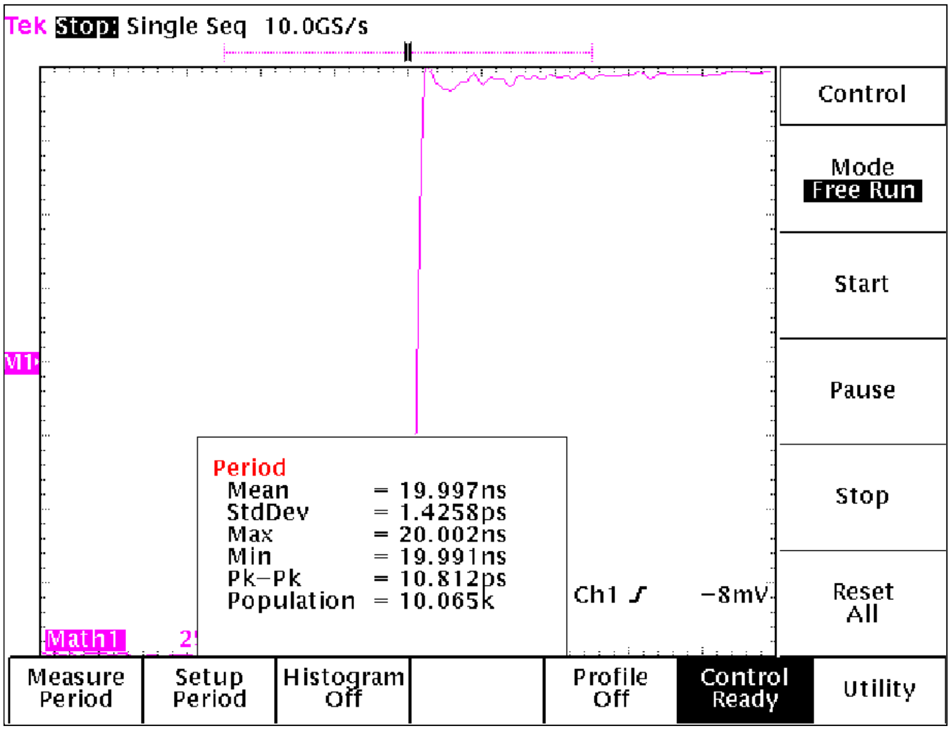
Tektronix

Technical Brief

A New Jitter Measurement Technique for the TDS Digital Oscilloscopes



Tektronix TDS694C oscilloscope performing a very precise timing measurement

Introduction

Rapidly ascending clock rates and tighter timing margins are creating a need for more robust jitter characterization techniques than have been available in the past. Traditional jitter measurements, which coupled histogram and other automatic measurements with statistical analysis, have been limited by their need to gather data over multiple acquisitions.

Today, high bandwidth acquisition circuits and extremely long record lengths are making possible a new level of accuracy in jitter measurements. This application note will provide:

- An overview of traditional jitter measurement techniques
- A new jitter measurement capability
- Applications for the new jitter measurement capability
- Jitter specifications

Understanding Jitter

Jitter is defined to be the deviation of a signal's transition from its ideal position in time or the timing variation from transition to transition. Excessive jitter can increase the bit error rate (BER) of a communications signal by incorrectly transmitting a data bit stream. In digital systems, jitter can violate timing margins, causing circuits to behave improperly. As a consequence, accurate measurement of jitter is necessary for determining the robustness of a system and how close it is to failing.

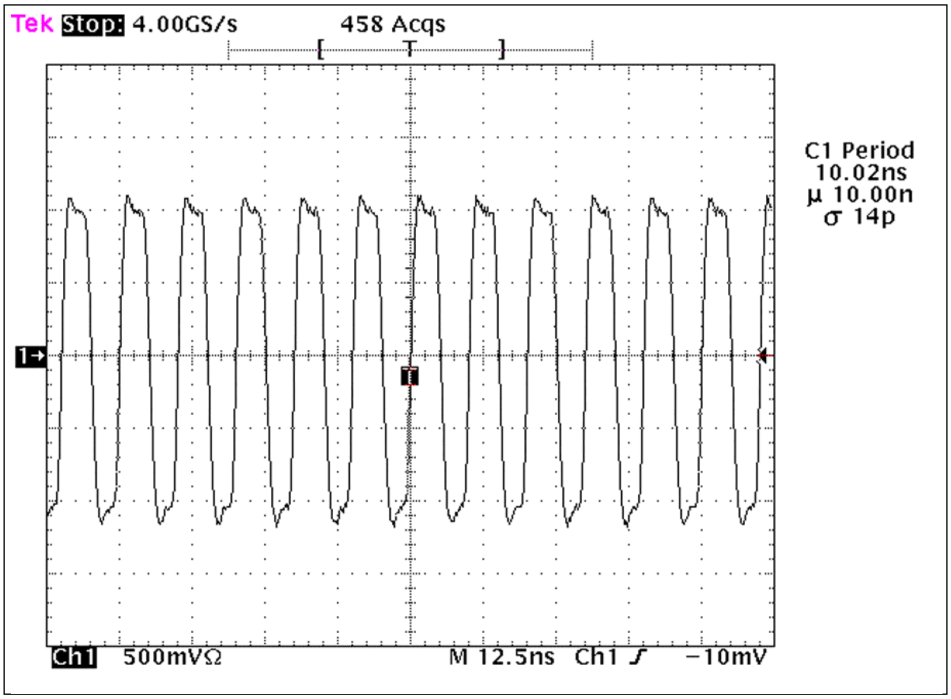


Figure 1. Automatic period measurement.

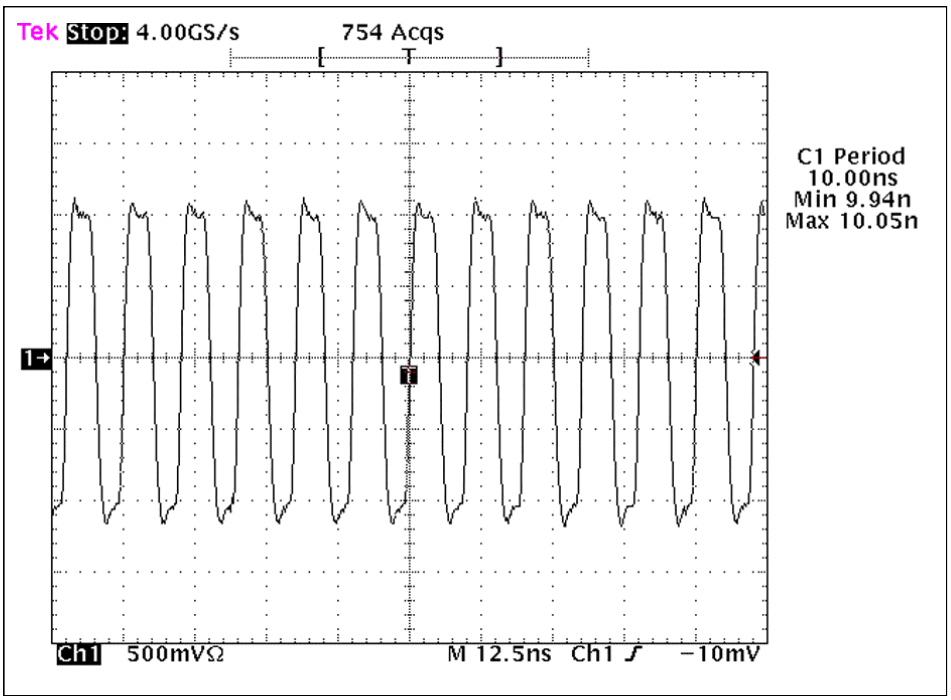


Figure 2. Using the min-max function.

Automatic Measurements and Statistics. Figure 1 shows the output of a Tektronix oscilloscope performing an automatic period measurement. In this example, the clock is assumed to be 10 ns. The automatic period measurement combined with a calculation of the mean (μ) and the standard deviation (σ) shows that the mean period is 10 ns, with a standard deviation of 14 ps.

The min-max automatic measurement function (Figure 2) shows that the clock period is jittering (deviating from its ideal position) by +50 ps/–60 ps. Using statistics on the Tektronix automatic measurements of frequency, delay, and duty cycle can also provide jitter information about a signal.

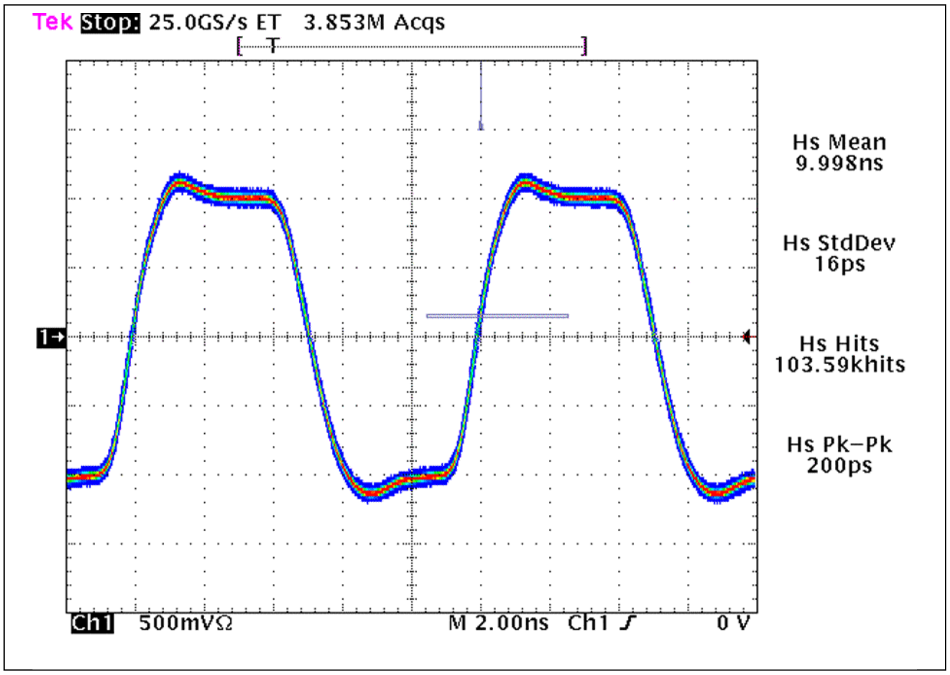


Figure 3. Histogram measurement of jitter.

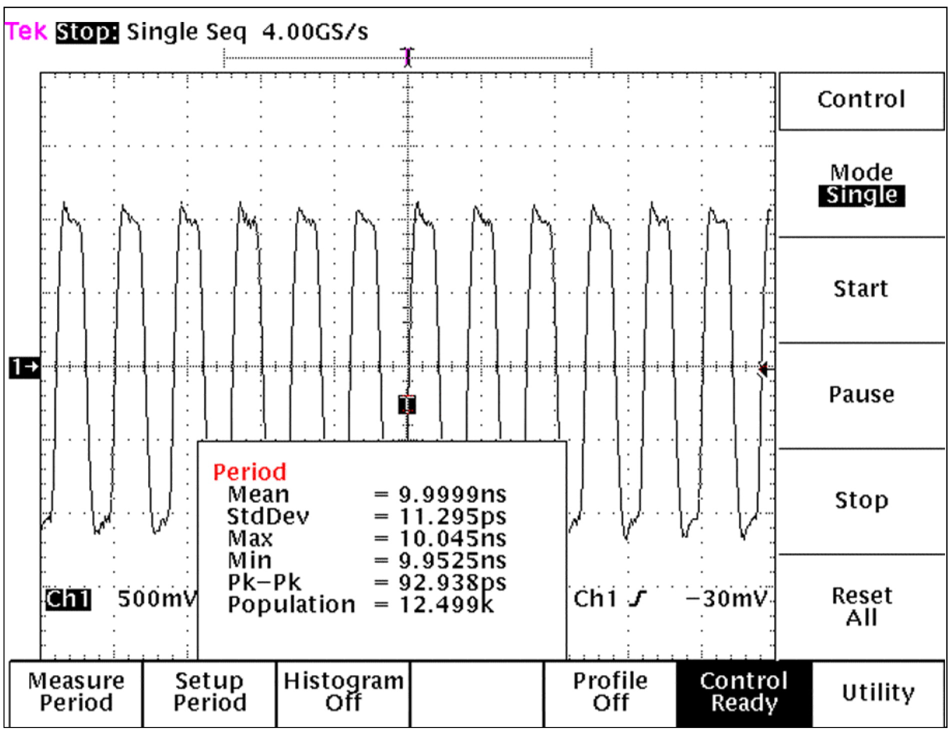


Figure 4. Period measurement with new jitter measurement technique.

Histograms and Histogram Statistics. Jitter can also be measured with the histogram technique, as shown in Figure 3. In this example, the 100 MHz clock is jittering with a standard deviation of 16 ps. In addition, the difference between the smallest and largest period is 200 ps. The histogram technique also provides other statistics, such as the sample size used in calculating the statistics (103.59 khits) and the mean (9.998 ns).

A New Way For Oscilloscopes To Measure Jitter

In Figure 4, a Tektronix TDS oscilloscope equipped with the new Tektronix TDSJIT1 jitter measurement package performs a period measurement on a 100 MHz clock. In this example, the clock period has a jitter of 11.295 ps RMS (StdDev), the smallest period is 9.9525 ns (Min) and the largest period is 10.045 ns (Max). The measurement package also provides automatic calculation of Mean, Pk-Pk, and Population.

How is this new technique different? Consider making a period measurement on a clock signal. The traditional automatic and histogram measurement techniques are performed over multiple triggered acquisitions as shown in Figure 5.

With automatic measurements, the scope essentially determines the set-up parameters (measurement level, etc.), makes measurements on the first complete waveform cycle, and the results are statistically accumulated from all acquisitions. The technique is highly automated and involves minimal user input.

With traditional histogram measurements, the user has some control of the measurement and can eyeball the best histogram location. It requires more user interaction than the automatic measurements. The user is rewarded with significantly more statistical information plus a histogram.

In both cases, however, data comes from multiple triggered acquisitions. A single period is measured in each acquisition and no measurements are made between acquisitions. Also, trigger jitter of the scope influences acquisitions and can add to measured jitter.

The new jitter measurement technique, performed by the Tektronix TDSJIT1 jitter measurement software, measures jitter on each and every period in an acquisition waveform whose length can range from 500 to 8 million points (Figure 6).

Jitter measurements can be performed on all contiguous cycles in a single triggered acquisition. This allows jitter measurements to be made, for example, on adjacent periods of a clock – providing a modulation view of the clock and other capabilities such as clock profiling.

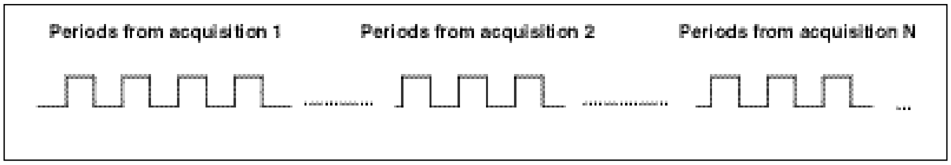


Figure 5. Multiple triggered acquisitions.

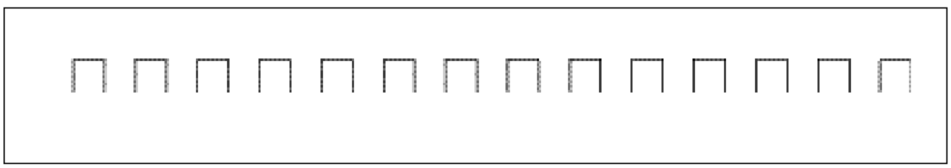


Figure 6. Contiguous periods from a single-triggered acquisition.

Period stability measurement. As timing margins decrease, clock systems must have very specific limits for period stability. In Figure 7, the TDS694C oscilloscope was allowed to accumulate 22,808 periods of a clock that has a period specification of 20 ns ±100 ps. The min and max read-outs indicate that the clock handily meets the requirement. In addition, the RMS value of 1.7718 ps can be used to estimate worse-case peak deviation. The interpolation techniques in the TDSJIT1 measurement package and the timing performance of the TDS694C result in these highly precise measurements.

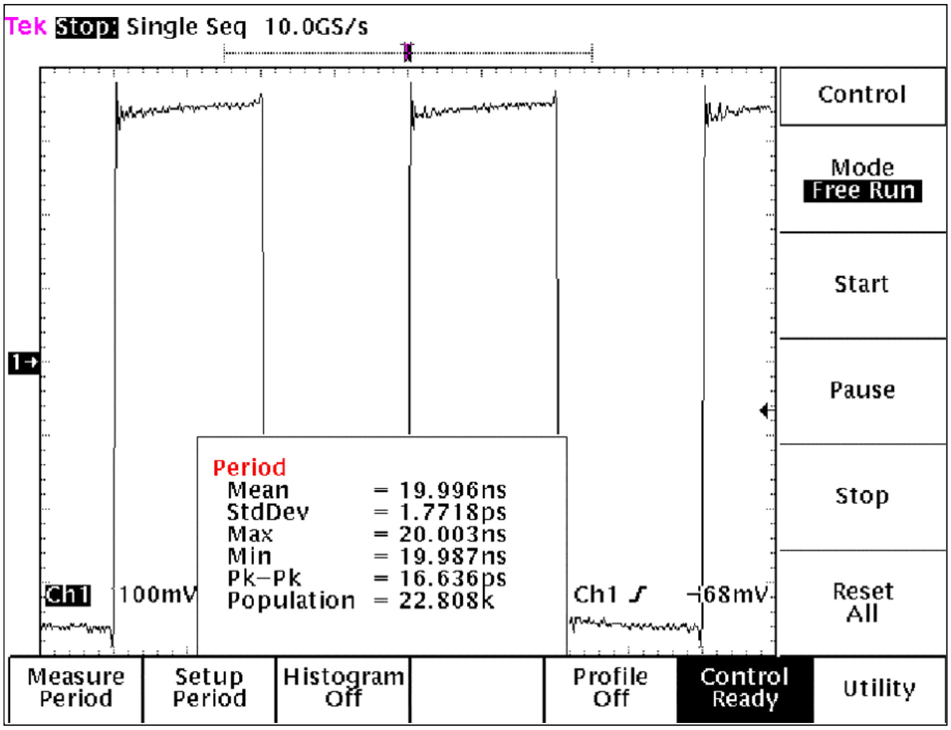


Figure 7. Period stability measurement.

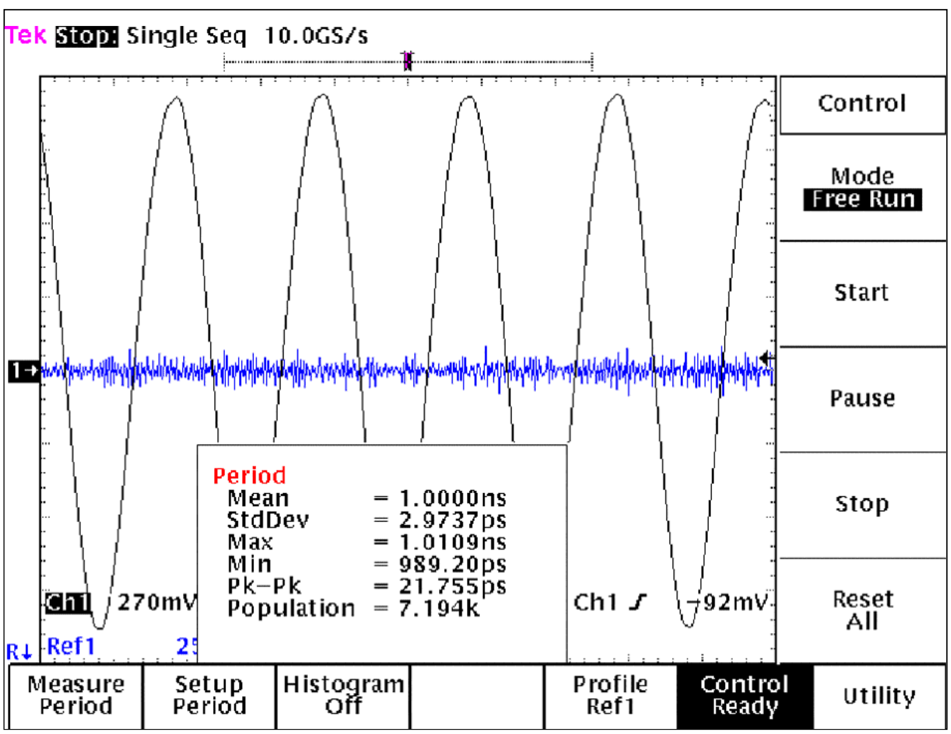


Figure 8. Period jitter in a PLL output.

PLL characterization. PLL performance can be viewed indirectly by observing the DC control voltage on the VCO. However, there are two problems that affect this method. First, probe loading can change and degrade the loop performance. Second, the loop components – i.e., the DC control voltage – are being integrated and are no longer accessible. The only observable signals are the reference input and the PLL output.

Tektronix TDS500D/600C/700D Digital Oscilloscopes equipped with the TDSJIT1 measurement package are ideally suited for PLL characterization. These oscilloscopes produce minimal loading effects and provide automatic measurement of Cycle-Cycle, Period, Frequency, and Skew.

The ability of PLL outputs to track their inputs depends upon the period-to-period variation of the input. Any loss of lock or excessive jitter will cause a lock-up in the processor system. Figure 8 shows TDSJIT1 measurements of the period jitter of a PLL output operating at 1 GHz. In this example, the peak-peak period deviation is 21.755 ps.

Another concern in the design of PLLs, is the effect of the power supply or data cross talk. Figure 8 also shows the Profile of the 7,194 period measurements. The Profile display shows each period measurement plotted against its cycle number in the acquisition record. Note that the profile waveform is randomly distributed with an RMS of less than 3 ps jitter. This indicates neither power supply nor cross talk coupling.

Frequency modulated clocks. Frequency modulation of the clock can occur when switching supply noise or cross talk from data makes its way into a clock. Using the TDSJIT1 Profile feature, you can plot the modulation effect over time and determine the frequency and source of the modulation.

The same can be done with spread spectrum clocking (SSC) techniques, which are used to help circuit designs meet stringent EMI requirements. Modulating a clock with a low frequency causes the energy to be spread over a range of frequencies. The energy still exists but is lower at any one frequency. This technique reduces EMI energy at any particular frequency.

Figure 9 shows the period of a 100 MHz clock modulated with a 31 kHz triangle wave. The profile feature of TDSJIT1 has been activated to show how SSC affects the period measurement.

In Figure 10, you see the cycle-cycle profile of the same clock. Note that the cycle-cycle profile does not show the 31 kHz modulation effects. Although the peak-peak measurement in Figure 9 is 139.18 ps, the maximum cycle-cycle variation in Figure 10 is only 102.01 ps. In properly designed SSC systems, the SSC contribution to cycle-cycle jitter can be characterized and ignored.

This technique is more accurate than the histogram technique – which will show jitter equal to the peak-peak modulation plus the inherent clock jitter. The peak-peak modulation is so large that it tends to swamp out the other jitter terms. Using the single-shot contiguous cycle technique, the modulation from one cycle to the next is fairly small.

In addition, the TDSJIT1 cycle-cycle measurement will show a much smaller value than the TDS histogram technique. With “true” cycle-cycle measurements, the contribution of low frequency SSC modulation is small enough from one cycle to the next that the clock jitter, not the modulation, will be seen. With this measurement, you can specify only the smaller cycle-cycle jitter; not the larger modulated peak cycle-cycle jitter.

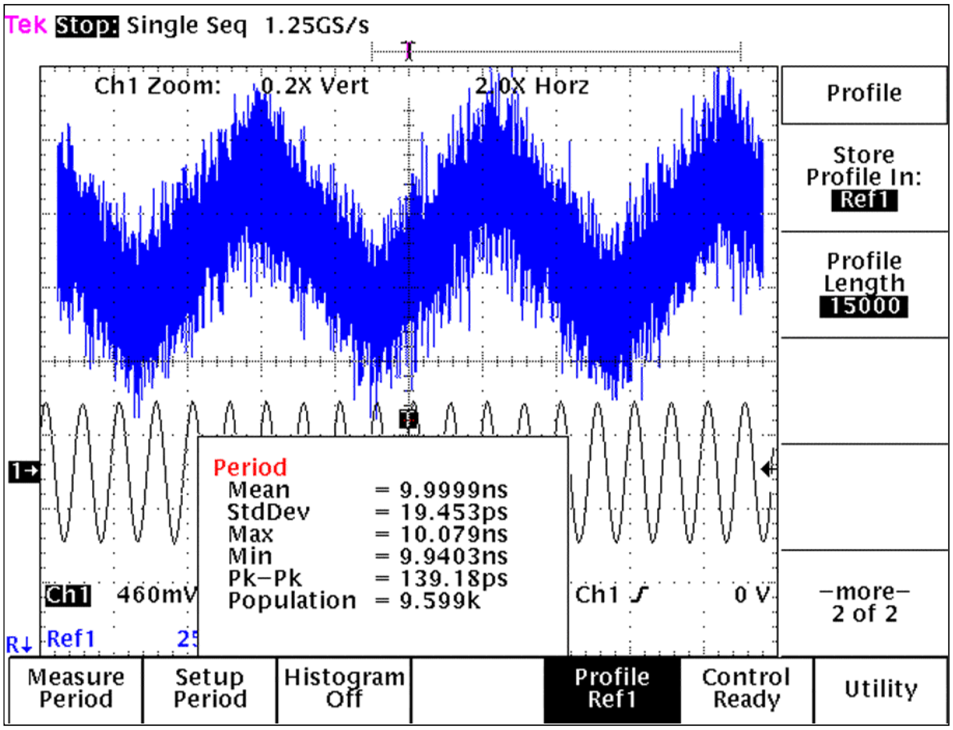


Figure 9. Profile measurement of SSC.

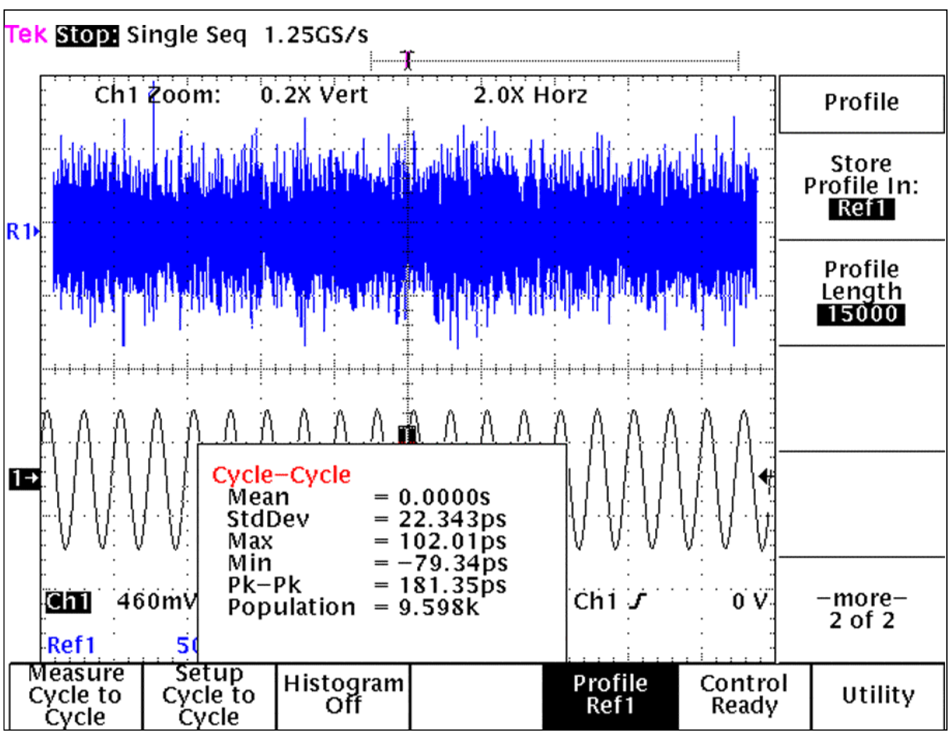


Figure 10. Cycle-cycle profile of SSC system.

Oscilloscope Specifications That Impact Jitter Measurements

The following provides brief descriptions of the most common digital oscilloscope specifications that will impact your jitter measurements. These specifications will vary from scope to scope.

Trigger jitter. The trigger jitter specification of your oscilloscope defines the amount of jitter you can expect the scope's triggering system to add to the device under test. It is applicable only to repetitive acquisition jitter measurements, not single-shot jitter measurements detailed here. It is, however, important when making jitter measurements using the traditional histogram/statistic techniques described above and in the Tektronix application note ***Performing Jitter Measurements with the TDS 700D/500D Digital Phosphor Oscilloscopes*** available for download at:

www.tektronix.com/Measurement/App_Notes

Repeatability. This specification determines how close your measurements are to each other. For example, let's assume that the period you are trying to measure is exactly 10 ns. If the measurement system always returns an 11 ns period, repeatability is excellent, but the measurement is still inaccurate. It is very important, therefore, that good repeatability be combined with excellent delta time accuracy – a measure of how close the system will measure to the real value (see below).

Resolution. This specification determines how precisely you can turn measurement values into "small" units. Like repeatability, this specification is contained within the delta time accuracy specification. If, for example, the measurement system returns 10.001 ns for a 10 ns period, it is providing a resolution of 1 ps.

Delta time accuracy. Delta time accuracy is the most important specification for single-shot timing measurements because it determines how close these measurements will be to the real values. It takes into account both the repeatability and resolution specifications mentioned above.

Delta time accuracy specifies the worst case peak deviation from what is expected. In an oscilloscope, it is based upon a number of factors including sample interval, time base accuracy, quantization error, interpolation error, amplifier vertical noise, and sample clock jitter. Each of these factors contributes to the timing error, so the combination of all these factors results in the delta time accuracy specification.

For example, the maximum delta time accuracy specification for the new 10 GS/s, 3 GHz Tektronix TDS694C is 15 ps. This worst case specification is a tested specification under varying input conditions. However, depending upon the input applied, the TDS694C has the ability to measure down to much smaller errors. In Figure 11, over 10,000 cycles of a very precise clock source was measured to have <1.5 ps RMS jitter and <11 ps peak error.

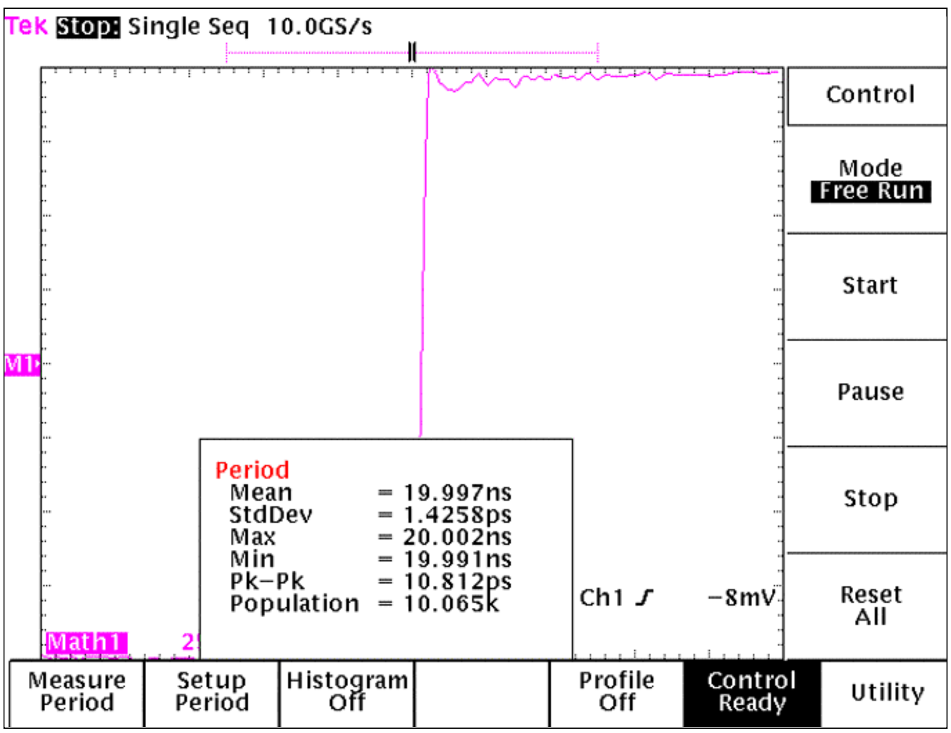


Figure 11. Delta time accuracy of the TDS694C.

Conclusion

With the Tektronix TDS Digital Oscilloscopes and the new TDSJIT1 measurement package, Tektronix introduces a way to make more accurate jitter measurements. By combining advanced interpolation techniques with the new TDSJIT1 measurement technique, new automatic measurement capabilities, an extremely high-bandwidth acquisition engine, and 8 MB record lengths on each channel, the TDS500D/600C/700D Digital Oscilloscopes allow the customer to make jitter measurements of unprecedented accuracy from single-triggered acquisitions.

For further information, contact Tektronix:

Worldwide Web: For the most up-to-date product information, visit our web site at www.tektronix.com.

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