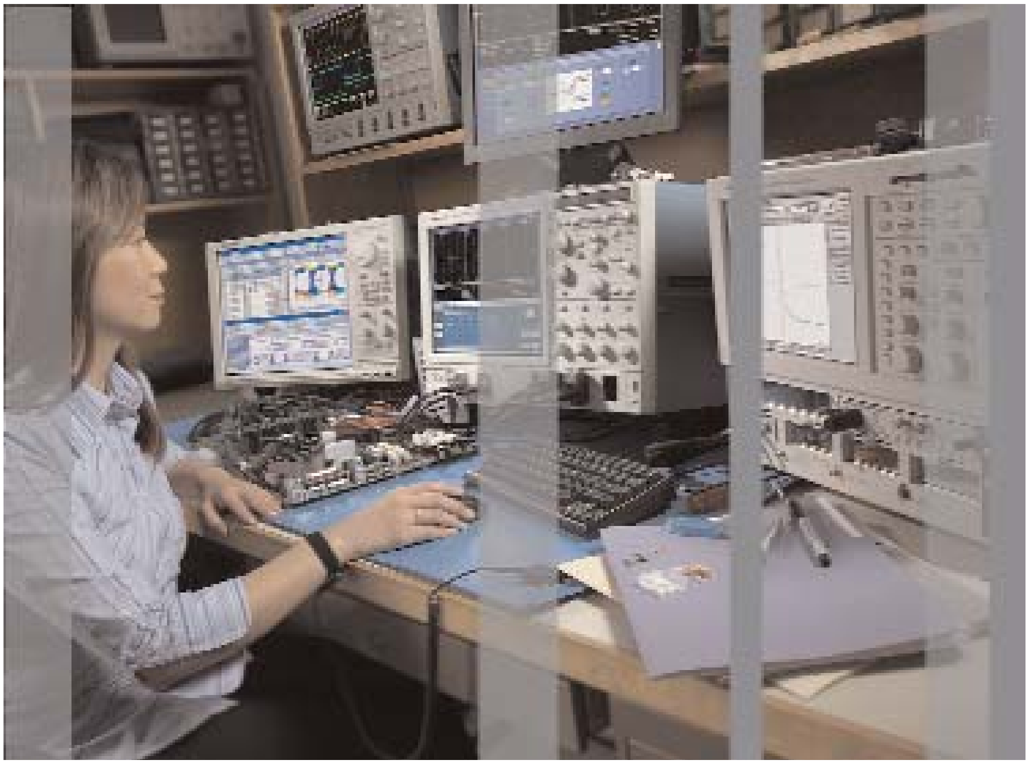
Application Note



Using Long Record Acquisitions

Using Long Records — The Basics

One of the more common applications of digital phosphor oscilloscopes is the capture and storage of analog waveforms. This facilitates the analysis of signal amplitude and timing features. Fundamentally, analog signals are digitized at some sampling interval, processed to be displayed, and then displayed on screen. Many constraints are placed on this process, like maximum sample rate, maximum number of samples, display resolution, and even processing time.

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Capture Limitations

Sampling imposes limitations: for example, the maximum sample rate limits high frequency content; and the number of samples limits at maximum sample rate, limits low frequency content. At 50GSa/s, a 50M sample record captures 1 millisecond of time. Due to sampling theory, the maximum frequency that can be accurately reconstructed is 25 GHz (sample_rate/2), and the practical minimum visible frequency is 1 kHz (1/record_length). Using a DPO/DSA70000 Series as an example, sampling at 50GSa/s with record lengths of 200M points, minimum frequencies approach 250 Hz with 20 GHz upper bandwidth (set by the acquisition system analog bandwidth). Note that by maintaining a long record and lowering the sample rate, even lower frequencies can be captured, trading off upper bandwidth and timing resolution.

When signals are captured with long records, they are generally displayed for visual analysis. Whenever a record exceeds the display resolution, the captured data must be decimated or only a smaller part of the data can be viewed. To visualize low frequency content across the entire acquisition, decimation is the only choice. But care must be taken to ensure information is properly accounted for between decimated points. For example, if between decimated display points the record contains anomalous peaks, it would be easiest to simply ignore them during processing (thus speeding the display update rate), but not displaying them can mislead users looking at the display. The Tektronix DPO7000 and MSO/DPO/DSA70000 Series oscilloscopes perform decimation that includes peak detection and incorporates patented display mechanisms using intensity and line width that ensure the entire data set is represented in the displayed waveform.

Display, Zoom, Cursors, Search and Mark

Tektronix oscilloscopes display details based on the entire record, and includes visual cues to indicate such things as minimum and maximum voltages and the number of samples at each level by varying the width and intensity of the displayed trace. This additional processing does require computation and can impact display update rates, so much of the computation is performed in specialized ASIC and associated logic devices.

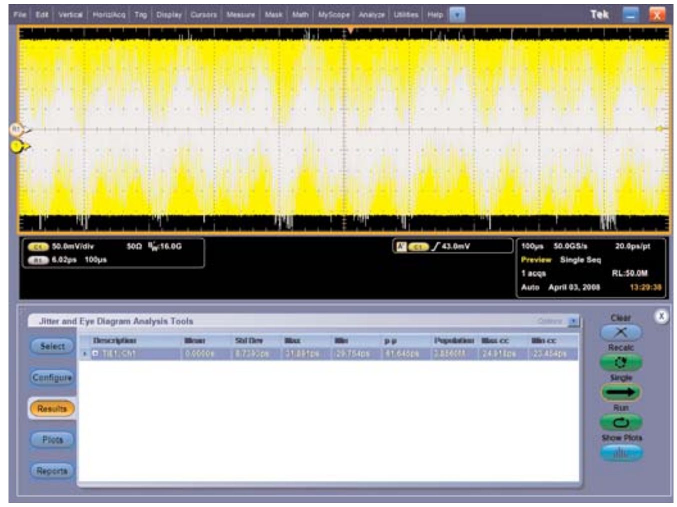

Figure 1. Capture and Display.

Beyond the basic look of an acquisition to see longer term effects like noise bursts or modulation patterns, often a closer look at the signal details is needed to examine the burst or modulation or other feature of interest. Zoom is a good initial tool for this. By selecting the region of interest and using a zoom window, the instrument expands the graticule to show the area of interest in more detail, enhancing both time and amplitude resolution. In zoom, decimation is reduced and additional signal features become visible or are more distinguishable. Zooming into a feature by repeating the zoom function is often required with long waveforms. Especially high speed serial signals. When examining a long record with a capture of ten million unit intervals and using zoom to single-out an odd unit interval that exceeds some threshold requires good response from the instrument and user interface. At 50GSa/s a single 5Gb/s unit interval is represented by only 10 samples in the record. It should be easy to see multiple zoom operations will be required as you dig deeper into the detailed waveform features — and why instrument zoom responsiveness is critical. Once you've zoomed into a waveform feature, cursors are useful for measuring time and amplitude details.

Figure 2. Search and Mark.

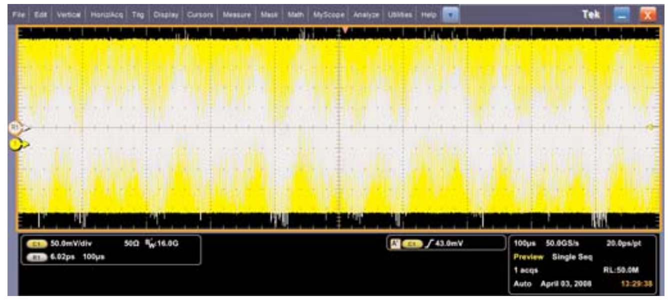

Figure 3. Measurement Trend of 50M point Record.

Another use for zoom is to compare different regions of the captured waveform. Or to compare two associated waveforms. The DSA70000 Series instruments provide multiple zoom windows to correlate the same or different waveforms. The zoom features also allow for manually or automatically scanning a zoomed waveform.

The Tektronix Search and Mark tool provides a facility to search of features based on many criteria, similar to Pinpoint® triggering. This yields marked regions that can be sequentially scanned for comparison, and even used as measurement gates. In Figure 2, a waveform is being examined for specific features. Using tools like Search and Mark allows for quick identification of the features, in this case DDR signals, specifically, DDR3 write bursts are being identified automatically and measured using DPOJET.

Another instrument feature that can affect waveform display performance and usability is the use of careful path analysis and applied filters to further calibrate waveform amplitude and phase response. This type of compensation is generally referred to as digital signal processing (DSP), and can make a marked improvement in overall system precision. All oscilloscopes have an analog path from the device under test to the acquisition ADC. These paths can be electrically compensated and calibrated from the instrument input connector to the ADC, but often some of this calibration is performed post acquisition. Additional post processing can be performed to further enhance the acquisition system accuracy, even providing compensation for channel losses from probes or cabling between the device under test and the instrument, as done using the Serial Data Link Analysis option on Tektronix oscilloscopes where transmitters, channels and receivers are modeled to predict system performance. Application of DSP can incur heavy computational loads and slow visual update rates, even in instruments using specialized hardware. For some applications the ability to disable the DSP allows more efficient debugging, especially where viewing changing aspects of the signal is more important than precision.

Another advantage to Tektronix' advanced ASIC hardware is the FastAcq feature, which is an implementation of DPX™ technology. With FastAcq the instruments can achieve 300,000 waveform updates per second, which allows a very rapid accumulation of signal information for debugging and analysis. Rather than building a long record of information, an overlaid record of information is built of repetitive events. Variations in the signal can easily be seen

S-rate	Record	Tduration	2.5Gb/s UI	6Gb/s UI
40.0E+9	1.0E+9	25.0E-3	62.5E+6	150.0E+6
40.0E+9	500.0E+6	12.5E-3	31.3E+6	75.0E+6
50.0E+9	200.0E+6	4.0E-3	10.0E+6	24.0E+6
50.0E+9	100.0E+6	2.0E-3	5.0E+6	12.0E+6
50.0E+9	50.0E+6	1.0E-3	2.5E+6	6.0E+6
50.0E+9	20.0E+6	400.0E-6	1.0E+6	2.4E+6
50.0E+9	10.0E+6	200.0E-6	500.0E+3	1.2E+6
50.0E+9	1.0E+6	20.0E-6	50.0E+3	120.0E+3

Table 1. Record Length vs. Unit Interval.

as color or intensity gradations.

Measurement Analysis

Once a signal is captured and displayed, visual analysis can only go so far. Some signal aspects are simply too complex for analysis using visual methods. For example, judging the period or frequency of a signal with timing accuracies available in today's instruments visually is nearly impossible. Instead, timing and amplitude measurements are best done using advanced analysis tools like DPOJET software that utilize sample by sample methods to determine measurements.

Inside advanced measurement tools, care must be taken to ensure adequate capability to fully support the acquisition system. Using a moderate frequency signal, a 100 MHz clock, acquired on a system having a 100M point record at 50GSa/s, we will capture 200,000 clock periods over a 2ms observation. This means that to measure every clock period in the acquisition, we must measure each of the 200,000 periods to properly evaluate the 100M point acquisition data. We can extend this by considering a few other real world cases. Common first generation computer serial data buses operate at 2.5Gb/s and 3Gb/s, with 5Gb/s and 6Gb/s on the immediate horizon, and 8Gb/s, 9.6Gb/s and 10.25Gb/s in development.

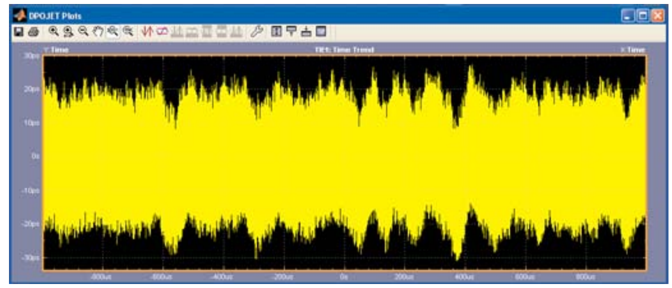

Figure 5. Measurement Trend of 9.3 million UI.

Extending to faster data rates, we can predict how many cycles or unit intervals will be captured. At 1Gb/s, 2 million unit intervals will be captured. At 2.5Gb/s, that same 100M point record contains 5 million unit intervals, and at 6Gb/s about 12 million unit intervals are captured. Extend this to a 200M point record, and 6Gb/s yields 24 million unit intervals captured. The following table shows number of UI captured at two common data rates, 2.5Gb/s and 6Gb/s. Sample rates are from two instruments that support long records, one sampling at a maximum of 40GSa/s, the other at 50GSa/s.

A measurement system must be able to handle these cases to be useful for evaluating and analyzing signals in common use today, especially high speed serial data links. DPOJET on a DSA70000 Series 20 GHz oscilloscope supports measurements of up to 35 million events, edges or UI per channel of acquisition.

What are the Ramifications of an Inadequate Measurement System?

In the strictest sense, measuring a million or ten million unit intervals can be done over a single acquisition, or over multiple acquisitions. Statistically, the results should correlate, however when comparing across sites or with different customers or vendors, especially when sharing data such as original waveforms, having a single dataset is best. Trying to correlate multiple acquired data sets is always difficult and in some cases impossible using the basic tools supplied with some instrumentation. So chose tools that allow the best use of your engineering talent.

Trend Analysis

Long records can be quite useful for debugging and other forms of fault analysis. If you are examining a signal and looking for problems caused by common artifacts like low frequency power supply noise, a common tool is using measurement trending. This method measures the acquired data then plots the measurement results to the display as a trend plot. Figure 5 displays a plot of a long measurement trend containing measurements of about nine million unit intervals. Modulation is clear and apparent in the trend, and has a time constant of about 100 µs. This level of information is often useful to discover sources of crosstalk, power supply shifts, and other forms of degraded signaling.

Plotting an SSC profile is another use of longer measurement trends. Figure 6 shows an unfiltered trend of a serial data signal (period measurement). Figure 7 shows the same signal and measurement, but the measurements are low pass filtered at 5 MHz so that high frequency variations are not included. Figure 8 shows a detail of a trend filtered at 1 MHz.

Long record acquisitions, like the 200 million point acquisitions available in the DSA70000 Series instruments, are only useful if the entire measurement system supports these longer records. DPOJET supports measurements on records up to 500 million points, up to 35 million events. DPOJET further supports trend analysis of up to 10 million measurements per plot. Plots can be exported to the main instrument graticule allowing for a one to one correlation of acquired waveform to measurement data.

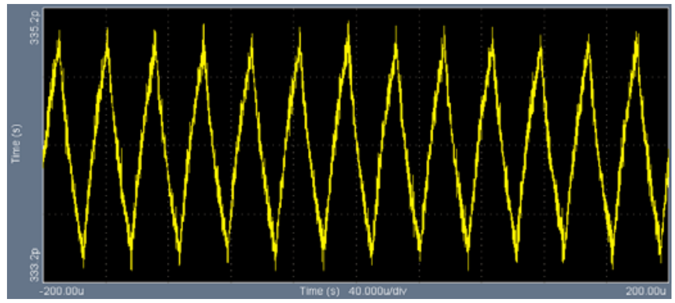

Figure 7. Period Measurement Trend, 5 MHz Low Pass.

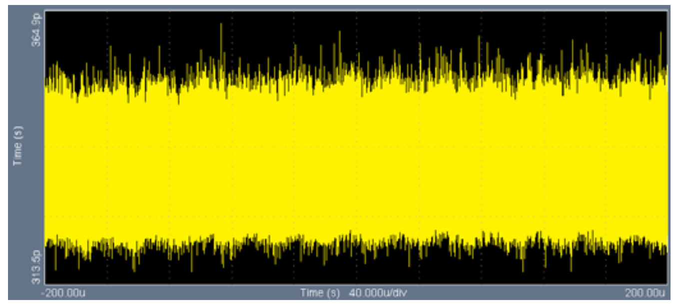

Figure 6. Period Measurement Trend.

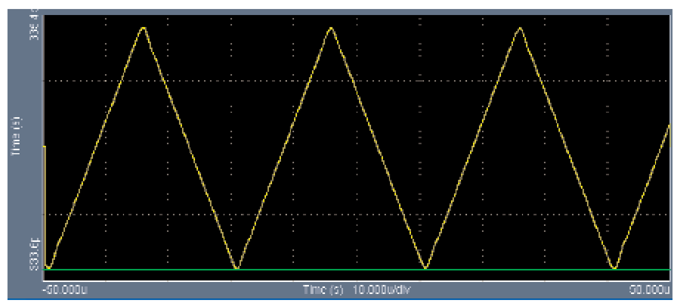

Figure 8. Period Measurement Trend, 1 MHz Low Pass.

A Comparison of Tools Using Real World Examples

To summarize why a review of the entire instrument capability is important, let's compare two long record length oscilloscopes capturing and measuring a common high speed serial signal making a simple Time Interval Error measurement while using trend analysis.

The signal source used is an LVDS driver producing an 8B/10B test pattern with a 50% transition density (TD) at approximately 6Gb/s. The signal is fed into a single channel input. Note: A Tektronix BERTScope¤ Bit Error Rate Tester producing a 5Gb/s or 6Gb/s PRBS7 signal driving −250mv will approximate the source used here. The exact data rate is unimportant. The key point is the upper limit on measurement depth versus record length.

The instruments are set to a nominal 100M point acquisition. The two instruments have different maximum sample rates, thus different time per division settings are required to maintain a similar record length.

The measurement is a simple TIE measurement using software based constant clock recovery as a reference. TIE reports the deviation of edges from their ideal instants as defined by the reference clock used. In one instrument, TIE is reported using a Tektronix DSA70000 Series 20 GHz oscilloscope with DPOJET software; in the other instrument the TIE measurement is reported using Agilent DSA91304A with N5400A.

The Tektronix DSA70000 Series is set to acquire 100M points at 50GSa/s. This yields 200 us/div, and 2ms total acquisition time. Note in Figures 9 and 10, the entire acquisition is measured and trend plotted. Yet in Figure 11, an Agilent display, information is missing.

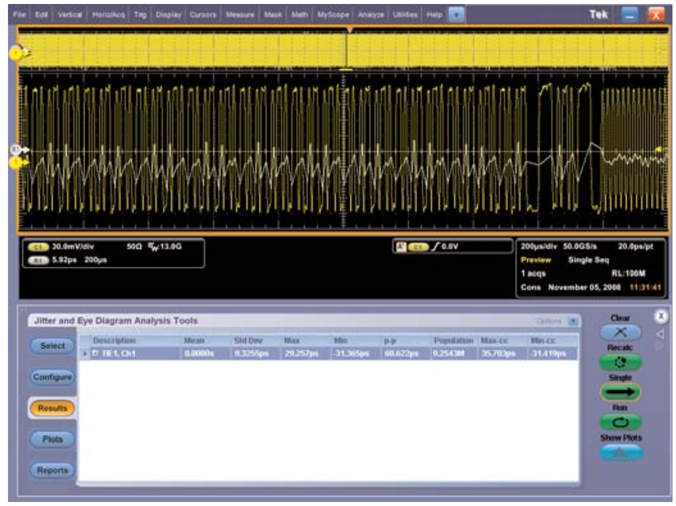

Figure 9. 100M Point Acquisition at 200us/div.

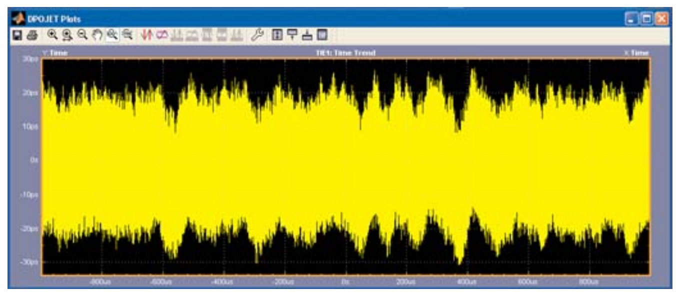

Figure 10. Trend Plot of Full 2ms Acquisition.

Figure 11. 100M Point Acquisition at 250us/div.

The Agilent DSA91304A is set to acquire 100M points at 40GSa/s. This yields 250us/div, and 2.5ms total acquisition time. It should yield a higher measurement count than the Tektronix instrument.

What is first interesting about Figure 11, the Agilent display is the trend plot is truncated before it reaches the full screen width. Observing the horizontal scale, we see the trend plot accounts for about 1.3ms, slightly more than one half the of acquisition time.

Yet we see only 1 million measurements were made. This is due to an internal limitation in the Agilent instrument. Only a certain amount of memory is allocated to measurements, and this allocation limits how the long records can be used. Even a simple one channel one measurement application exceeds the instrument s limited capabilities.

And the number of measurements, 1 million edges, identifies another question. Shouldn't there be more edges for that 1.3ms covered by the trend plot? At 6Gb/s, that's about 7.8 million UI, or 3.8 million edges at 50% TD. As the horizontal scale is changed to 125us/div and 50M points, the measurement count remains fixed at the limit of 1 million, yet the duration of the trend plot changes to cover a different time period. This is either a defect in the Agilent instrument software, or a novel way of decimating (or skipping) some measurements to retain the appearance of better long record support.

In an earlier firmware release, the measurement to record relationship was more direct, and intuitive. Figure 12 shows 2 million measurements over about 400 us, which is correct for the 5Gb/s signal applied in that example.

With Tektronix instruments, the relationship of measurements to record length is direct. Figure 12 shows a 2ms record with 9.2M measurements. Figure 13 displays a 1 ms acquisition with the resulting 1/2 measurement count of 4.6M measurements.

Figure 12. Truncated Trend Plot.

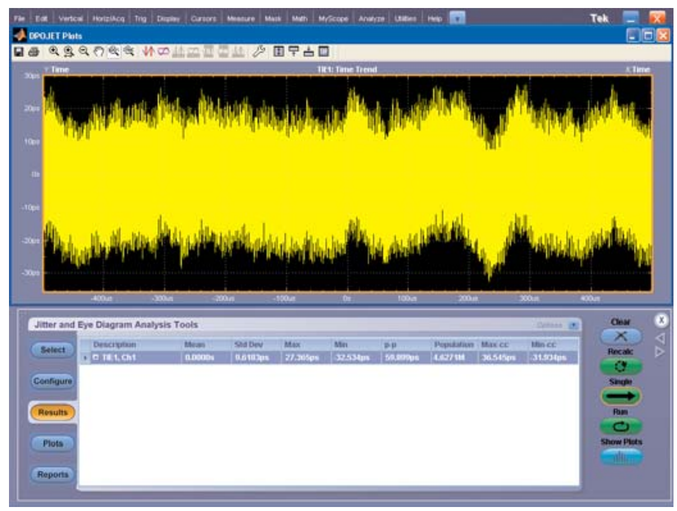

Figure 13. 50M Point Acquisition at 100us/div.

Summary

When choosing instruments for debug, analysis, and measurement applications where long duration capture and low frequency high bandwidth analysis is crucial, ensure your choice of instrument is designed to adequately support your intended measurement applications. As shown in the previous figures, inherent system limitations can directly negate the implied benefits of having long records available.

Making measurements on long record acquisitions stresses the instrument and operating system. A 200M point record requires nearly one gigabyte of memory to represent as a single precision numeric vector (math waveforms). Measurement results like TIE require the higher precision afforded by double precision numeric vectors. Together, proper handling of the rather large waveform and measurement result vectors requires careful advance planning and design to fully support the full system capabilities.

Tektronix oscilloscope measurement tools have a long history of providing full system support for the instrument. From TDSJIT through DPOJET software, each new class of instrument is provided measurement capability fully adequate to address the longer record lengths the base instrumentation provides. DPOJET supports the maximum 500M record on the DPO7000 Series and maximum 250M record on the DSA70000 Series instruments, providing up to 35 million measurement results per channel and trend plotting of up to 10 million results.

You can be confident the Tektronix DPO7000 Series and DSA70000 Series instruments provide the best capture and analysis solutions and continue to set the state-of-the-art other brands continue to follow.

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