Improve Your Ability to Capture Elusive Events: Why Oscilloscope Waveform Update Rates are Important

Application Note 1551

Introduction

Bandwidth, sample rate, and memory depth are the most common specifications engineers evaluate when they select a digitizing oscilloscope. However, waveform update rate is another important factor to consider. The rate at which an oscilloscope acquires waveforms and updates the display determines the probability of capturing random and infrequent events such as glitches. This application note uses a debugging application – an attempt to capture a random and infrequently occurring metastable state – to illustrate the importance of waveform update rates. Using various acquisition modes, we also compare the waveform update rates of four competitively priced portable oscilloscopes with bandwidth up to 500 MHz from three different vendors. In addition, waveform update rates of higher bandwidth oscilloscopes are included in the appendix section of this document.

When you evaluate an oscilloscope, its responsiveness can influence your decision. To get a good feel for whether a scope is responsive, simply probe a relatively fast repetitive signal and view the response. If the scope's display updates too slowly, the sluggishness can make using the scope a frustrating experience. This is especially true with some of today's deeper-memory oscilloscopes, as processing deep-memory records can slow the update rate. In general, if a scope's display is updated at least twenty times per second, the displayed waveform will appear "live" and the scope will feel responsive. But the importance of waveform update rates extends far beyond responsiveness issues. A "live" feel gives no indication of a scope's probability of capturing infrequent and random events.

Some of today's scope vendors advertise update rates in the hundreds-of-thousands of waveforms-per-second range, but the human eye cannot discern differences in performance at this level. However, when you are debugging high-speed digital circuitry, scope update rates in these ranges are critical because they increase the probability of capturing infrequent events. If the signals you need to observe on a scope's display were always exactly repetitive (no anomalies), extremely fast update rates would not be very important. But when the signals are not exactly repetitive – when anomalies do occur – the random and infrequently occurring events are likely to cause you the most headaches. Faster update rates enhance the probability of capturing elusive events and thereby alleviate debugging headaches.

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Capturing a metastable state using real-time sampling

Figure 1 shows a random metastable state (glitch) that occurs on average just one time every 50,000 cycles of the data signal. If you knew in advance that this event occurs randomly, you could set up most scopes to trigger on the glitch condition – based on a minimum pulse width setting – to reliably capture the glitch on each acquisition of the scope. But if you were unaware of the glitch's existence, you might simply probe various signals in your design to verify proper signal fidelity with the scope set up to trigger on standard rising or falling edge conditions.

Because of their relatively slow update rates, most scopes need to acquire data for more than just a few seconds in order to capture infrequent events. If you plan to use the typical debugging model where you probe each test point for just a few seconds and you want to capture the infrequently occurring events that may occur at each node, you need a scope with an extremely fast update rate.

The glitch shown in Figure 1 was captured using Agilent's 6000 Series oscilloscope, which can update waveforms as fast as 100,000 times per second using real-time sampling, even with sin(x)/x reconstruction. At this update rate, the scope has a statistical probability of capturing this particular errant signal approximately two times per second. Uncompromised industry-leading update rates are achieved in Agilent oscilloscopes through the use of Agilent's proprietary MegaZoom III technology.

Once we discover that our circuitry exhibits unexpected behavior, we can begin to further debug our system. Using the logic channels of our mixed signal oscilloscope (MSO), we are able set up a combinational logic pattern trigger condition across multiple analog and digital channels. This process reveals that our system occasionally violates a critical setup-and-hold-time specification due to clock jitter, as shown in Figure 2.

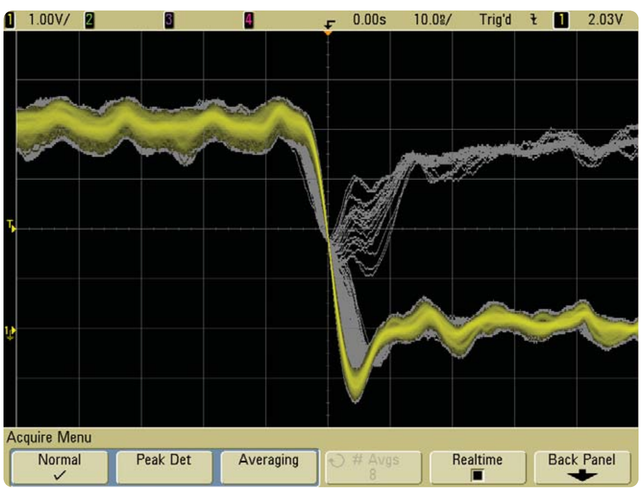

Figure 1. Infrequent metastable state captured on Agilent's MSO6000 Series oscilloscope using real-time sampling.

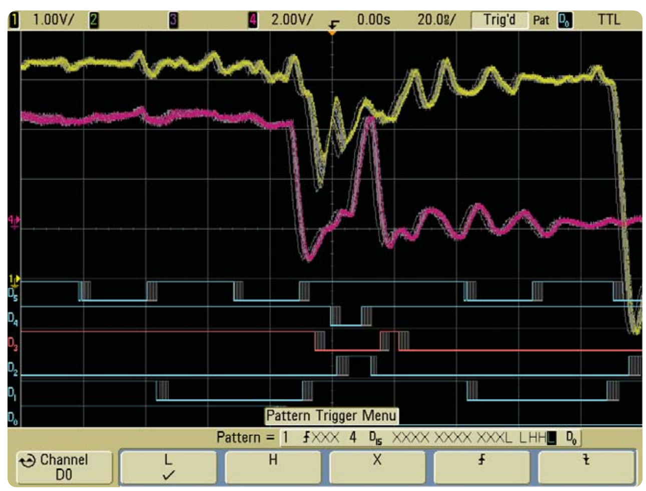

Figure 2. Pattern triggering reveals a setup-and-hold-time violation.

Figure 3 shows an attempt to capture the same anomaly using a Tektronix TDS3000B Series oscilloscope in its default real-time acquisition mode using 10 k points of maximum memory. But since this scope updates at less than 800 times per second in this particular setup condition, after holding the probe onto the test point for 10 seconds, we don't capture any anomalies. With this update rate, it will require holding the probe onto the test point for an average of 1 minute to capture one infrequent glitch that occurs just one time in every 50,000 cycles.

If you initially suspected that there might be an infrequent glitch, you might engage this scope's Fast Trigger mode, which limits the scope's memory depth to 500 points in order to enhance its update rate. So you must decide which is more important to debug your digital system: sample rate and memory depth, or update rate. But even with this special Fast Trigger mode of acquisition, which improves the update rate to nearly 3,000 waveforms per second at this setting (10 ns/div), you would need to maintain probe contact with the test point for nearly 20 seconds, on average, to capture the glitch. If you were using the typical debugging method of quickly moving your probe from test point to test point every few seconds, you would probably miss this event using either acquisition mode.

Figure 4 shows a similar example using Tektronix' higher-performance TDS5000B Series scope, which has a waveform update rate banner specification of 100,000 waveforms per second. But this scope has an even lower probability of capturing the anomaly since its default real-time acquisition update rate is limited to just 180 waveforms per second. Although 180 waveforms per second is more than fast enough to give the scope a "live" feel, using this default mode of acquisition will require holding the probe onto the test point for an average of nearly 5 minutes to capture just one glitch.

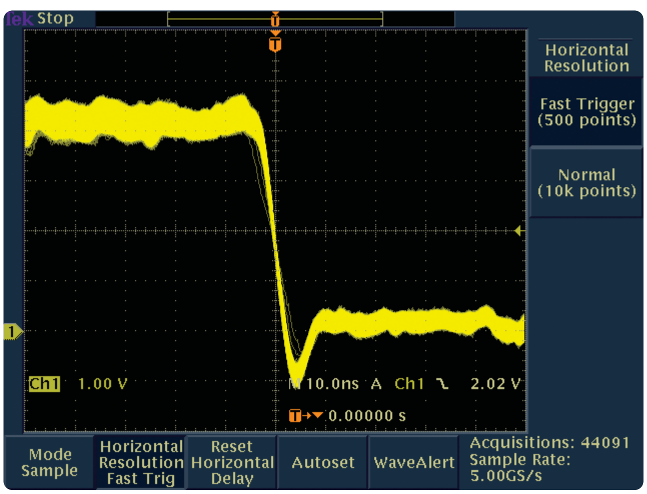

Figure 3. The Tektronix TDS3000B Series scope fails to capture the metastable state after 10 seconds of acquisition time.

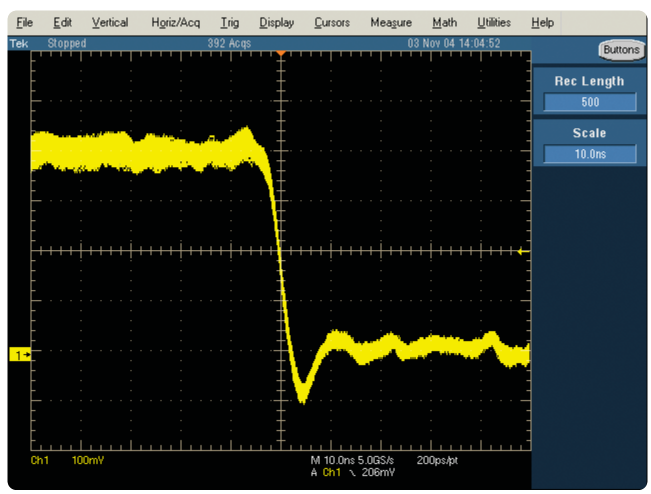

Figure 4. The Tektronix TDS5000B Series scope fails to capture the metastable state after 10 seconds using real-time sampling.

Capturing a metastable state using real-time sampling (continued)

Figure 5 shows an attempt to capture the infrequent metastable state using a LeCroy WaveSurfer 400 Series scope in its default real-time acquisition mode. But since this scope's real-time update rate measures just 165 waveforms per second at this time base setting, again, we are unable to capture the anomaly after holding the probe on the test point for more than 10 seconds. To capture this glitch using the LeCroy WaveSurfer oscilloscope requires approximately 5 minutes of probing on the same test point.

Using special acquisition modes
In the previous examples using real-time acquisition modes on four different scopes, only the Agilent MSO6000 Series oscilloscope with MegaZoom technology was able to reliably capture the infrequent metastable state (Figure 1). But what about using other "special" acquisition modes? As we mentioned above, the Tektronix TDS5000B Series scopes claim a banner waveform update rate specification of more than 100,000 waveforms per second. This update rate should be sufficient to capture the infrequent event (1 in 50,000 cycles). Using Tektronix's FastAcq acquisition mode, the TDS5000B Series scopes can indeed capture waveforms with update rates exceeding 100,000 acquisitions per second, as shown in Figure 6. But to use this mode, you must make a number of tradeoffs. The FastAcq mode:

- limits the scope's maximum sample rate to 1.25 GSa/s
- limits memory depth
- disables the use of waveform math
- disables the use of sin(x)/x reconstruction
- disables connect-the-dots
- disables the ability to pan and zoom on a captured waveform

FastAcq is basically a special equivalent-time/repetitive sampling mode with lots of tradeoffs in functionality and performance. But if you know when to use it, it works. Using this special mode of acquisition, we were able to reliability capture the infrequently occurring metastable state resulting in a display showing a scattering of dots – not complete waveforms.

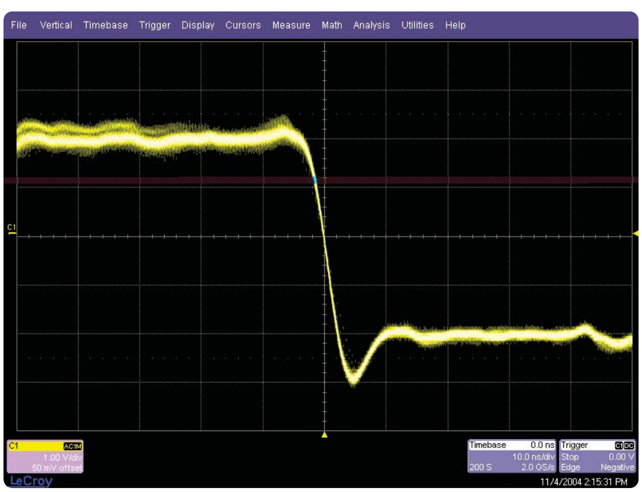

Figure 5. The LeCroy 400 Series scope fails to capture the metastable sate after 10 seconds using real-time sampling.

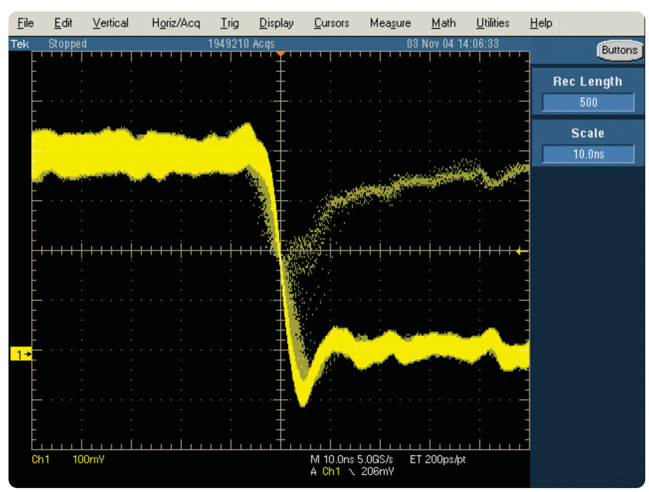

Figure 6. The Tektronix TDS5000B Series scope using FastAcq acquisition is able to capture the infrequent metastable using equivalent-time sampling.

Defining complete waveforms

Not all waveforms are created equal. How do you define a complete waveform? By definition, when you use real-time sampling with sin(x)/x reconstruction, each acquisition will produce a complete waveform consisting of a minimum of 500 to 1000 points. But when you use equivalent-time/repetitive sampling, including Tektronix's FastAcq mode on TDS5000B Series scopes, each repetitive acquisition cycle will produce incomplete waveforms with samples widely spaced on the faster time base ranges. For example, at 200 ps/div, Tektronix's FastAcq mode produces just 2.5 points (on average) during each acquisition cycle, since the scope limits the maximum sample rate to 1.25 GSa/s. This is an insufficient number of points to define a complete waveform. Even though this scope can attain an acquisition rate of more than 100,000 acquisitions per second at these faster time base ranges using FastAcq, it does not produce 100,000 complete waveforms per second at these settings. Therefore, to compare waveforms per second between the various competitive oscilloscopes using equivalent-time sampling techniques, we must normalize the acquisition rate on the faster time base ranges in order to compute "complete" waveforms-per-second update rates.

To provide a meaningful comparison in this application note, we have standardized on 500 points as the minimum for a complete waveform. At 10 ns/div (which was the time base setting used for the capture of our metastable state), Tektronix's FastAcq mode has a measured acquisition rate of 140,000 acquisitions per second. But each acquisition produces just 125 points because this mode of acquisition limits the scope's maximum sample rate to just 1.25 GSa/s. If we use the 500-point normalization factor, we see that the Tektronix scope produces approximately 35,000 complete or normalized waveforms per second (acquisition rate/[500 points/ acquired points per acquisition]), which is respectable, but it is approximately one third the waveform update rate of Agilent's MSO6000 Series scope at this setting – and with the Agilent scope, you don't need to select a special acquisition mode and the related tradeoffs.

Comparing waveforms per second

In addition to the selected acquisition mode, there are many other setup condition variables that affect a scope's update rate, including time base range, measurements, number of active channels, memory, complexity of displayed waveform, etc. Figure 7 shows a chart of waveforms per second as a function of time base setting for all four scopes, using each scope's fastest acquisition mode. Setup conditions for the data collected in this waveform update rate test were optimized for each scope to exhibit its best-case update rate performance. These setup conditions included single channel acquisitions, with the trigger reference point set at center-screen, and with measurements and waveform math turned off.

Obtaining the fastest update rate in the two Tektronix oscilloscopes required selecting the special Fast Trigger mode on the TDS3000B Series scope, and selecting the FastAcq mode on the TDS5000B Series scope. Equivalent-time sampling was used on the LeCroy WaveSurfer scope. However, achieving the fastest update rate with the Agilent 6000 Series scope did not require the selection of a special operating mode. The Agilent scope obtains its overall fastest update rates using the default real-time sampling mode with sin(x)/x and connect-the-dots (vectors) engaged. Although Tektronix's FastAcq mode approaches the performance of Agilent's 6000 Series scopes, and it is a good choice for capturing the infrequently occurring metastable state, you must know when to use this special mode of acquisition, and you must take the performance and functionality tradeoffs into consideration.

For comparison, Figure 8 shows a chart of waveforms-per-second update rates for all four scopes using each scope's default real-time acquisition mode. Please note that the vertical scale of these graphs is logarithmic. In most situations, Agilent's MSO6000 Series scope achieves update rates that are orders of magnitude faster than competitive oscilloscopes when using the default real-time sampling mode.

Measured and computed data used for the update rate charts shown in Figures 7 and 8 can be found in Appendices A and B of this document, including Agilent's equivalent-time mode, which is not shown in these graphs.

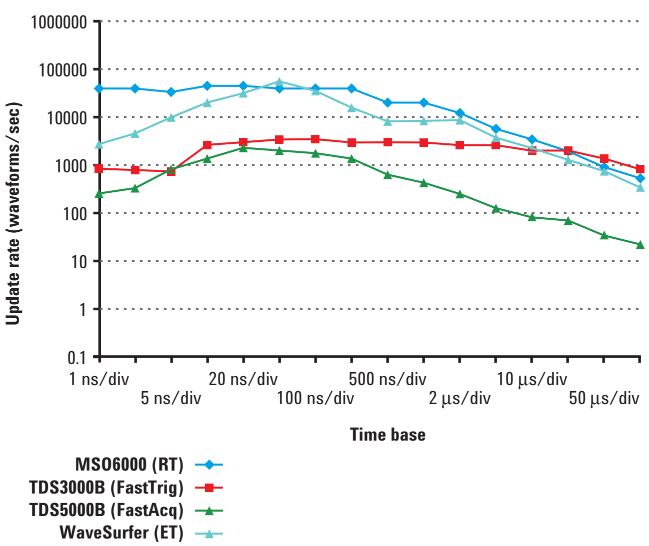

Figure 7. Each scope's fastest waveform update rate mode as a function of time base setting.

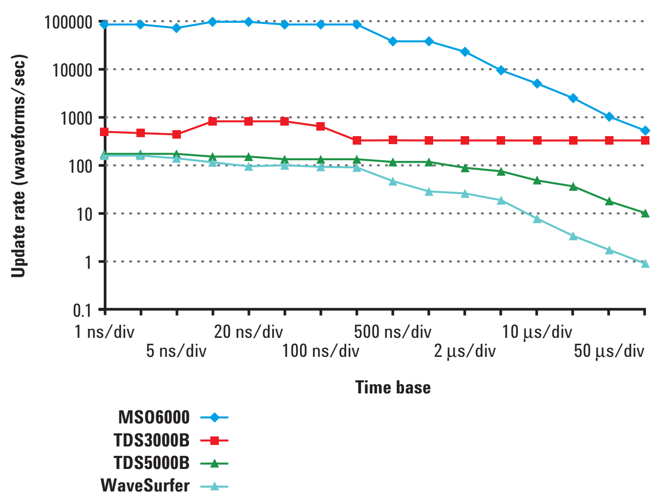

Figure 8. Waveform update rates using each scope's default real-time sampling mode.

Summary

Although engineers often overlook waveform update rate performance when they select a digitizing oscilloscope, waveform update rate can have a huge impact on your ability to find and fix intermittent circuit problems. Agilent's 6000 Series oscilloscopes with MegaZoom III technology provide the fastest waveform update rates in their class and do not require users to select special operating modes that may entail tradeoffs in performance and functionality. And with the 16 logic-timing channels available in the Agilent mixed signal oscilloscope, finding the root cause of intermittent failures becomes a much easier task.

To view an on-line video that demonstrates the importance of waveform update rates and display quality, go to **www.agilent.com/find/scope-demo**, and then click on the video titled, "Expanding Beyond Two Dimensions."

Glossary

Equivalent-time sampling Digitizing an input signal repetitively using multiple acquisition cycles

FastAcq A special equivalent-time sampling mode employed in some Tektronix oscilloscopes that improves update rates, but with tradeoffs in oscilloscope acquisition performance and functionality

MegaZoom III Agilent proprietary third-generation oscilloscope technology that provides fast update rates and high-resolution display quality 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 of the inputs

Mixed signal oscilloscope (MSO) An oscilloscope with additional channels of logic timing analysis with direct time-correlation and combinational 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

Sin(x)/x reconstruction Characteristics of DSP filtering that reconstructs a real-time sampled waveform to provide higher resolution that more accurately represents the actual signal when Nyquist rules are observed

Appendix A: Real-time update rate tables

Table 1: Agilent 6000 Series oscilloscope

Sec/div	Sample rate	Memory[1]	Waveforms/sec[2]	Points/sec[3]
1 ns/	4 GSa/s	40	74,000	3 M
2 ns/	4 GSa/s	80	74,000	6 M
5 ns/	4 GSa/s	200	60,000	12 M
10 ns/	4 GSa/s	400	95,000[4]	38 M
20 ns/	4 GSa/s	800	95,000[4]	76 M
50 ns/	4 GSa/s	2000	74,000	150 M
100 ns/	4 GSa/s	4000	74,000	300 M
200 ns/	4 GSa/s	8000	73,000	580 M
500 ns/	4 GSa/s	20,000	33,000	660 M
1 µs/	4 GSa/s	40,000	33,000	1.3 G
2 µs/	4 GSa/s	80,000	19,000	1.5 G
5 µs/	4 GSa/s	200,000	7,600	1.5 G
10 µs/	4 GSa/s	400,000	4,000	1.6 G
20 µs/	4 GSa/s	800,000	2,000	1.6 G
50 µs/	4 GSa/s	2,000,000	800	1.6 G
100 µs/	4 GSa/s	4,000,000	400	1.6 G

1. Memory depths are based on actual on-screen digitized points and do not include sin(x)/x reconstructed points.
2. Using sin(x)/x reconstruction, complete waveforms are generated for each acquisition cycle.
3. Points/second is defined as the total number of non-reconstructed points digitized in one second. For real-time acquisition, it is the product of the scope's on-screen memory depth times the waveforms-per-second update rate.
4. Up to 100,000 waveforms per second can be achieved by disabling pre-trigger acquisition.

Table 2: Agilent Infiniium 54830 Series Oscilloscope

Sec/div	Sample rate	Memory[1]	Waveforms/sec[2]	Points/sec[3]
1 ns/	4 GSa/s	40	1,200	48 k
2 ns/	4 GSa/s	80	650	52 k
5 ns/	4 GSa/s	200	420	84 k
10 ns/	4 GSa/s	400	320	128 k
20 ns/	4 GSa/s	800	240	192 k
50 ns/	4 GSa/s	2000	130	260 k
100 ns/	4 GSa/s	4000	120	480 k
200 ns/	4 GSa/s	8000	120	960 k
500 ns/	4 GSa/s	20,000	130	2.6 M
1 µs/	4 GSa/s	40,000	160	6.4 M
2 µs/	4 GSa/s	80,000	150	12 M
5 µs/	4 GSa/s	200,000	150	30 M
10 µs/	4 GSa/s	400,000	140	56 M
20 µs/	4 GSa/s	800,000	140	112 M
50 µs/	4 GSa/s	2,000,000	120	240 M
100 µs/	4 GSa/s	4,000,000	80	320 M
200 µs/	4 GSa/s	8,000,000	50	400 M
500 µs/	4 GSa/s	20,000,000	20	400 M
1.0 ms/	4 GSa/s	40,000,000	12	480 M
2.0 ms/	4 GSa/s	66,000,000	8	530 M

1. Memory depths are based on actual on-screen digitized points and do not include sin(x)/x reconstructed points.
2. Using sin(x)/x reconstruction, complete waveforms are generated for each acquisition cycle.
3. Points/second is defined as the total number of non-reconstructed points digitized in one second. For real-time acquisition, it is the product of the scope's on-screen memory depth times the waveforms-per-second update rate.

Appendix A: Real-time update rate tables (continued)

Table 3: Tektronix TDS3000B Series scope (Default 10K mode)

Sec/div	Sample rate	Memory[1]	Waveforms/sec[2]	Points/sec[3]
1 ns/	5 GSa/s	50	460	23 k
2 ns/	5 GSa/s	100	440	44 k
4 ns/	5 GSa/s	200	410	82 k
10 ns/	5 GSa/s	500	775	390 k
20 ns/	5 GSa/s	1,000	775	775 k
40 ns/	5 GSa/s	2,000	775	1.6 M
100 ns/	5 GSa/s	5,000	620	3.1 M
200 ns/	5 GSa/s	10,000	310	3.1 M
400 ns/	2.5 GSa/s	10,000	330	3.3 M
1 µs/	1 GSa/s	10,000	310	3.1 M
2 µs/	500 MSa/s	10,000	320	3.2 M
4 µs/	250 MSa/s	10,000	320	3.2 M
10 µs/	100 MSa/s	10,000	325	3.2 M
20 µs/	50 MSa/s	10,000	320	3.2 M
40 µs/	25 MSa/s	10,000	325	3.2 M
100 µs/	10 MSa/s	10,000	315	3.2 M

1. Memory depths are based on actual on-screen digitized points and do not include sin(x)/x reconstructed points.
2. Using sin(x)/x reconstruction, complete waveforms are generated for each acquisition cycle.
3. Points/second is defined as the total number of non-reconstructed points digitized in one second. For real-time acquisition, it is the product of the scope's on-screen memory depth times the waveforms-per-second update rate.

Table 4: Tektronix TDS3000B Series scope (Fast Trigger mode)

Sec/div	Sample rate	Memory[1]	Waveforms/sec[2]	Points/sec[3]
1 ns/	5 GSa/s	50	730	37 k
2 ns/	5 GSa/s	100	730	73 k
4 ns/	5 GSa/s	200	610	120 k
10 ns/	5 GSa/s	500	2800	1.4 M
20 ns/	2.5 GSa/s	500	3300	1.7 M
40 ns/	1.25 GSa/s	500	3500	1.8 M
100 ns/	500 MSa/s	500	3500	1.8 M
200 ns/	250 MSa/s	500	3300	1.7 M
400 ns/	125 MSa/s	500	3300	1.7 M
1 µs/	50 MSa/s	500	3100	1.6 M
2 µs/	25 MSa/s	500	2900	1.5 M
4 µs/	12.5 MSa/s	500	2500	1.3 M
10 µs/	5 MSa/s	500	1800	900 k
20 µs/	2.5 MSa/s	500	2000	1 M
40 µs/	1.25 MSa/s	500	1250	630 k
100 µs/	500 kSa/s	500	670	340 k

1. Memory depths are based on actual on-screen digitized points and do not include sin(x)/x reconstructed points.
2. Using sin(x)/x reconstruction, complete waveforms are generated for each acquisition cycle.
3. Points/second is defined as the total number of non-reconstructed points digitized in one second. For real-time acquisition, it is the product of the scope's on-screen memory depth times the waveforms-per-second update rate.

Table 5: Tektronix TDS5000B Series scope

Sec/div	Sample rate	Memory[1]	Waveforms/sec[2]	Points/sec[3]
1 ns/	5 GSa/s	50	180	9 k
2 ns/	5 GSa/s	100	180	18 k
4 ns/	5 GSa/s	200	150	30 k
10 ns/	5 GSa/s	500	120	60 k
20 ns/	5 GSa/s	1000	90	90 k
40 ns/	5 GSa/s	2000	90	180 k
80 ns/	5 GSa/s	4000	90	360 k
200 ns/	5 GSa/s	10,000	90	900 k
400 ns/	5 GSa/s	20,000	40	800 k
1 µs/	5 GSa/s	50,000	30	1.5 M
2 µs/	5 GSa/s	100,000	30	3 M
4 µs/	5 GSa/s	200,000	20	4 M
10 µs/	5 GSa/s	500,000	8	4 M
20 µs/	5 GSa/s	1,000,000	4	4 M
40 µs/	5 GSa/s	2,000,000	2	4 M
100 µs/	5 GSa/s	5,000,000	1	5 M

1. Memory depths are based on actual on-screen digitized points and do not include sin(x)/x reconstructed points.
2. Using sin(x)/x reconstruction, complete waveforms are generated for each acquisition cycle.
3. Points/second is defined as the total number of non-reconstructed points digitized in one second. For real-time acquisition, it is the product of the scope's on-screen memory depth times the waveforms-per-second update rate.

Table 6: LeCroy WaveSurfer 400 Series oscilloscope

Sec/div	Sample rate	Memory[1]	Waveforms/sec[2]	Points/sec[3]
1 ns/	2 GSa/s	20	170	3.4 k
2 ns/	2 GSa/s	40	170	6.8 k
5 ns/	2 GSa/s	100	170	17 k
10 ns/	2 GSa/s	200	165	33 k
20 ns/	2 GSa/s	400	160	64 k
50 ns/	2 GSa/s	1,000	130	130 k
100 ns/	2 GSa/s	2,000	130	260 k
200 ns/	2 GSa/s	4,000	130	520 k
500 ns/	2 GSa/s	10,000	120	1.2 M
1 µs/	2 GSa/s	20,000	110	2.2 M
2 µs/	2 GSa/s	40,000	90	3.6 M
5 µs/	2 GSa/s	100,000	70	7.0 M
10 µs/	2 GSa/s	200,000	50	10 M
20 µs/	2 GSa/s	400,000	30	12 M
50 µs/	2 GSa/s	1,000,000	20	20 M
100 µs/	2 GSa/s	2,000,000	10	20 M

1. Memory depths are based on actual on-screen digitized points and do not include sin(x)/x reconstructed points.
2. Using sin(x)/x reconstruction, complete waveforms are generated for each acquisition cycle.
3. Points/second is defined as the total number of non-reconstructed points digitized in one second. For real-time acquisition, it is the product of the scope's on-screen memory depth times the waveforms-per-second update rate.

Table 7: LeCroy WaveRunner 6000 Series oscilloscope

Sec/div	Sample rate	Memory[1]	Waveforms/sec[2]	Points/sec[3]
1 ns/	5 GSa/s	50	230	12 k
2 ns/	5 GSa/s	100	210	21 k
5 ns/	5 GSa/s	250	200	50 k
10 ns/	5 GSa/s	500	200	100 k
20 ns/	5 GSa/s	1,000	70	70 k
50 ns/	5 GSa/s	2,500	70	180 k
100 ns/	5 GSa/s	5,000	60	300 k
200 ns/	5 GSa/s	10,000	50	500 k
500 ns/	5 GSa/s	25,000	30	750 k
1 µs/	5 GSa/s	50,000	25	1.3 M
2 µs/	5 GSa/s	100,000	15	1.5 M
5 µs/	5 GSa/s	250,000	9	2.3 M
10 µs/	5 GSa/s	500,000	5	2.5 M
20 µs/	5 GSa/s	1,000,000	3	3 M

1. Memory depths are based on actual on-screen digitized points and do not include sin(x)/x reconstructed points.
2. Using sin(x)/x reconstruction, complete waveforms are generated for each acquisition cycle.
3. Points/second is defined as the total number of non-reconstructed points digitized in one second. For real-time acquisition, it is the product of the scope's on-screen memory depth times the waveforms-per-second update rate.

Appendix B: Equivalent-time update rate tables

Table 8: Agilent 6000 Series oscilloscope (ET mode)

Sec/div	Sample rate[1]	Memory[2]	Acq/sec	Waveforms/sec[3]	Points/sec[4]
1 ns/	4 GSa/s	40	200,000	16,000	8 M
2 ns/	4 GSa/s	80	190,000	30,000	15 M
5 ns/	4 GSa/s	200	170,000	68,000	34 M
10 ns/	4 GSa/s	400	160,000	130,000	64 M
20 ns/	4 GSa/s	800	90,000	90,000	72 M
50 ns/	4 GSa/s	2000	74,000	74,000	150 M
100 ns/	4 GSa/s	4000	74,000	74,000	300 M
200 ns/	4 GSa/s	8000	73,000	73,000	580 M
500 ns/	4 GSa/s	20,000	33,000	33,000	660 M
1 µs/	4 GSa/s	40,000	33,000	33,000	1.3 G
2 µs/	4 GSa/s	80,000	19,000	19,000	1.5 G
5 µs/	4 GSa/s	200,000	7,600	7,600	1.5 G
10 µs/	4 GSa/s	400,000	4,000	4,000	1.6 G
20 µs/	4 GSa/s	800,000	2,000	2,000	1.6 G
50 µs/	4 GSa/s	2,000,000	800	800	1.6 G
100 µs/	4 GSa/s	4,000,000	400	400	1.6 G

1. Sample rate is defined as the actual real-time sample rate for each repetitive acquisition. This is not the repetitive "effective" sample rate.
2. Memory depth based on actual on-screen digitized points acquired each repetitive acquisition cycle.
3. Equivalent-time waveforms-per-second are based on normalized waveforms consisting of a minimum of 500 points, which requires repetitive acquisitions on some of the faster time base ranges.
4. Points/second is defined as the total number of non-reconstructed points digitized in one second. For equivalent-time acquisition, it is the product of the scope's on-screen memory depth times the acquisitions-per-second update rate.

Table 9: Agilent Infiniium 54830 Series oscilloscope (ET mode)

Sec/div	Sample rate[1]	Memory[2]	Acq/sec	Waveforms/sec[3]	Points/sec[4]
1 ns/	2 GSa/s	20	25,000	1,000	500 k
2 ns/	2 GSa/s	40	25,000	2,000	1 M
5 ns/	2 GSa/s	100	23,000	4,600	2.3 M
10 ns/	2 GSa/s	200	19,000	7,600	3.8 M
20 ns/	2 GSa/s	400	15,000	12,000	6 M
50 ns/	2 GSa/s	1000	9,000	9,000	9 M
100 ns/	2 GSa/s	2000	5,000	5,000	10 M
200 ns/	2 GSa/s	4000	3,000	3,000	12 M
500 ns/	2 GSa/s	10,000	1,300	1,300	13 M
1 µs/	2 GSa/s	20,000	700	700	14 G
2 µs/	1 GSa/s	20,000	700	700	14 G
5 µs/	500 MSa/s	25,000	550	550	14 G
10 µs/	250 MSa/s	25,000	530	530	13 G
20 µs/	125 MSa/s	25,000	500	500	12 G
50 µs/	50 MSa/s	25,000	420	420	11 G
100 µs/	25 MSa/s	25,000	310	310	8 G

1. Sample Rate is defined as the actual real-time sample rate for each repetitive acquisition. This is not the repetitive "effective" sample rate.
2. Memory depth based on actual on-screen digitized points acquired each repetitive acquisition cycle.
3. Equivalent-time waveforms-per-second are based on normalized waveforms consisting of a minimum of 500 points, which requires repetitive acquisitions on some of the faster time base ranges.
4. Points/second is defined as the total number of non-reconstructed points digitized in one second. For equivalent-time acquisition, it is the product of the scope's on-screen memory depth times the acquisitions-per-second update rate.

Appendix B: Equivalent-time update rate tables (continued)

Table 10: Tektronix TDS5000B Series scope (FastAcq Mode)

Sec/div	Sample rate[1]	Memory[2]	Acq/sec	Waveforms/sec[3]	Points/sec[4]
1 ns/	1.25 GSa/s	12.5	120,000	3,000	1.5 M
2 ns/	1.25 GSa/s	25	140,000	7,000	3.5 M
4 ns/	1.25 GSa/s	50	140,000	14,000	7.0 M
10 ns/	1.25 GSa/s	125	140,000	35,000	18 M
20 ns/	1.25 GSa/s	250	125,000	63,000	31 M
40 ns/	1.25 GSa/s	500	130,000	130,000	65 M
80 ns/	1.25 GSa/s	1,000	65,000	65,000	65 M
200 ns/	1.25 GSa/s	2,500	28,000	28,000	70 M
400 ns/	1.25 GSa/s	5,000	13,000	13,000	65 M
1 µs/	500 MSa/s	5,000	13,000	13,000	65 M
2 µs/	250 MSa/s	5,000	12,000	12,000	60 M
4 µs/	125 MSa/s	5,000	4,700	4,700	24 M
10 µs/	125 MSa/s	12,500	2,500	2,500	31 M
20 µs/	125 MSa/s	25,000	1,300	1,300	33 M
40 µs/	125 MSa/s	50,000	690	690	35 M
100 µs/	125 MSa/s	125,000	280	280	35 M

1. Sample Rate is defined as the actual real-time sample rate for each repetitive acquisition. This is not the repetitive "effective" sample rate.
2. Memory depth based on actual on-screen digitized points acquired each repetitive acquisition cycle.
3. Equivalent-time waveforms-per-second are based on normalized waveforms consisting of a minimum of 500 points, which requires repetitive acquisitions on some of the faster time base ranges.
4. Points/second is defined as the total number of non-reconstructed points digitized in one second. For equivalent-time acquisition, it is the product of the scope's on-screen memory depth times the acquisitions-per-second update rate.

Table 11: LeCroy WaveSurfer 400 Series oscilloscope (ET mode)

Sec/div	Sample rate[1]	Memory[2]	Acq/sec	Waveforms/sec[3]	Points/sec[4]
1 ns/	500 MSa/s	5	3,800	40	19 k
2 ns/	500 MSa/s	10	3,400	70	34 k
5 ns/	500 MSa/s	25	3,400	170	85 k
10 ns/	500 MSa/s	50	3,100	310	160 k
20 ns/	500 MSa/s	100	3,100	620	310 k
50 ns/	500 MSa/s	250	2,400	1,200	600 k
100 ns/	500 MSa/s	500	1,700	1,700	850 k
200 ns/	500 MSa/s	1,000	1,200	1,200	1.2 M
500 ns/	500 MSa/s	2,500	540	540	1.4 M
1 µs/	500 MSa/s	5,000	330	330	1.7 M
2 µs/	500 MSa/s	10,000	160	160	1.6 M
5 µs/	2 GSa/s	100,000	70	70	7.0 M
10 µs/	2 GSa/s	200,000	50	50	10 M
20 µs/	2 GSa/s	400,000	30	30	12 M
50 µs/	2 GSa/s	1,000,000	20	20	20 M
100 µs/	2 GSa/s	2,000,000	10	10	20 M

1. Sample Rate is defined as the actual real-time sample rate for each repetitive acquisition. This is not the repetitive "effective" sample rate.
2. Memory depth based on actual on-screen digitized points acquired each repetitive acquisition cycle.
3. Equivalent-time waveforms-per-second are based on normalized waveforms consisting of a minimum of 500 points, which requires repetitive acquisitions on some of the faster time base ranges.
4. Points/second is defined as the total number of non-reconstructed points digitized in one second. For equivalent-time acquisition, it is the product of the scope's on-screen memory depth times the acquisitions-per-second update rate.

Table 12: LeCroy WaveRunner 6000 Series oscilloscope (ET mode)

Sec/div	Sample rate[1]	Memory[2]	Acq/sec	Waveforms/sec[3]	Points/sec[4]
1 ns/	5 GSa/s	50	2,200	220	110 k
2 ns/	5 GSa/s	100	2,200	440	220 k
5 ns/	5 GSa/s	250	1,900	950	480 k
10 ns/	5 GSa/s	500	1,500	1,500	750 k
20 ns/	5 GSa/s	1,000	1,100	1,100	1.1 M
50 ns/	5 GSa/s	2,500	600	600	1.5 M
100 ns/	5 GSa/s	5,000	360	360	1.8 M
200 ns/	5 GSa/s	10,000	50	50	500 k
500 ns/	5 GSa/s	25,000	30	30	750 k
1 µs/	5 GSa/s	50,000	25	25	1.3 M
2 µs/	5 GSa/s	100,000	15	15	1.6 M
5 µs/	5 GSa/s	250,000	9	9	2.3 M
10 µs/	5 GSa/s	500,000	5	5	2.5 M
20 µs/	5 GSa/s	1,000,000	3	3	3 M

1. Sample Rate is defined as the actual real-time sample rate for each repetitive acquisition. This is not the repetitive "effective" sample rate.
2. Memory depth based on actual on-screen digitized points acquired each repetitive acquisition cycle.
3. Equivalent-time waveforms-per-second are based on normalized waveforms consisting of a minimum of 500 points, which requires repetitive acquisitions on some of the faster time base ranges.
4. Points/second is defined as the total number of non-reconstructed points digitized in one second. For equivalent-time acquisition, it is the product of the scope's on-screen memory depth times the acquisitions-per-second update rate.

Related Literature

Publication Title	Publication Type	Publication Number
Agilent Infiniium 54830 Series Oscilloscopes	Data Sheet	5988-3788EN
Agilent 6000 Series Oscilloscopes	Data Sheet	5989-2000EN
Oscilloscope Display Quality Impacts Ability to Uncover Signal Anomalies - Agilent 6000 Series Scopes Versus Tek TDS3000B	Application Note	5989-2003EN
Oscilloscope Display Quality Impacts Ability to Uncover Signal Anomalies - Agilent 6000 Series Scopes Versus LeCroy WaveSurfer 400	Application Note	5989-2004EN
Deep Memory Oscilloscopes: The New Tools of Choice	Application Note	5988-9106EN
Evaluating Oscilloscope Vertical Noise Characteristics	Application Note	5989-3020EN
Ten Things to Consider When Selecting Your Next Oscilloscope	Application Note	5989-0552EN

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