DTS MEASUREMENT TECHNIQUE

Getting Started

Introduction

The focus of this note is to quickly familiarize you with DTS measurement fundamentals. This information will help you understand the DTS sampling method and allow you to more comfortably utilize all of it's capabilities. Refer to the manual for a more detailed description of all possible tool configurations.

At its most basic level, the DTS is a very accurate and repeatable time measurement device. It measures the time between two events. Inside the DTS, many time measurements (samples) taken and compiled into a histogram. The statistical information from this histogram is the lowest level of information provided by the DTS, and can be viewed on the front panel. This information includes sample size, mean, peak to peak, and 1-sigma (Referred to as "JT" on the front panel).

This information can then be sent over the GPIB interface to the Wavecrest Virtual Instruments (VI) software, Advanced Production Interface (API) software, or to a users' custom software. The information from many histograms can be compiled into plots, providing further information about signal integrity. This information includes values of jitter accumulation, jitter frequency and power, and magnitude of components of Deterministic and Random Jitter.

Different Measurement Methodologies of the Wavecrest DTS and Digital Sampling Oscilloscopes (DSO)

The DTS *does not* reconstruct waveforms and it is *not* a triggered instrument. This is very important to understand and remember.

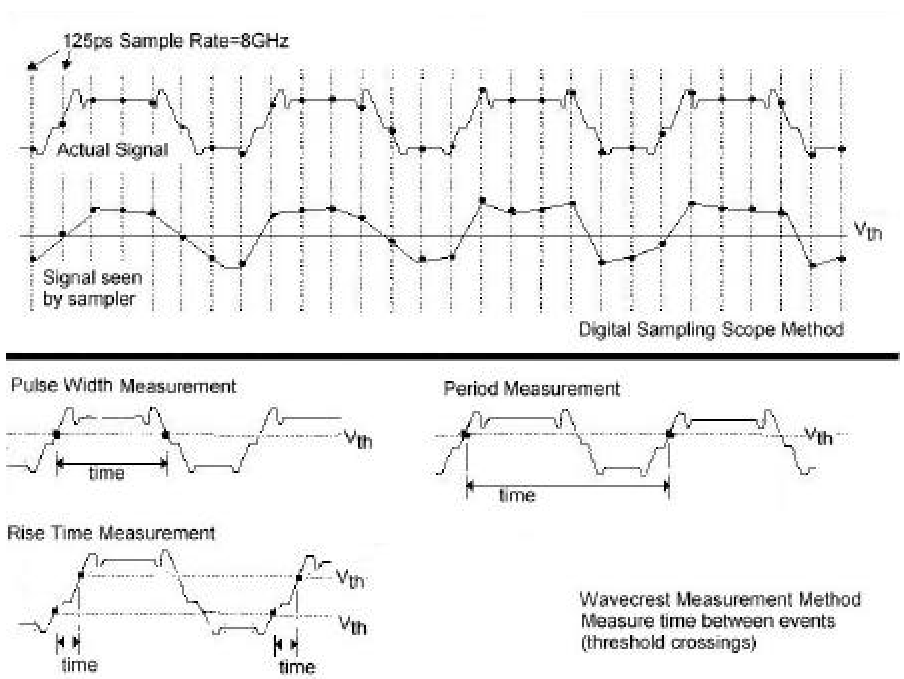

Figure 1. DSO and DTS measurement differences. DSO samples may not occur at the threshold crossing. Digital circuits respond to threshold crossings, so accurate time measurement of these events is vital for jitter analysis.

The DTS measures the time between two "events" which are threshold crossings. This differs from the digital sampling oscilloscope which measures the voltages with respect to time relative to a trigger.

A benefit of making Event based measurements is that the actual edge placement can be determined (to the 800fs hardware resolution of the DTS). Sampling scopes interpolate data between sampled points to determine the time of the threshold crossing (see figure 1). Accurately determining edge placement is vital to gather jitter information. Also, DTS measurements do not use a trigger ensuring that there is no possibility of synchronizing a measurement to a jitter source. Use of a trigger with jitter on it could mask out a jitter contributor. The DTS uses asynchronous random sampling of events to derive a solid statistical distribution of the event times and will not mask out any jitter contributors.

How does the DTS make a single time measurement?

The DTS measures the time between two events. The events to be measured are determined by the comparators and Nth Event counters. The time between the events is determined by the interpolators and course counter. The results are then processed by the CPU. See Figure 2.

Channel 1 and Channel 2 function identically. For simplicity figure 2 shows only one channel.

- "Ref. Start" is the voltage of the Start Event threshold crossing.
- "Ref. Stop" is the voltage of the Stop Event threshold crossing.
- The Nth Event counters allow the DTS to skip a number of edges measuring the time over a number of events. This allows the DTS to see jitter in the modulation domain.

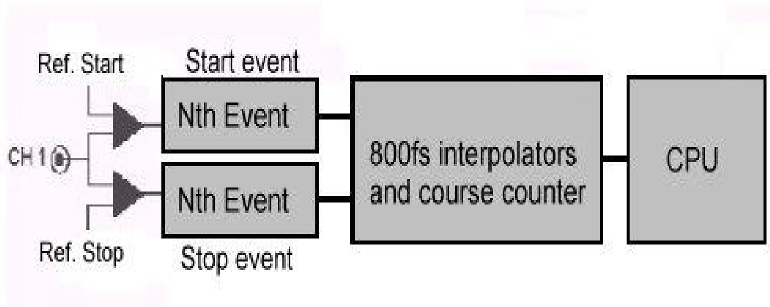

Figure 2 DTS simplified block diagram

All Events are based on threshold crossings. There are two interpolators, one for start and one for stop. A start event is a threshold crossing of the Ref. Start voltage. When this occurs, the start interpolator begins a time measurement. The start ramp is required to charge over a full cycle of the 100MHz time base (period of 10ns) in addition to the time that may have elapsed since the ramp began to charge. This ramp is always between 10ns and 20ns in length (see figure 3). This process insures that only the linear portion of the ramp is used. The stop event then causes the stop ramp to charge in a similar fashion.

The ramps can be thought of as the fine-count part of the measurement. The DTS derives its accuracy and resolution from the ramps. The ramps and calibration method are proprietary Wavecrest technology. The internal calibration routine builds a look-up table for an analog to digital converter (ADC). The table is created by dividing the 10ns usable portion of each ramp into over 14000 increments or bins. Each bin is less than 800fs from its neighbor giving the DTS its fine hardware resolution. This look-up table provides the time information needed to determine when the ramp stopped charging.

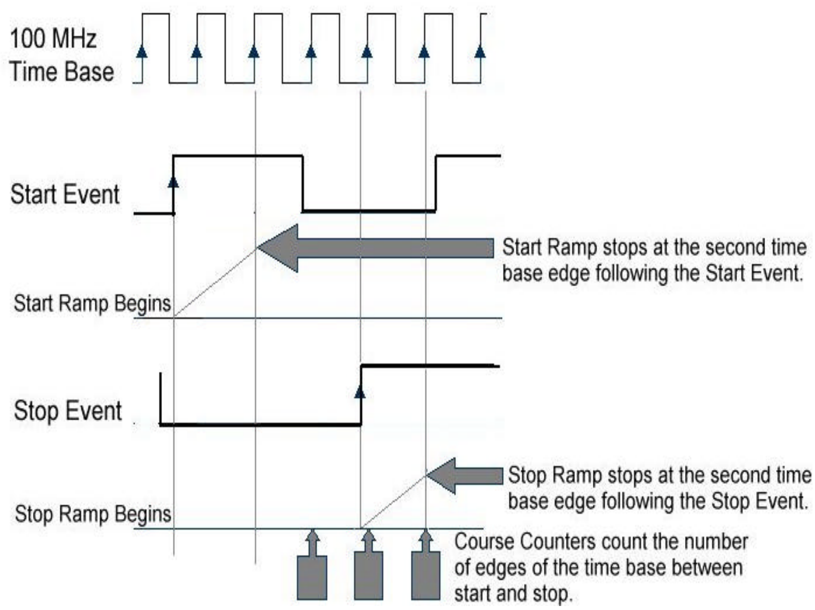

Figure 3 Diagram of time measurement.

Measurements longer than the ramps are covered by the course counter. The course counter counts cycles of the 100MHz time base between the ramps. In this way, events separated by up to 2 seconds are measured with the same 800fs hardware resolution. The time base is very stable over this amount of time.

Having made a single measurement, how does the DTS derive information about the waveform?

The DTS continues to compile a large number of measurements (set by "Sample Size" on the front panel or "Hits per Edge" in VISI6 software). It gathers samples asynchronously every 21μs to 25μs. This time is purposely randomized in order to provide a valid statistical distribution of events that make up the waveform. Additionally, by randomizing this acquisition time, there is no chance of masking out a jitter signal that could match a sampling rate. A histogram is created from these measurements.

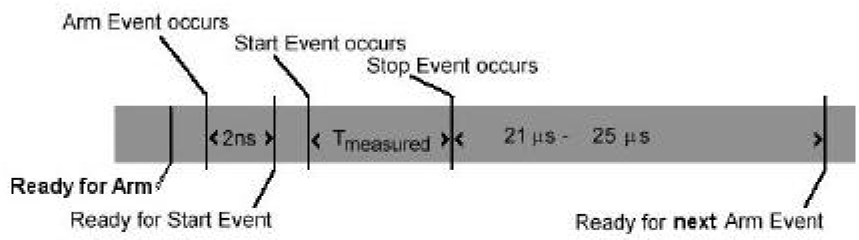

Figure 4 Measurement timeline when using External Arm

The DTS uses an Arm event to determine when a measurement is made. This is not a trigger because measurements are not made relative to it. Rather, it is a "get-ready" or enable signal, which tells the ramps, and CPU that a measurement is about to be made. The Automatic (internal) Arm defaults to Arm on Stop. This uses the last measured Stop Event as the arm (get ready) for following events to be measured. An External Arm may be used to measure relative to some other signal. In this case, there is an internal delay of 2ns between the Arm event and the first event to be measured. Assuming a single channel measurement, the event occurring on the measurement channel 2ns after the Arm will be the Start Event as seen in Figure 4.

The burst of measurements taken, form a histogram from which more meaningful statistical information can be derived (such as mean, peak to peak and 1-sigma). Other tools in the *Virtual Instruments* software make use of the Nth event counters from figure 2. By skipping a number of edges, the Nth event counters give the DTS the ability to derive information about the long-term characteristics of the waveform.

Histogram of measurements

The measurements are compiled as a histogram. A histogram is a way of displaying a statistical distribution of samples. In the case of the DTS, the number of samples in the histogram is set by Sample Size. The time measurements are binned according to the time on the x-axis. The height of the bin is determined by how many samples (y-axis) are in it.

From the histogram, we can then determine peak-to-peak, 1-sigma, and mean. See figure 5.

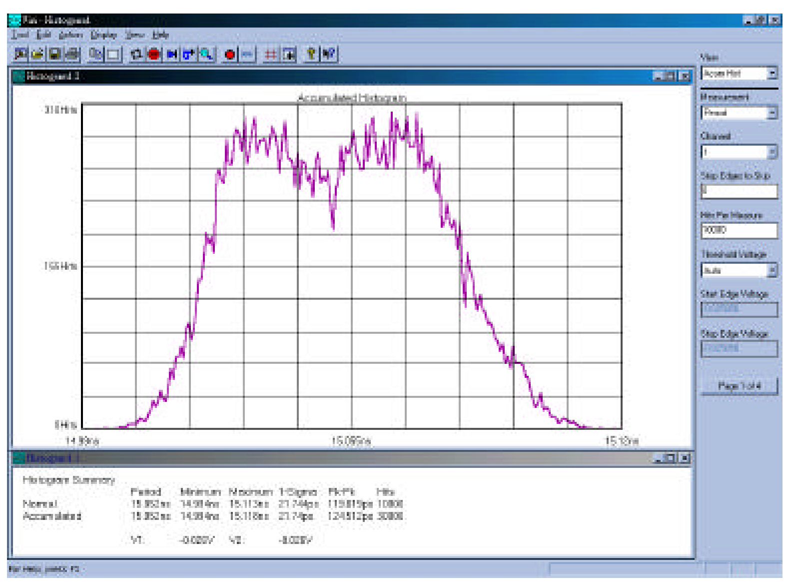

Figure 5 Shows a Histogram of period measurements

Jitter Accumulation—Viewing the modulation domain

The High Frequency Modulation Analysis tool automatically increments the stop counter. This allows the DTS to make a histogram, say over one period, then two periods and on to a designated stop point. Data from the histograms can then be plotted relative to number of events, allowing the user to see any jitter modulation.

In figure 6, periods are shown, though any function such as rise time, fall time, propagation delays or frequency can also be measured. The DTS makes many random time measurements every 21 to 25µs. After gathering the number of samples set by sample size, the DTS forms a histogram of single period measurements. The stop count is automatically incremented, and the preceding steps are repeated to build a histogram of two periods, etc. This entire process automatically continues until the High Stop Count has been met.

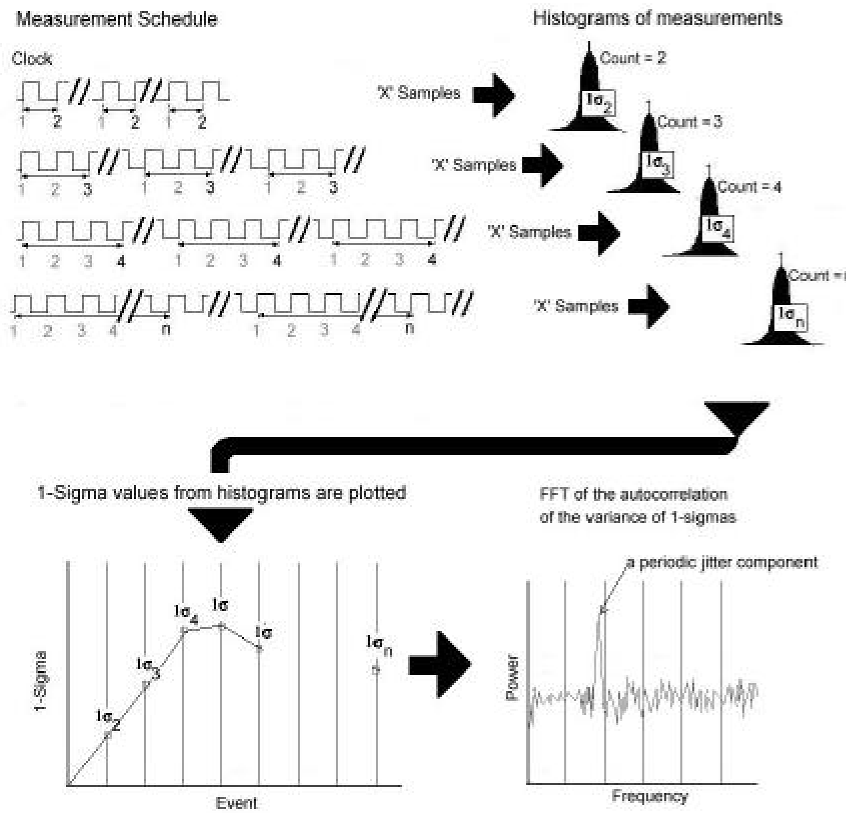

Figure 6 The High Frequency Modulation Analysis increments the Stop Counters to build many histograms and plot the accumulation of jitter.

The statistical data from the histograms—such as 1-sigma—can be plotted relative to the event. Any jitter modulation of the clock will show up in this plot as a periodic rise and fall. Performing an FFT of the autocorrelation of the variance from the 1-sigma information will give a frequency vs power plot allowing the user to see the frequency components of the jitter modulation.

Locktime Tool

In a different tool, Locktime, *both* the Start and Stop counters are automatically incremented. The Locktime tool enables the user to view information about the measured function (period, frequency, rise/fall time, and propagation delay between two channels) using an external arm as a point of reference (as described in figure 4). A recurring signal must be used as the point of reference since a measurement is made after every arm event. This allows user can view any synchronous jitter pattern that may exist. The tool also allows the user to view the frequency or period settling time of a PLL after a change, such as a lock signal or input frequency change.

For this example, although period measurement will be described, measuring other functions is conceptually the same. After an arm event, Locktime measures single functions, such as period, and compiles a histogram. Each of these is measured randomly every 21µs to 25µs. After gathering the number of samples set by sample size, the Start and Stop counters are incremented to measure the period following the one it previously measured, compiling a histogram. This process automatically continues until the High Stop Count has been met. See figure 7.

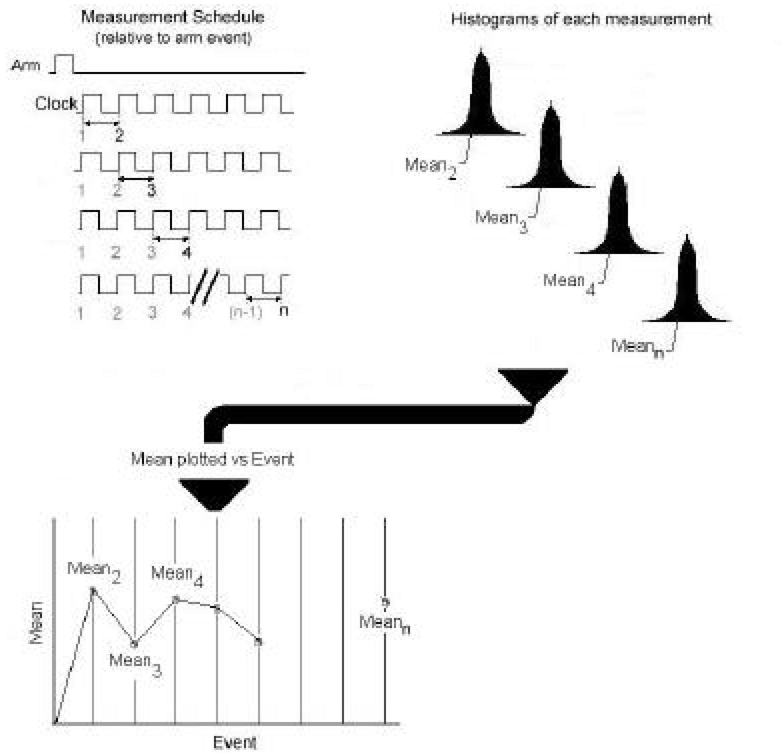

Figure 7 Locktime example

Conclusion

The DTS and Virtual Instruments software tools give the user the ability to accurately measure functions such as rise-time, fall-time, period, frequency, pulse width, and propagation delay. Histograms of measurements provide statistical information such as mean, 1-sigma, peak-to-peak, maximum and minimum values. In addition to basic measurements, the DTS and software tools allow the user to determine frequency components and magnitude of jitter from an FFT.

Advanced software tools beyond the scope of this paper are also available: “Tail-Fit” allows decomposition of jitter into random and deterministic components. “DataCom” performs analysis of jitter on data patterns relative to the ideal pattern. The Random Data with Bit Clock tool analyzes rising and falling edges of data relative to a bit-clock and presents information similar to an eye diagram.

Refer to the Getting Started for each tool for a better understanding of how each one makes its measurement and displays the data.

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