MEASUREMENT THEORY

For the SIA-3000

Introduction

The focus of this note is to quickly familiarize you with SIA-3000 measurement fundamentals. This information will help you understand the sampling methodology and allow you to more comfortably utilize all of the SIA-3000's capabilities. Refer to the User's Manual for a more detailed description of all possible tool configurations.

At its most basic level, the SIA-3000 is a very accurate and repeatable time measurement device. It measures the time between two events. Inside the instrument, many time measurements (samples) are taken and compiled into a histogram. Histograms are the most basic level of information provided by the SIA-3000. The basic statistics from a histogram include sample size, mean, peak to peak, 1-sigma, maximum and minimum values. Most of the analysis tools plot statistics from many histograms.

The Histogram Tool provides the capability to analyze the histogram itself. If the histogram is non-Gaussian, the Tail-Fit algorithm will separate the Random Jitter (RJ) and Deterministic Jitter (DJ) to provide an estimation of Total Jitter (TJ) at a particular bit error rate.

Different Measurement Methodologies of the Wavecrest SIA-3000 and Digital Sampling Oscilloscopes (DSOs)

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

The SIA measures the time between "events" which are threshold crossings. This differs from the digital sampling oscilloscope, which measures the voltages with respect to time relative to a time-base synchronized by a trigger.

A benefit of making "event" based measurements is that the actual edge placement can be determined (with the 200 femto-second hard-ware resolution of the SIA). Sampling scopes may 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, SIA-3000 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 SIA uses asynchronous random sampling of events to derive a solid statistical distribution of the event times and will not mask out any jitter contributors.

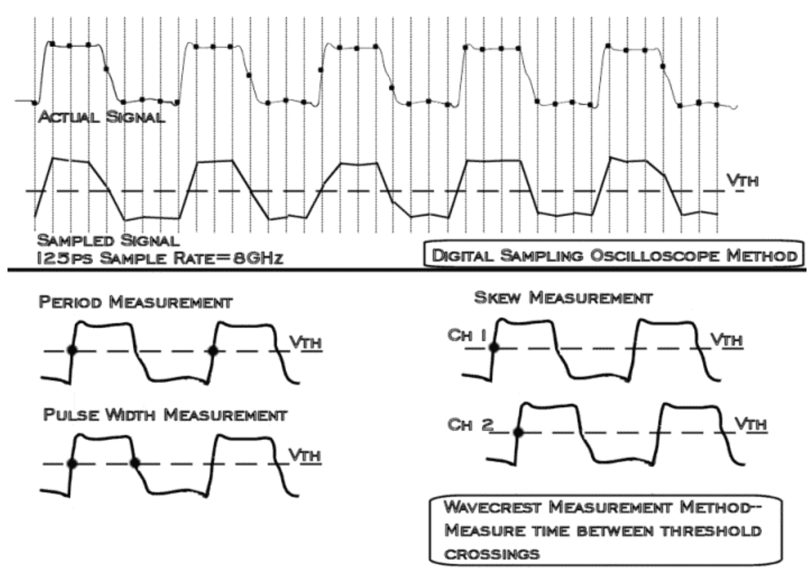

Figure 1. DSO and SIA measurement differences. DSO samples may not occur at the threshold crossing. Digital circuits respond to threshold crossings, so accurate time measurement of these events is vital for jitter analysis.

How does the SIA make a single time measurement?

The SIA measures the time between events. The events to be measured are determined by the Nth Event counters. The precise time between events is determined by the analog interpolators (ramps). See Figure 2.

The Input

Figure 2 shows only one channel. All other measurement channels function similarly. The inputs are each 50ohms to ground. Impedance matching modules are available for LVDS/CML to provide 100ohms between the differential inputs. The input signal can be single-ended or differential. If the signal is single-ended, the non-inverting input is used.

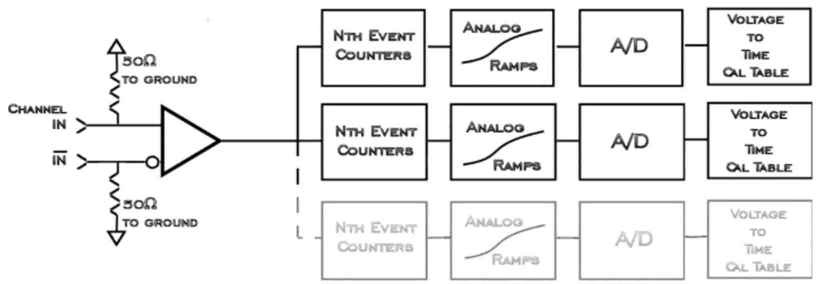

Figure 2. Simplified Block Diagram

The Receiver/Comparator

The differential receiver produces the "event" which, for a single ended signal, is a threshold crossing. For a differential signal the event is the crossing point of the differential signals. The differential receiver output is split to pass the events to the Nth Event counters.

The Nth Event Counters

The counters allow a specified number of edges to be skipped providing the capability to perform modulation analysis or analyze the time between specific edge relationships. Most measurements use only two counters and associated paths. Some measurements, such as "Adjacent Cycle", use a third counter and path. So, for a period measurement, the counters would be set to one and two. When an Nth event counter has registered a specified number of events, the ramp following that counter will start.

The Analog Interpolators/Ramps

The ramps are the main timing circuitry used to measure time between events. The descriptions to follow will discuss "start events" and "stop events". This terminology relates to a *measurement*; so a period measurement "start event" would be a rising edge, the "stop event" would be the next rising edge. This is to distinguish from the start and stop of a *ramp*. A "start event" and "stop event" will each start individual ramps which will then be stopped by the internal time base (Figure 3).

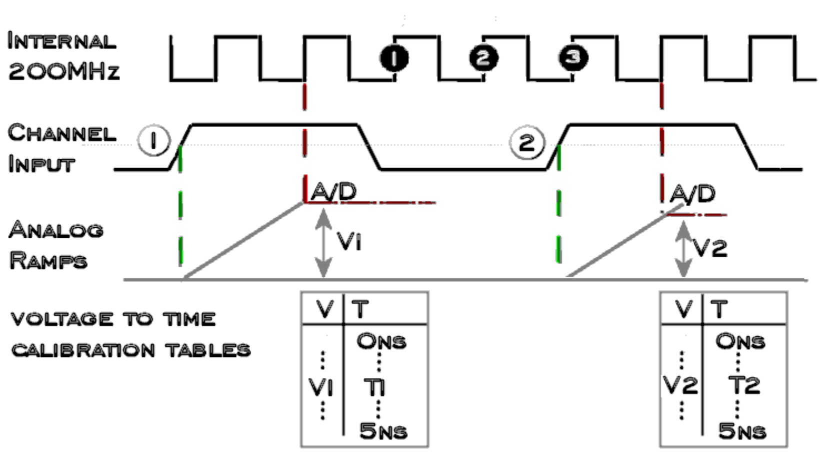

Figure 3. Time measurement example (measured signal is slower than internal 200MHz oscillator)

The ramps can be thought of as the fine-count (vernier) part of the measurement. The ramps and calibration method are patented WAVECREST technology. In Figure 3, two counters and ramps are used. The Nth event counters are set to one and two to capture the first and second edge respectively of the period. While the ramps are initiated by the signal being measured on the input channel, they are stopped by the internal 200MHz time-base. Once a ramp stops, the voltage is read by an analog-to-digital converter (ADC). The rule for stopping the ramp is that the ramp must charge over more than one full period of the 200MHz clock but less than two. In other words, the ramp is stopped by the second rising edge of the 200MHz clock. This ensures that the ramp stops in a linear region. The voltage measurement is then used to find a time from the "voltage-to-time" lookup table.

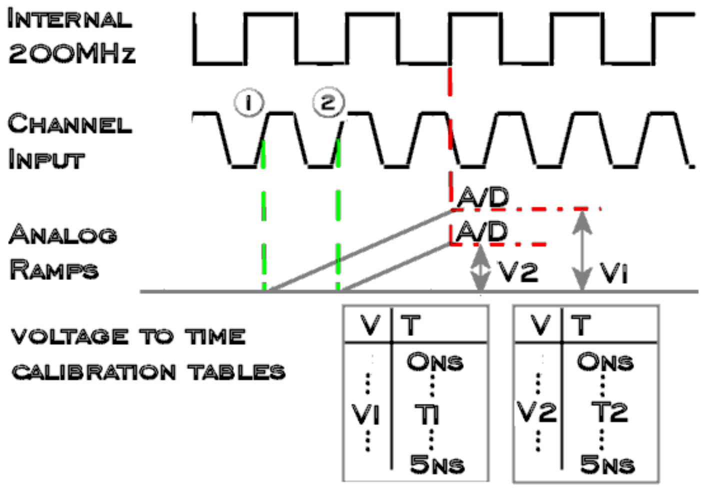

Figure 4. Time measurement example (measured signal is faster than internal 200MHz)

The "Timer Calibration" builds this lookup table (and characterizes the ramps). The table is created by dividing the usable 5ns portion of each ramp into more than 41000 increments or bins. Each bin is less than 100 femtoseconds (fs) from its neighbor giving the SIA an overall hardware resolution of ~200fs per measurement.

Measurements longer than a period of the internal clock are covered by a course counter. Figure 3 shows the course counter adding three edges of the internal clock to the measurement. The course counter counts cycles of the 200MHz time base between the ramps. In this way, events separated by up to 2 seconds are measured with the same 200fs hardware resolution. The time base is very stable over this amount of time. In the case where Course counters are used, it is then important to note that the 200MHz clock is actually synchronized to an ovenized 10MHz oscillator. This provides the best of short-term stability of the 200MHz clock and long-term stability of the 10MHz clock. The equation used to calculate one time measurement between events is

Equation 1. $(T_2-T_1)+5ns*Course\ Count$

Notice that in Figure 4, the course counters are not necessary. This case shows a period measurement for any signal faster than 200MHz.

Using three ramps in the SIA-3000 allows the measurement of three consecutive edges. "Cycle-to-cycle" can be displayed by measuring three adjacent edges. The difference between the two periods is then displayed. For this type of measurements, the three ramps are used and the counters are then set to one, two and three.

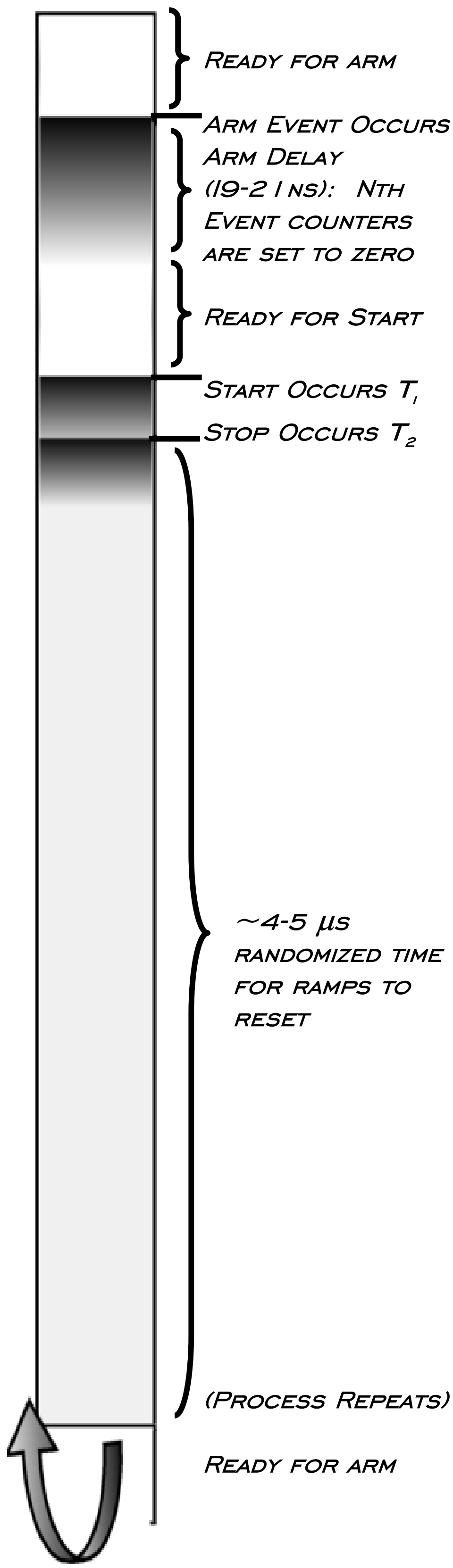

Figure 5. Measurement Timeline

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

The SIA continues to compile a large number of measurements (set by "Hits per Edge" in most tools). It gathers samples asynchronously (without a trigger) in a randomized window of between 4µs to 5µs. This randomized sampling time provides a sound statistical population of randomly sampled events and ensures there is no chance of masking out a jitter component that could match a sampling rate. These measurements are all compiled into a histogram.

The SIA uses an Arm event to determine when a measurement can 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. In doing this, the counters are set to zero, thus the next edge is 1. Arming Mode defaults to Arm on Stop. For a detailed description of arming, see the "Understanding Arming" quick reference guide. A channel other than the measurement channel may arm a measurement; arming mode would be set to "External". There is an adjustable arm delay of between 19 and 21ns before the system is ready for a "Start Event".

The time between a "Start Event" and a "Stop Event" can now be measured. Following the measurement, the ramp circuitry resets and the system is ready for an arm in 4 to 5µs.

Histogram of measurements

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). The Tail-Fit™ algorithm also allows separation of Random and Deterministic Jitter. These components can be used to calculate Total Jitter. See "Histogram Quick Reference Guides".

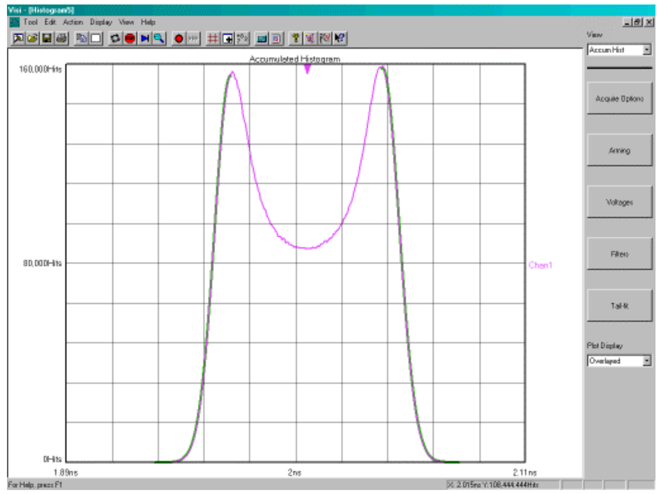

Figure 6. Typical display of histogram.

Jitter Accumulation and Periodic Jitter—Viewing the modulation domain

Other tools in the *VISI* software make use of the Nth event counters from Figure 2. By skipping a number of edges, the Nth event counters give the SIA-3000 the ability to derive information about the long-term timing characteristics of the signal. The spectral content of the jitter can also be determined. This is periodic jitter (PJ)

The High Frequency Modulation Analysis tool automatically increments the stop counter. This allows the SIA 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. Performing an FFT of the autocorrelation of the variance from the 1-sigma information will give a frequency vs power plot. This shows the frequency components of the jitter modulation. Figure 7. Measuring Periodic Jitter shows the measurement theory.

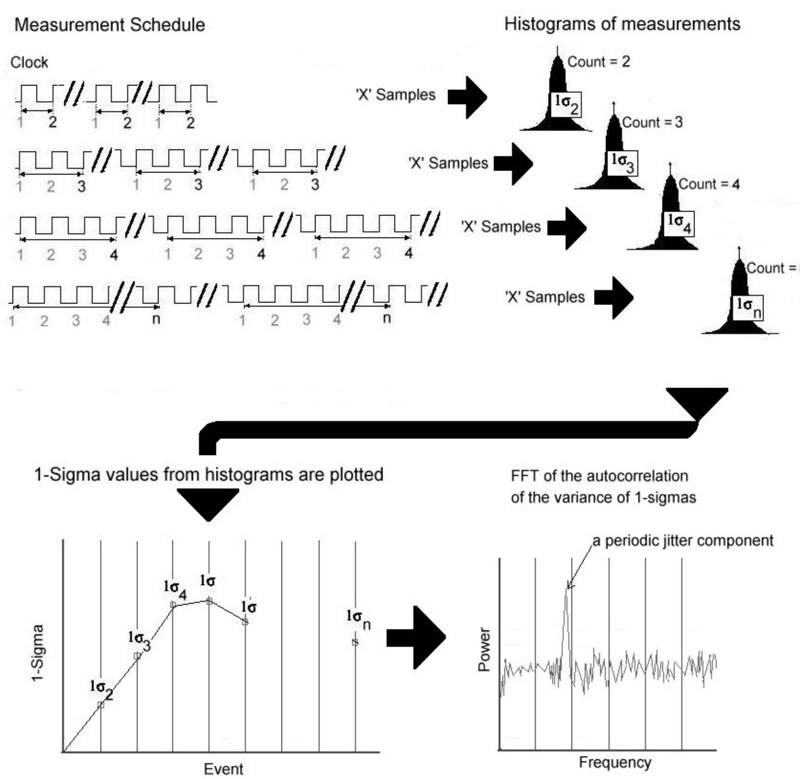

Figure 7. Measuring Periodic Jitter

Conclusion

The SIA-3000 and VISI software tools provide the ability to accurately measure different components of jitter. Histograms of measurements provide statistical information such as mean, 1-sigma, peak-to-peak, maximum and minimum values. Using the Tail-Fit algorithm, Random, Deterministic and Total Jitter can be measured. Other software modules allow similar types of measurements on Serial Data Signals

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

FEEL FREE TO CONTACT US:

WAVECREST CORPORATION
7626 GOLDEN TRIANGLE DR
EDEN PRAIRIE MN 55344
WWW.WAVECREST.COM
1(952)-646-0111

09.12.02_tag