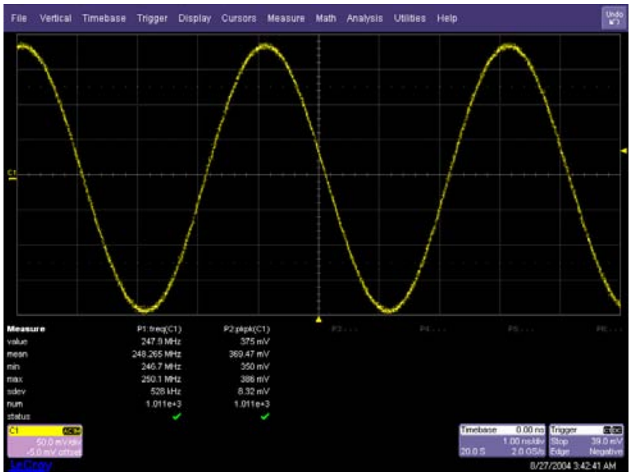
Not All Sampling Modes Are Created Equal



Introduction

The key to any good oscilloscope system is its ability to accurately capture and display your signal – known as signal fidelity. In the face of faster clock rates and edge speeds, increasingly complex signals and mounting time-to-market pressures, an oscilloscope's signal fidelity is a critical factor to your success.

Not all sampling modes are created equal; they have a significant impact on your oscilloscope's signal fidelity, particularly when examining complex, high-speed data in today's digital designs.

Tektronix oscilloscopes, which employ sin(x)/x interpolation as a default sampling mode (and the only selection in the TDS3000B Series oscilloscopes), provide high signal fidelity and repeatable waveform displays, with accurately placed points.

The LeCroy WaveSurfer 454 uses equivalent-time (ET) sampling technology, which LeCroy refers to as random interleaved sampling (RIS), at high sweep speeds to increase sampling resolution above its highest real-time sample rate of 2 GS/s.

LeCroy maintains that RIS mode should only be used to capture repetitive waveforms – a limitation not exhibited by Tektronix oscilloscopes. This brief examines the impact of sampling modes on an oscilloscope's signal fidelity, and explains why you should heed LeCroy's advice not only when examining exactly repetitive waveforms, but also when observing high-speed data, such as eye diagrams, as well as asynchronous signals and synchronous, but uncorrelated signals.

EXAMINING REPETITIVE SIGNALS

Good measurement practice suggests that a signal should occupy the majority of the oscilloscope's dynamic range for the highest fidelity display and measurement accuracy.

Unlike Tektronix oscilloscopes, such as the TDS3054B, which provide a little headroom at the top and bottom of the display, the WaveSurfer 454 appears to clip the signal at the top graticule line.

Although this clipping behavior may not be unexpected, the resulting display is.

Figure 1 shows a 250 MHz sine wave, well within the specified bandwidth of the oscilloscope, and well below the real-time sample rate. When acquired by the WaveSurfer 454 in RIS mode, it looks like a sine wave.

In figure 2, aside from the artifacts of low sample rate and linear interpolation, does the display of the first negative peak of the waveform amplitude accurately represent the signal?

Does it suggest a noise spike that is perhaps only one digitizing level high, or does it represent a huge transient? Can you tell? If you were using this oscilloscope to debug your design, would you start looking for trouble in your design or in the oscilloscope?

What if your debugging process <u>forced</u> the use of single-shot acquisitions? Would you be able to solve the problem with this display?

Figure 1. WaveSurfer 454, RIS mode

Figure 2. WaveSurfer 454, real-time mode, linear interpolation

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In figure 3, sin(x)/x interpolation has been selected in the channel 1 vertical setup menu, which has removed the inaccurate impression of a noise spike. In figure 4, with the TDS3054B oscilloscope, there is no distortion because the instrument has more than a division of "head-room" above and below the graticule.

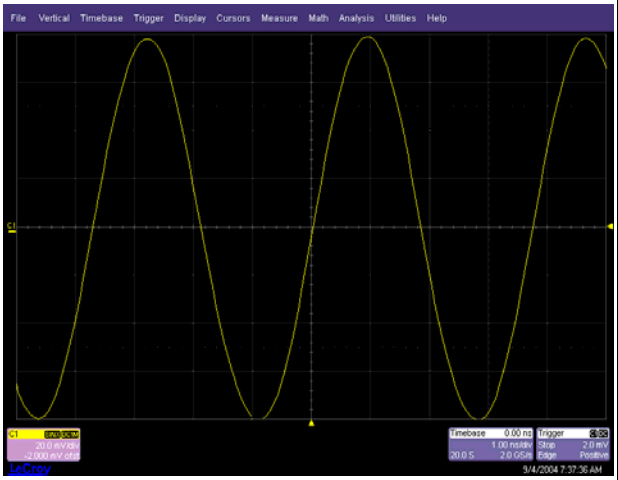


Figure 3. WaveSurfer 454, real-time mode, sin(x)/x interpolation

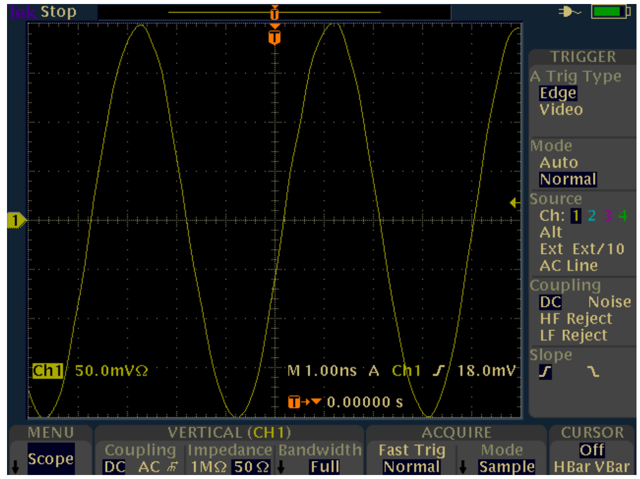


Figure 4. TDS3054B

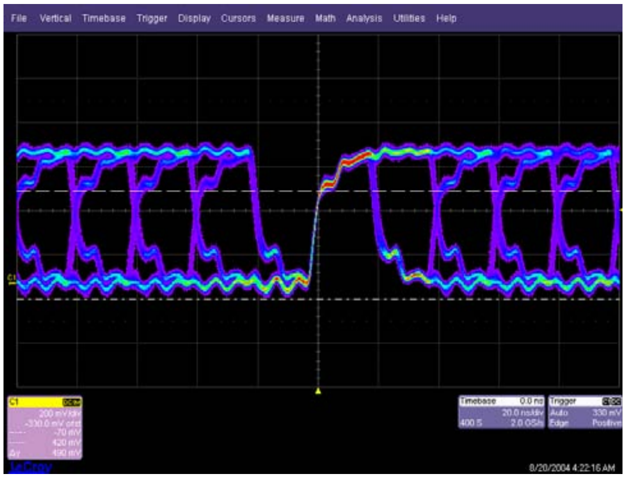
EXAMINING EYE DIAGRAMS AND NON-REPETITIVE WAVEFORMS

As a reminder, LeCroy maintains that the RIS sampling mode should only be used to capture repetitive waveforms. Although this is sound advice in most LeCroy oscilloscopes, the DSP bandwidth flattening/enhancement algorithms in some LeCroy high-bandwidth models result in failure to correctly display eye diagrams at full bandwidth by confusing the RIS sampling mode.

Furthermore, the WaveSurfer 454 exhibits an RIS sampling mode problem that appears unrelated to DSP, and selecting bandwidth limiting does not resolve this issue. This problem is simply a point-placement issue that causes inaccurate waveforms to appear when examining eye diagrams or similar non-repetitive waveforms.

Figure 5 shows a 50 Mb/s NRZ signal displayed on the WaveSurfer 454 in real-time mode. In real-time mode, the eye diagram looks fine.

In figure 6, the acquisition mode was changed to RIS mode using default linear interpolation. Where did all the noise come from? Notice that, at the trigger edge, everything looks normal. At the trigger edge, all points adjacent in time are also adjacent in voltage. At other time-adjacent points in the trace, points on one trigger may be at the opposite logic level on the next trigger. It appears that the further apart time-adjacent points are in amplitude, the more error appears in the resulting display.



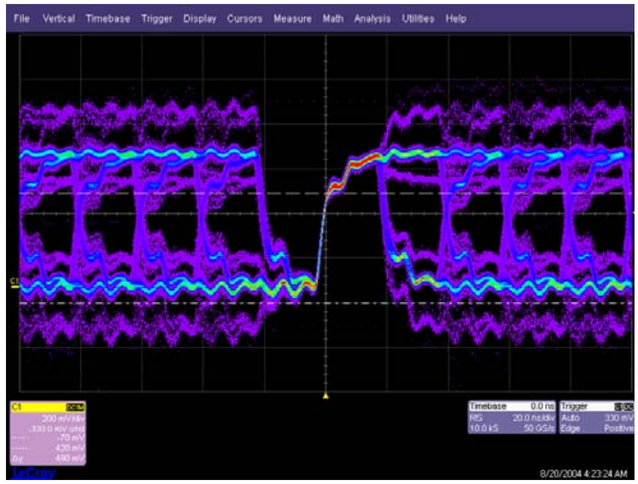
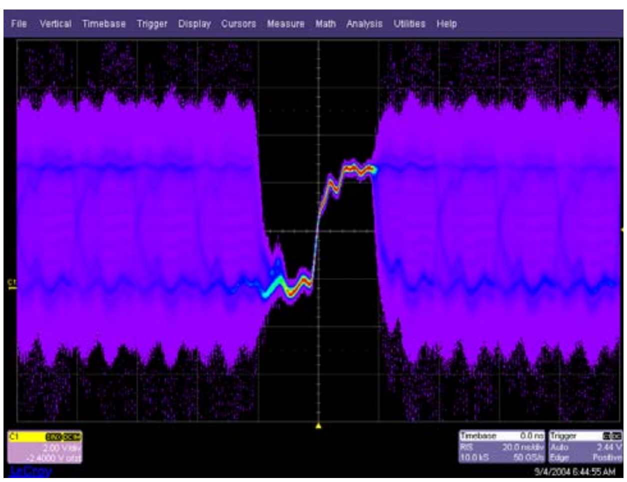


Figure 5. WaveSurfer 454, real-time mode

Figure 6. WaveSurfer 454, RIS mode, linear interpolation

In figure 7, sin(x)/x interpolation has been applied to the RIS mode display, which simply connects the dots, filling in the eye diagram completely. All of these images were created by using infinite persistence. In figure 8, the TDS3054B oscilloscope shows no such point-placement problem.



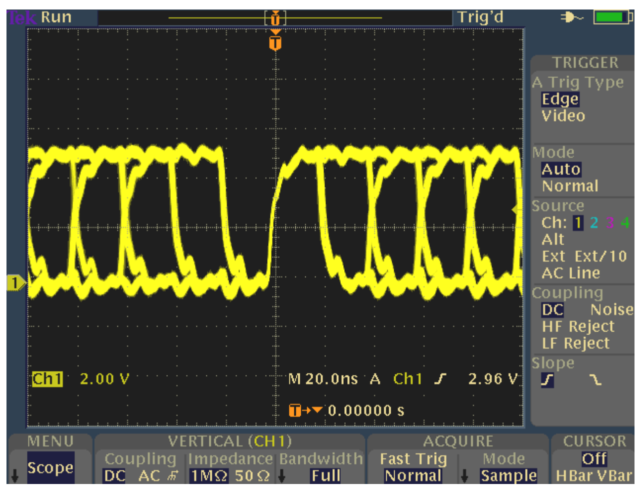


Figure 7. WaveSurfer 454, RIS mode, sin(x)/x interpolation

Figure 8. TDS3054B

EXAMINING ASYNCHRONOUS SIGNALS

Figure 9 shows clock and data signals displayed on the WaveSurfer 454 in real-time mode. In this example, the clock signal on channel C1 looks fine, and the envelope of the data signal on channel C2 has a constant amplitude.

In figure 10, the acquisition mode was changed to RIS mode. Where did all the noise on channel C2 come from? Notice that at the clock signal, C1 (which is the trigger source) looks normal. However, the envelope of channel C2 now has random-amplitude noise added.

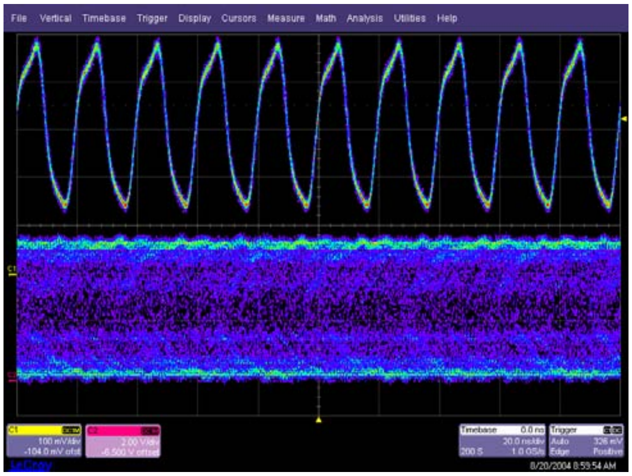


Figure 9. WaveSurfer 454, real-time mode

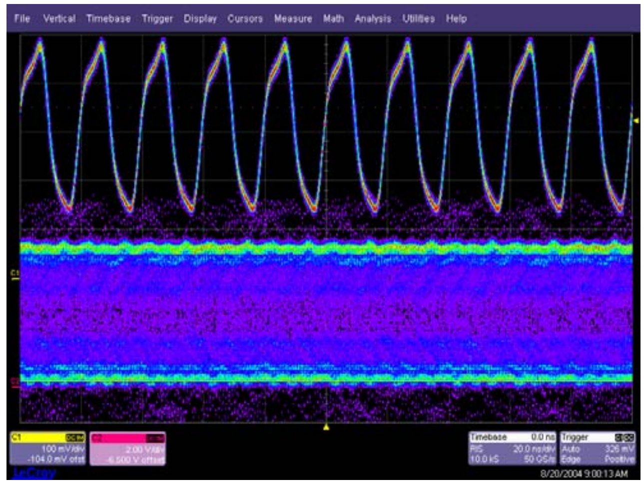


Figure 10. WaveSurfer 454, RIS mode, trigger on C1

In figure 11, the trigger source was simply changed from C1 to C2. Again, the channel that is the trigger source is displayed correctly, but the other channel is not. In figure 12, the TDS3054B avoids all these problems with an alternate trigger selection that allows stable triggering on each channel alternately.

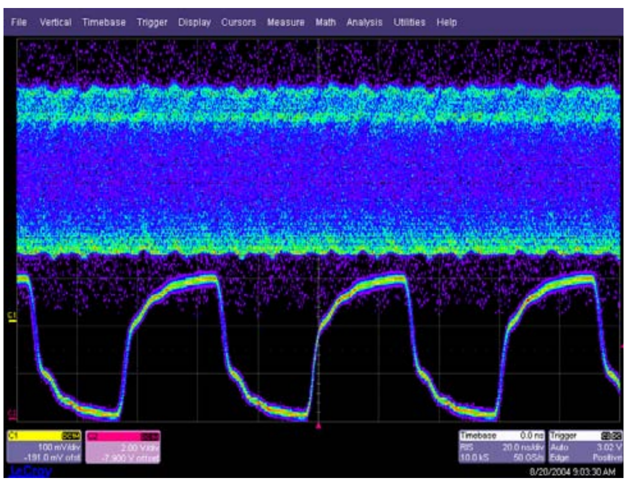


Figure 11. WaveSurfer 454, RIS mode, trigger on C2

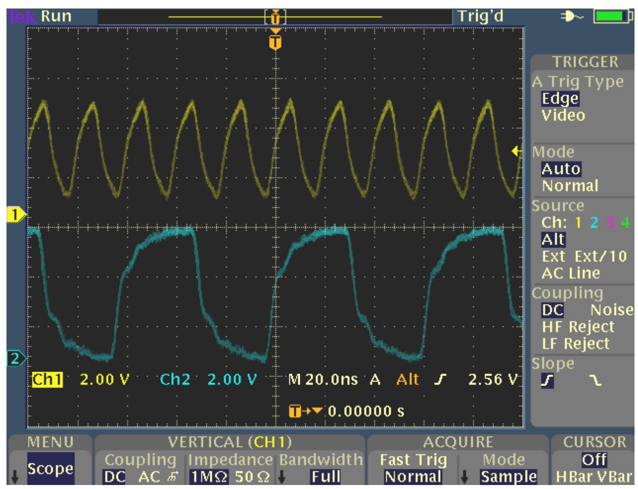


Figure 12. TDS3054B, alternate trigger

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EXAMINING SYNCHRONOUS, BUT UNCORRELATED SIGNALS

So, RIS mode displays cannot be used to observe asynchronous signals. What about signals that are synchronous, but uncorrelated?

In figure 13, the signal on channel C2 is changed to an OC1 signal and the trigger source is again C1. In this case, the signals are synchronous, but uncorrelated (the OC1 data signal may be high or low during any given clock period). Again, the noise appears. There is no such noise in the TDS3054B display in figure 15.

Is this just a display phenomenon?

In figure 14, frequency and amplitude measurements were added. Amazingly, the frequency of the ~50 MHz signal measured on this 500 MHz oscilloscope has an average value of 14.24 GHz and the 5 Volt logic signal has peaks in excess of 10 Volts! Find the correct values in figure 16 from the TDS3054B.

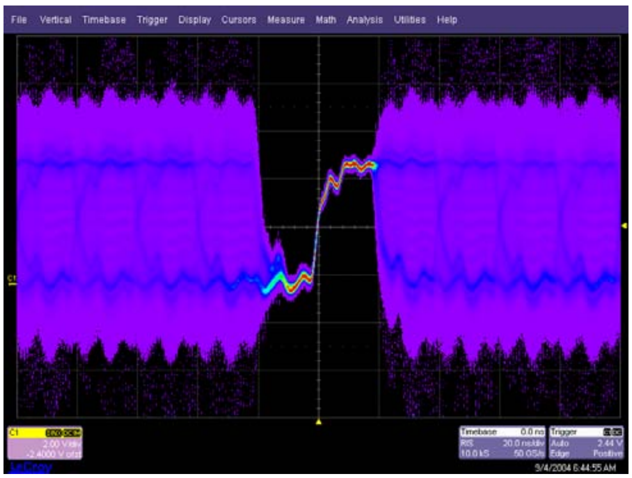

Figure 13. WaveSurfer 454, RIS mode, trigger on C1

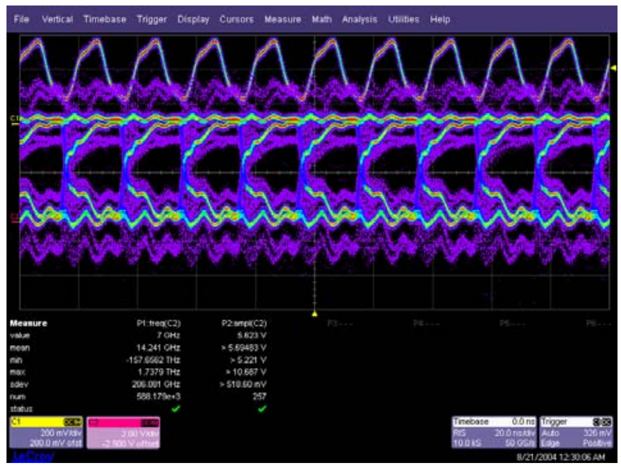

Figure 14. WaveSurfer 454, RIS mode, with measurements

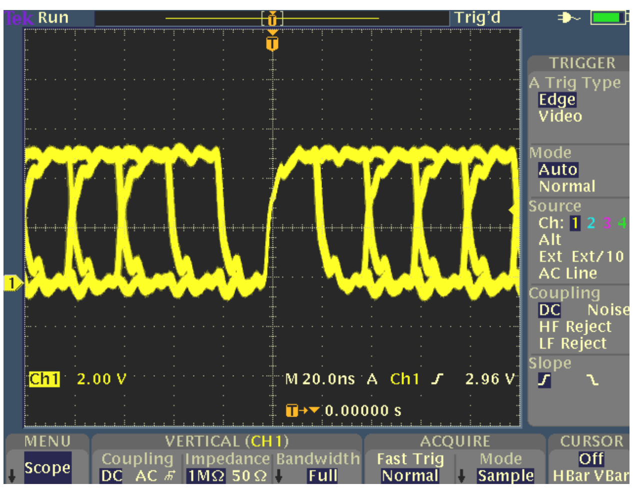

Figure 15. TDS3054B, trigger on channel 1

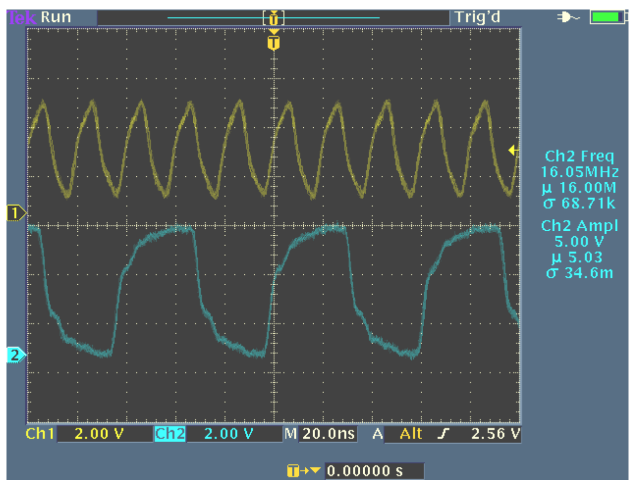

Figure 16. TDS3054B, alternate trigger

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CONCLUSION

In the face of faster clock rates and edge speeds, increasingly complex signals and mounting time-to-market pressures, you need an oscilloscope that works for you – one that accurately captures and displays your signal – one that gives you answers you can trust.

Now more than ever, signal fidelity is essential to your success. Tektronix oscilloscopes provide high signal fidelity and repeatable waveform displays, with accurately-placed waveform points.

With limited sample rate, default linear interpolation, and RIS acquisition problems, the WaveSurfer 454 may provide a disappointing experience when working with any high-speed signals. Inaccurately-placed points in the RIS mode display will hamper the debug of signals present in today's real-world digital designs, obscuring eye-shape errors and providing misleading displays when examining asynchronous signals and synchronous, but uncorrelated signals. Since the acquired data is incorrect, post-processing does not work correctly and provides misleading results.

While LeCroy maintains that RIS mode should only be used to capture strictly repetitive signals, Tektronix oscilloscopes have no such limitation. All Tektronix oscilloscopes with equivalent-time (ET) sampling mode will correctly render high-speed signals with accurately-placed points. In fact, Tektronix recommends that you use ET mode to observe these signals with the highest time resolution, to ensure that you get the true answers you need – when you need them.