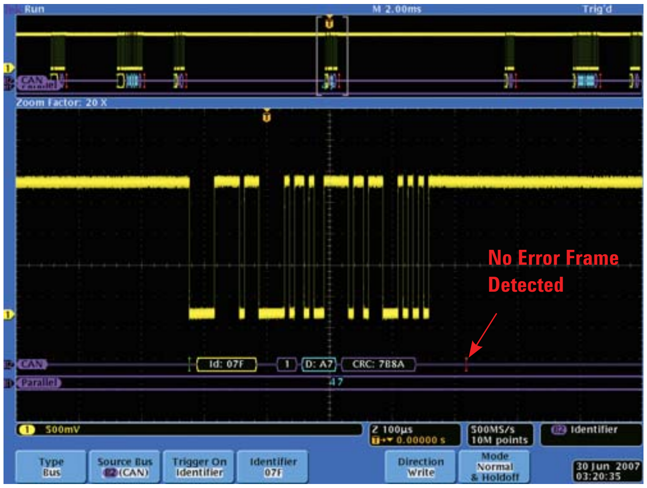
```
FRAMES: 0000106064   OVLD: 000000000(0.0%)   ERR: 000001989(1.9%)   UTIL: 23.6%
```

Figure 7. Agilent’s MSO7104A reliably captures and decodes CAN error frames using hardware-based decoding.



Serial bus measurement comparisons: Tektronix MSO4104

Figure 8 shows the same measurement using Tektronix' MSO4104A. In order to maximize the scope's sample rate, 10 M points of acquisition memory was manually selected. Again, the MSO was set up to trigger on data frame 07F$_{HEX}$. But since this scope utilizes post-processed software-based decoding, the waveform and decode update rates were extremely low at just one protocol decode every 5 seconds. The probability of capturing an error frame with a 2% occurrence rate after 5 seconds of observation time was just 2%.



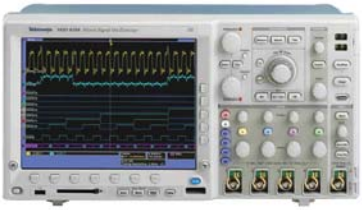


Figure 8. Tek's MSO4104A fails to capture and decode CAN error frames with a software-based decoding update rate of just one 1 decode every 5 seconds.

Summary

If finding and debugging random and infrequent problems are important to you, then waveform and decode update rates are an important consideration in choosing the oscilloscope for your measurements.

Update rates directly determine an oscilloscope's probability of capturing and displaying random circuit problems.

DSOs with fast update rates are more responsive, show more subtle signal detail, and find infrequent events better than scopes with slower update rates.

With the addition of logic timing channels and serial bus decoding, MSOs should enhance your ability to quickly debug embedded designs. But if waveform and decode update rates are degraded when using the additional MSO functionality, the probability of capturing infrequent signal problems will also be degraded.

Agilent's third-generation InfiniiVision oscilloscopes provide the highest waveform and serial decode update rates. InfiniiVision MSOs do not compromise update rate when you use logic channels and serial bus decoding capabilities. Agilent's InfiniiVision DSOs and MSOs achieve fast, uncompromised update rates through a higher level of hardware integration that minimizes oscilloscope dead time.

Appendix A

Waveform and decode update rate comparisons

As we mentioned earlier, there are many factors that can affect a mixed signal oscilloscope's waveform and serial bus decode update rate. Oscilloscope vendors will typically highlight just the scope's "banner" or best-case waveform update rate, which is typically obtained under a very limited set of setup conditions.

A scope's timebase setting is usually the primary setup condition that affects update rates. This is because the timebase setting determines the acquisition display window of time. As you adjust the scope's timebase to longer time-per-division settings, the scope will digitize longer waveforms. For instance, at 2 ms/div the scope's on-screen acquisition time is 20 milliseconds. If a scope had zero dead time, which is theoretically impossible, the absolute best-case waveform update rate would be 50 waveforms per second (1/20 ms).

If it is important for you to know what your scope's waveform and decode update rates are, then it must be measured under the various setup conditions that you anticipate using. Don't simply rely on the scope vendor's banner update rate claim.

Measuring a scope's update rate is not that difficult. Most scopes provide a trigger output signal – typically used to synchronize other instruments to the scope's triggering. You can measure a scope's update rate by measuring the average frequency of this output trigger signal using an external counter. But remember that the potential trigger rate of the signal used as a trigger source for the scope must exceed the scope's anticipated update rate. Otherwise the scope's update rate will be limited by the slower trigger rate.

Table 2 below shows measured update rates for three mixed signal oscilloscopes based on the following four setup variables:

1. Timebase setting
2. Analog channels only
3. Analog + logic channels
4. Analog + logic channels + serial bus decoding

In all cases, the MSO's default real-time sampling mode was used and memory was either manually or automatically optimized such that each scope sampled at its maximum rate for each timebase setting tested, while also minimizing memory depth. Standard edge triggering was used with the input trigger source frequency set to provide approximately five potential trigger events for each acquisition cycle based on the timebase setting. Not only does this insure that the trigger rate exceeded the potential waveform update rate of each MSO, but it also provided an input signal frequency that was reasonable for each timebase setting tested. In order to enhance each scope's update rate, parametric measurements and waveform math functions were not selected for this update rate comparison.

Appendix A (continued)

Waveform and decode update rate comparisons

Table 2. Waveform and serial decode update rate comparisons

	Agilent MSO7104A			Tek MSO4104A			LeCroy WR104Xi-MS500		
Timebase	2 analog	+ Logic channels	+ Serial decode[1]	2 analog	+ Logic channels	+ Serial decode[1]	2 analog	+ Logic channels	+ Serial decode[1]
500 ps/div	94,000	94,000	94,000/60	1900	130	30/5			
1 ns/div	74,000	74,000	74,000/60	2100	130	30/5			
2 ns/div	74,000	74,000	74,000/60	2200	130	30/5	30	27	26
5 ns/div	60,000	60,000	60,000/60	2200	130	30/5			
10 ns/div	60,000	60,000	60,000/60	2200	125	30/5			
20 ns/div	95,000	95,000	95,000/60	45,000	125	30/5	30	27	25
50 ns/div	74,000	74,000	74,000/60	43,000	125	30/5			
100 ns/div	63,000	63,000	63,000/60	43,000	125	30/5			
200 ns/div	63,000	63,000	63,000/60	41,000	125	35/4	27	27	17
500 ns/div	30,000	30,000	30,000/60	9,000	125	45/3.5			
1 µs/div	30,000	30,000	30,000/60	4,400	125	45/3.5			
2 µs/div	8,000	8,000	8,000/60	2,300	125	45/3.5	20	17	8
5 µs/div	7,600	7,600	7,600/60	360	120	90/1.3			
10 µs/div	4,000	4,000	4,000/60	270	115	90/1.3			
20 µs/div	2,000	2,000	2,000/60	140	115	90/1.3	5	4	1
50 µs/div	800	800	800/60	25	24	24/0.2			
100 µs/div	800	800	800/60	17	17	17/0.2			
200 µs/div	450	450	450/60	11	11	11/0.2	5	2.4	1
500 µs/div	160	160	160/60	11	11	11/0.2			
1 ms/div	60	60	60	10	10	10/0.2			
2 ms/div	40	40	40	9	9	9/0.2	5	2	1
5 ms/div	18	18	18	7.6	6.3	6.3/0.2			
10 ms/div	9	9	9	5.2	4.5	4.5/0.2			
20 ms/div	4.5	4.5	4.5	3.3	3.1	3.1/0.2	1.8	1.6	0.6
50 ms/div	1.9	1.9	1.9	1.8	1.8	1.8/0.2			
100 ms/div	0.92	0.92	0.92	0.9	0.9	0.9/0.2			

1. In this column, the first number represents the waveform update rate while the second number represents the serial decode update rate. Waveform and decode update rates are often different. Since oscilloscope displays are typically refreshed at a 60-Hz rate for serial decode, it is impossible to obtain higher than 60 decodes per second without overwriting characters, which would then make it impossible to read the decoded string. However, waveform update rates can exceed the display's refresh rate by mapping multiple acquisitions to the scope's display for each refresh.

Glossary

Dead time the time an oscilloscope uses to process digitized waveforms for display; during dead time, the scope is essentially "blind" to any signal activity

MegaZoom III technology an Agilent-proprietary acquisition and display technology that provides extremely fast waveform and serial bus decode update rates (> 100,000 real-time waveforms per second), while automatically optimizing memory depth and sample rate

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 of the inputs

Mixed signal oscilloscope (MSO) an oscilloscope with additional channels of logic timing analysis with direct time correlation and combinational logic/pattern triggering across both analog and digital inputs

Real-time sampling digitizing an input signal from a single-shot acquisition using a high rate of sampling

Serial decode update rate the number of serial protocol decoded strings an oscilloscope can capture and display in one second

Waveform update rate the number of waveforms an oscilloscope can capture and display in one second

Related literature

Publication title	Publication type	Publication number
Agilent 7000 Series InfiniiVision Oscilloscopes	Data Sheet	5989-7736EN
Agilent 6000 Series InfiniiVision Oscilloscopes	Data Sheet	5989-2000EN
Agilent 5000 Series InfiniiVision Oscilloscopes	Data Sheet	5989-6110EN
Agilent InfiniiVision Series Oscilloscope Probes and Accessories	Data Sheet	5968-8153EN
Using an Agilent InfiniiVision MSO to Debug an Automotive CAN Bus	Application Note	5989-5049EN
Debugging Embedded Mixed-Signal Designs Using Mixed Signal Oscilloscopes	Application Note	5989-3702EN
Choosing and Oscilloscope with the Right Bandwidth for your Applications	Application Note	5989-5733EN
Evaluating Oscilloscope Sample Rates vs. Sampling Fidelity	Application Note	5989-5732EN
Evaluating Oscilloscope Vertical Noise Characteristics	Application Note	5989-3020EN

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