

*WAVECREST CORPORATION*

Examining Clock Signals And Measuring Jitter  
with the *WAVECREST* SIA-3000™

Application Note No. 142

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U.S. Patent Nos. 4,908,784 and 6,185,509, 6,194,925, 6,298,315 B1, 6,356,850, 6,393,088 and R.O.C. Invention Patent No. 146548; other United States and foreign patents pending.

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# EXAMINING CLOCK SIGNALS AND MEASURING JITTER WITH THE *WAVECREST* SIA-3000™

## Application note #142

### Introduction

The purpose of this application note is to highlight the various clock measurement tools available in the *VISI*™ software. The basic steps for specific tool setup and interpretation of the resulting plots are covered. More details for each tool are provided in the following *WAVECREST* Quick Reference Guides: *Understanding Jitter*, *SIA-3000 Measurement Technique*, *Oscilloscope*, *Histogram*, and *High Frequency Modulation*. These guides provide details of tool settings, measurement setup and theory of measurement.

This application note will discuss how to use the various *VISI*™ tools to fully characterize your signal. These tools allow many different parameters of a clock signal to be measured including:

- Random Jitter (RJ)
- Deterministic Jitter (DJ)
- Total Jitter (TJ)
- Periodic Jitter (PJ)
- Cycle-to-Cycle Jitter
- Duty Cycle
- Frequency
- Low Frequency Periodic Jitter
- Spectral View of PJ and RJ
- Timing Characteristics:
  - Positive Pulse width
  - Negative Pulse width
  - Period (rising edge to rising edge)
  - Negative Period (falling edge to falling edge)
- Long term changes (varying Vcc or Temperature)
- Skew or Propagation delay between any combination of rising and falling edges on 2 channels

## OSCILLOSCOPE

TO MEASURE:

RISETIME

FALLTIME

VOLTAGE PARAMETERS

EYE MASK

FOR MORE INFORMATION  
ON THIS TOOL, REFER  
TO:

**OSCILLOSCOPE QUICK  
REFERENCE GUIDE**

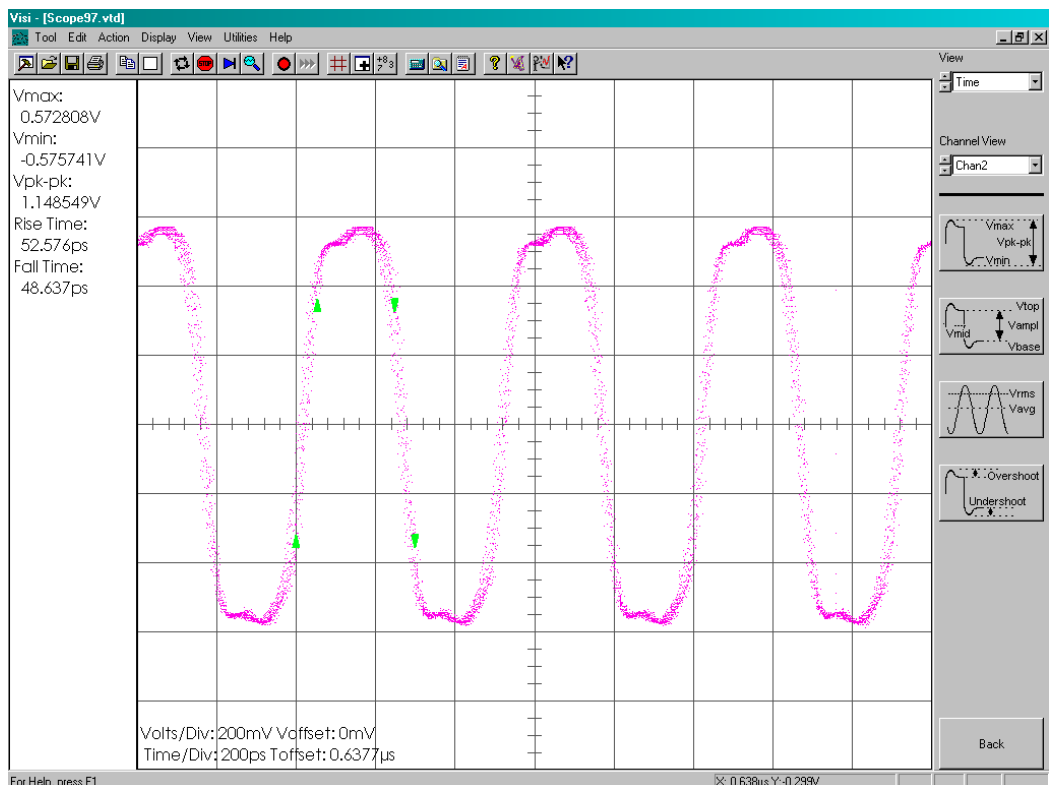


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## Amplitude Measurements

Assuming the engineer has an idea of the device's pins or test setup probe points, it is helpful to view the signal in the **Oscilloscope Tool**. Eye masks can be created using the integrated sampling oscilloscope on the channel cards. The information in this tool is for qualitative analysis as well as measuring voltage parameters including rise or fall times. A different measurement engine is used for jitter analysis (those tools follow this page).

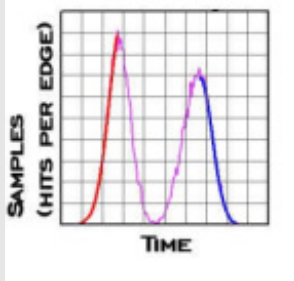
- Connect the clock signal under test to IN1 on the front panel.
- Press the **Oscilloscope** button. This will open the Oscilloscope tool. The channel and trigger settings default to IN1.
- Press the **Auto Scale** button to configure the display and perform an initial measurement. Signal should be  $\leq 1V_{pk-pk}$  single ended or  $\leq 2V_{pk-pk}$  differential.
- Press the **SINGLE/STOP** button to acquire the signal. The signal will be displayed.



**Figure 1 - Oscilloscope example**



## HISTOGRAM



TO MEASURE:



FOR MORE INFORMATION  
ON THIS TOOL, REFER  
TO:

**HISTOGRAM QUICK  
REFERENCE GUIDE**



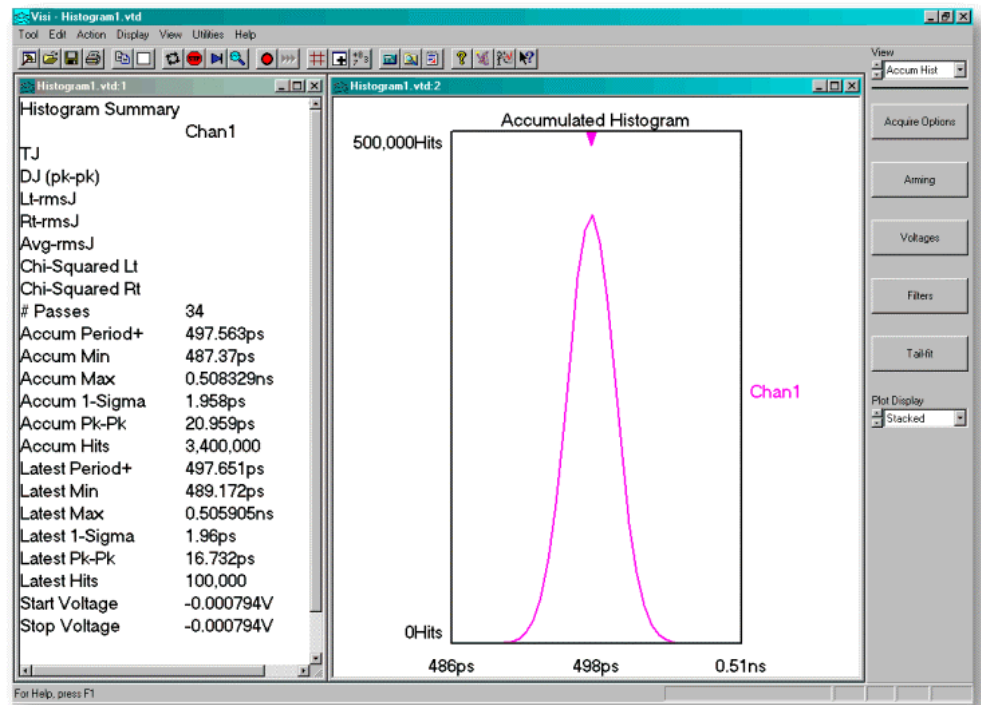
AVAILABLE AT  
[WWW.WAVECREST.COM](http://WWW.WAVECREST.COM)

## Measuring Jitter with Histogram tool: 1-sigma, peak-to-peak

- Press “Tool” to open the main menu
- Press **Clock** then **Histogram** to open the histogram tool.
- Press the **SINGLE/STOP** button on the front panel or the top menu. The tool defaults to make a period measurement (rising edge to the next rising edge). The tool defaults to a sample size of 10,000 measurements.

Basic statistics displayed on the Histogram Summary View are: Mean, Min, Max, 1-sigma, peak-to-peak, and number of hits (Figure 2).

Results from the most recent pass are displayed as “Latest” text. Results from accumulated statistics are display as “ACCUM” text. The Maximum Histogram view (below) shows all accumulated measurements.

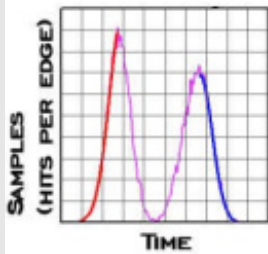


**Figure 2 - Histogram Period Measurement**

A histogram can be made of PERIOD (+), PERIOD (-), PULSE WIDTH (+) and PULSE WIDTH (-) measurements.

These Histogram statistics may be sufficient for jitter analysis when no deterministic jitter is present, but with the addition of DJ, it is helpful to perform a more comprehensive analysis. When the histogram is Gaussian, the 1-sigma equals the Random Jitter (RJ). The addition of Deterministic Jitter (DJ) will increase the 1-sigma. *WAVECREST's* Tail-Fit™ algorithm can be enabled to better estimate the true RJ.

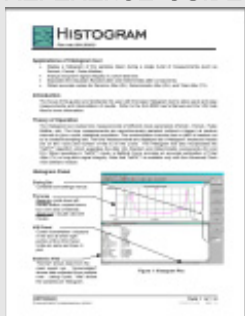
## HISTOGRAM WITH TAIL-FIT™ ENABLED



TO MEASURE:



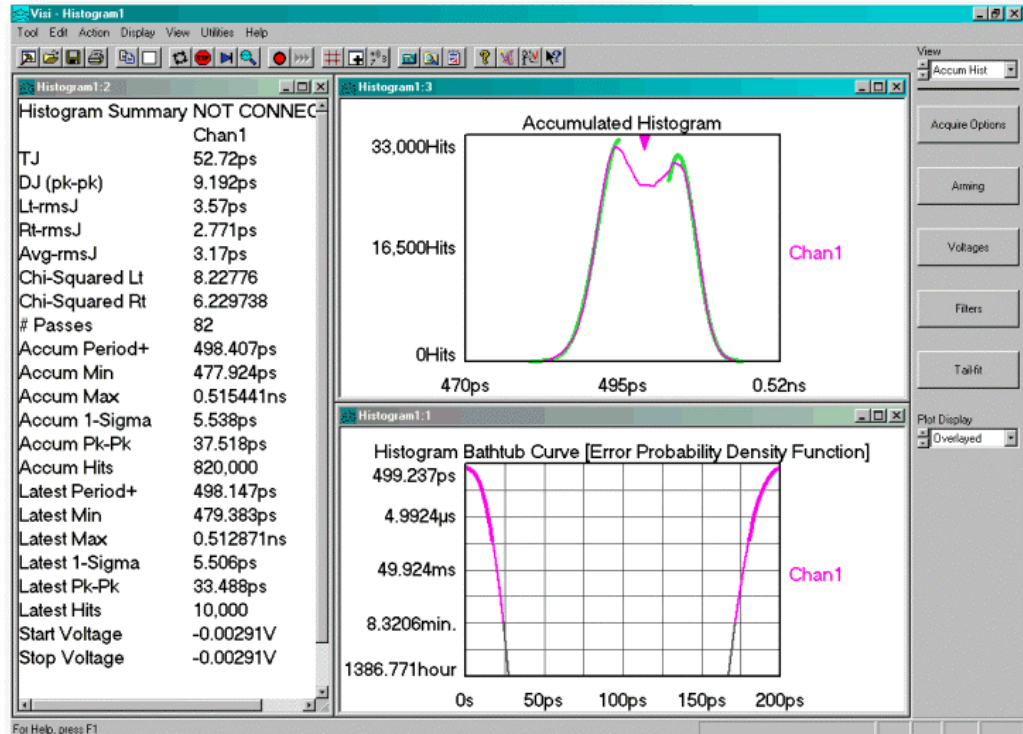
FOR MORE INFORMATION ON THIS TOOL, REFER TO: **HISTOGRAM QUICK REFERENCE GUIDE**




AVAILABLE AT [WWW.WAVECREST.COM](http://WWW.WAVECREST.COM)

## Use Tail-Fit™ to separate RJ and DJ. Predict Total Jitter (TJ) at a specific Bit Error Rate (BER) or amount of time

- Press the Tail-Fit button. This will open the Tail-Fit menu
- Under the Tail-Fit selection, change “off” to “Enabled”.
- Press Clear to clear your measurements.
- Press RUN. The measurement will stop when the tail regions can be fit. Additional information can now be displayed.



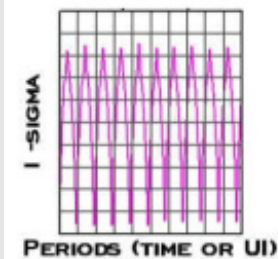
**Figure 3 - Results of Histogram with Tail-Fit™ enabled. Measurement is on a 2GHz clock**

- Add a view by pressing ADD VIEW on the front panel or press  on the top menu bar. Change this view to “bathtub” to display the bathtub curve.

We can now see additional values in Figure 3 summary view at the top (which were not available in Figure 2). The first value is Total Jitter (TJ), which includes contributions from all deterministic and random components, and is a pk-pk value specified for a Bit Error Rate (BER), or amount of time. The Bathtub curve shows the TJ as a function of BER or time. To predict TJ, we must measure DJ and RJ accurately. Random jitter (RJ) is characterized by a Gaussian distribution and assumed to be unbounded. As a result, it generally affects long-term device stability. Because RJ is Gaussian in nature, the distribution is quantified by the standard deviation ( $1\sigma$ ) and mean ( $\mu$ ). Because RJ can be modeled as a Gaussian distribution, it can be used to predict pk-pk jitter as a function of BER or time. The Tail-Fit™ algorithm curve fits a Gaussian model independently to the right and left sides of the distribution. The Values of DJ, LtRMS (left-tail RJ), and RtRMS (right-tail RJ) are displayed below the TJ. Chi-squared values are also displayed as an indication of the goodness of fit from model to acquired measurements. Once DJ has been found, we can determine the causes.

## HIGH FREQUENCY MODULATION

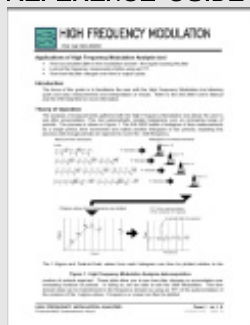
### I-SIGMA VIEW



### TO MEASURE:



FOR MORE INFORMATION ON THIS TOOL, REFER TO: HIGH FREQUENCY MODULATION—QUICK REFERENCE GUIDE



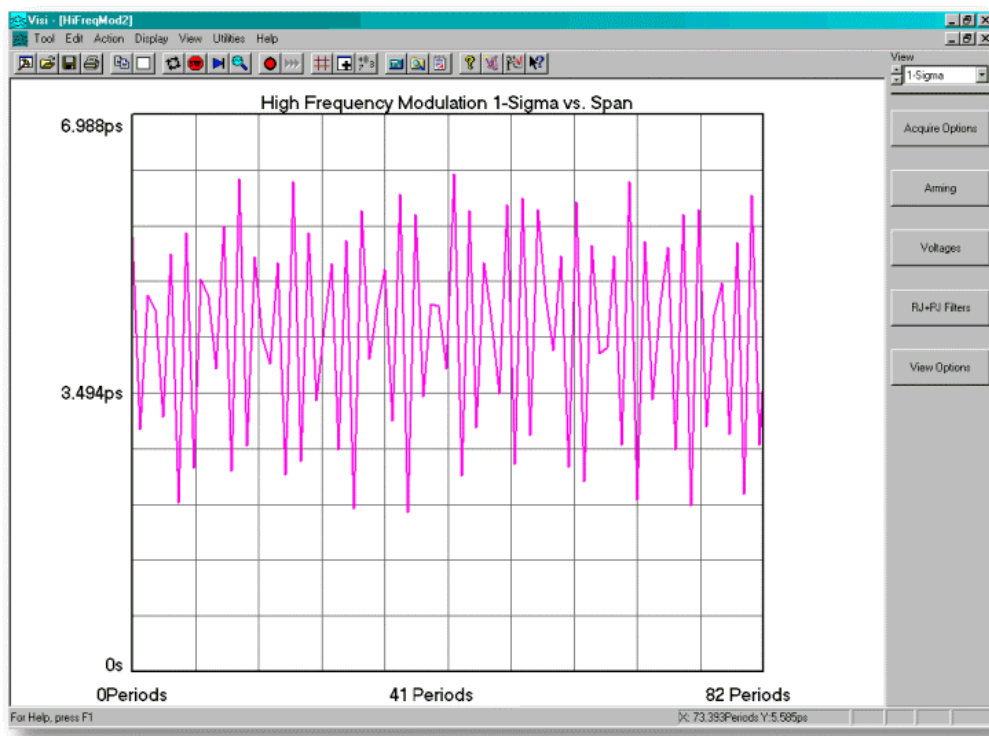
AVAILABLE AT [WWW.WAVECREST.COM](http://WWW.WAVECREST.COM)

## Find the causes of DJ; Identify Periodic Jitter (PJ), crosstalk and modulation

The High Frequency modulation tool shows accumulation of jitter over many cycles and the frequency and amplitude. First, look at the 1-sigma view to see jitter accumulation. This is important because this is the record that will be used for an FFT calculation showing the PJ components.

- From the main menu, press **Clock**, then **High Frequency Modulation** to open the tool.
- Press the **SINGLE/STOP** button on the front panel or the top menu.

This will make a measurement from the “HPF -3db freq” up to  $\frac{1}{2}$  the clock rate. The HPF corner frequency is set in **Acquire Options** menu. This determines the low frequency end of the acquisition. The High-end maximum frequency is always  $\frac{1}{2}$  the clock frequency or less.

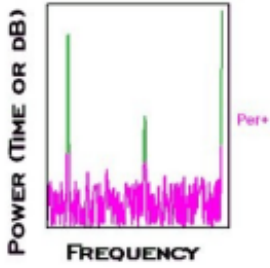


**Figure 4 - 1-Sigma values vs. number of periods skipped. Analysis of 2GHz clock from Figure 2. Note that this is a zoomed view to show details every couple of edges.**

Each point on this plot is the 1-sigma from a histogram. Each histogram encompasses an increasing number of edges, up to 82 in Figure 4. A histogram is made from rising edge to rising edge; the 1-sigma value is plotted on the y-axis at Period 1 on the x-axis. Then a histogram is made from a rising edge to the second rising edge (skipping an edge and thus measuring two periods). This 1-sigma value now corresponds to Period 2 on the x-axis. This process is repeated until enough edges are skipped to encompass the frequency set in “HPF -3dB freq”.

When modulation is present, these 1-sigma values change periodically, as in Figure 4. The example shows alternating high and low values every other edge. Other periodicities are apparent. From these measurements we can determine the periodic jitter frequencies and magnitudes.

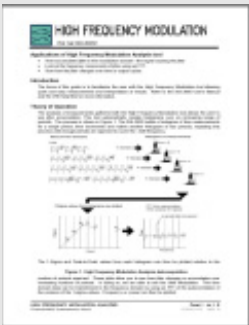
**HIGH FREQUENCY MODULATION  
FFT N-CLK VIEW**



TO MEASURE:




FOR MORE INFORMATION ON THIS TOOL, REFER TO:  
**HIGH FREQUENCY MODULATION—QUICK REFERENCE GUIDE**

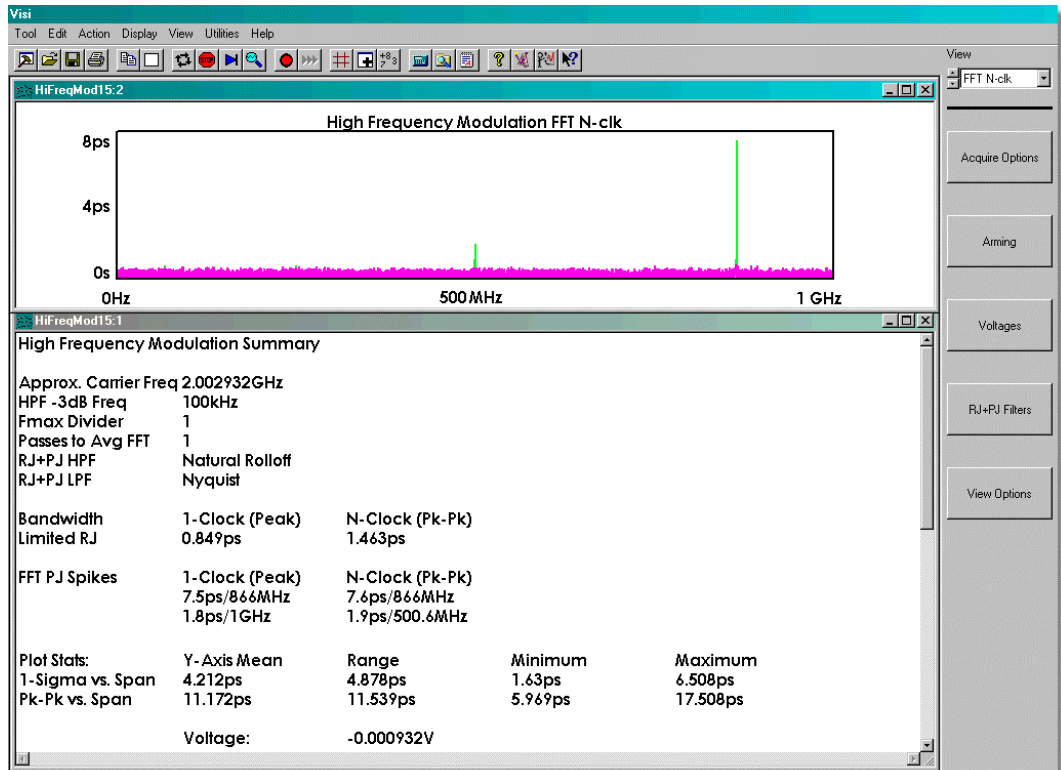


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**Continue analysis of Periodic Jitter (PJ). Identify the Spectral content of the jitter**

To provide frequency and amplitude of jitter, we use Accumulated Time Analysis, a patented *WAVECREST* algorithm that creates a frequency vs. jitter diagram.

- While still in the High Frequency Modulation tool, you can now change views from the 1-sigma view to the FFT N-clk view.
- Add a view by pressing ADD VIEW on the front panel or press  on the top menu bar. Change this view to Summary.

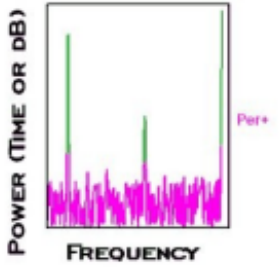


**Figure 5 - FFT shows jitter frequencies and amplitudes. Analysis of 2GHz clock from Figure 3. Shows jitter at 866MHz**

The cause of the bimodal histogram in Figure 3 is now apparent in this FFT. For the purposes of this example, Periodic Jitter was added to the 2GHz clock. The summary page shows the amplitude of this highest peak in the N-Clk (Pk-Pk) column as 7.6ps at 866MHz. Having identified the major contributor to jitter, the engineer can now work to eliminate it. Usually, it is at a frequency that is familiar, such as some multiple of a reference clock or crosstalk from another clock.



**LOW FREQUENCY MODULATION  
FFT 1-CLK VIEW**

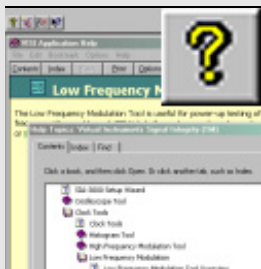


TO MEASURE:



FOR MORE INFORMATION ON THIS TOOL, REFER TO:

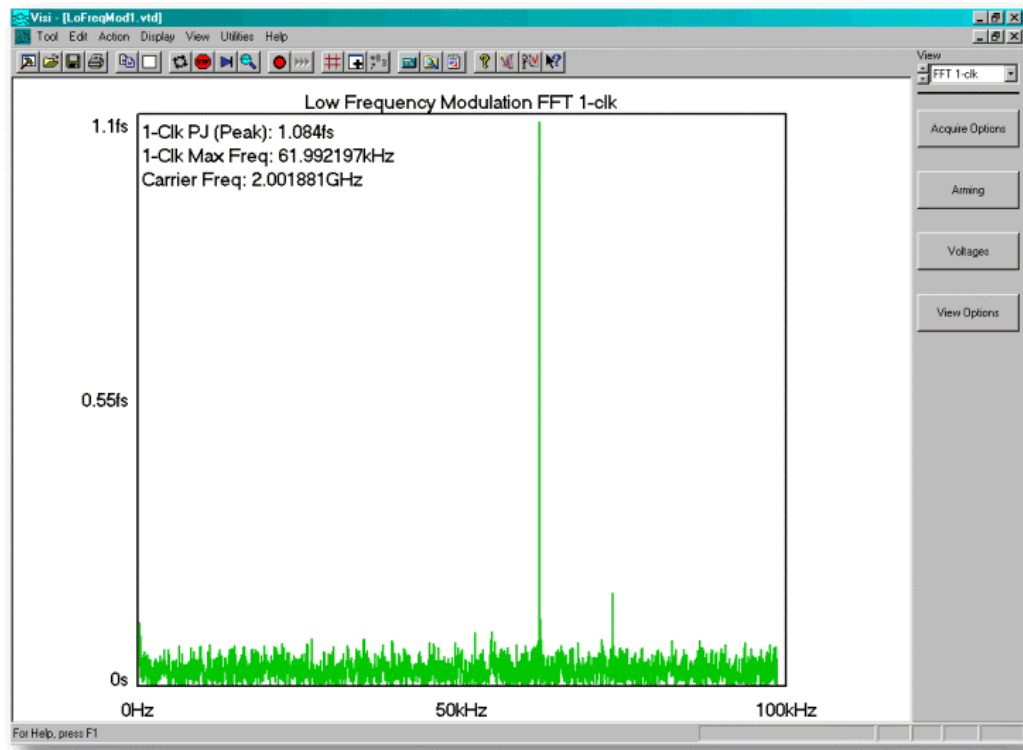
**VISI ONLINE HELP**



**Continue analysis of Periodic Jitter (PJ); Identify possible Low Frequency Jitter content**

Often it is not necessary to identify jitter at very low frequencies (in this tool <100kHz). Low frequency modulation *can* be analyzed in the *High Frequency Modulation* tool, but the acquisition time becomes very long for lower “HPF –3dB freq” settings. So, the Low Frequency modulation tool acquires measurements in a different way allowing faster acquisition when looking for low frequency jitter or wander on a high speed clock.

- From the main menu, press **Clock**, then **Low Frequency Modulation** to open the tool.
- Choose the “Maximum Frequency”, which must be 100kHz or less.
- “Minimum Data Points” determines the number of time measurements in the record. Increasing this value will reduce the possibility of aliasing, increase FFT resolution and allow lower frequency components to be acquired.
- Press the SINGLE/STOP button on the front panel or the top menu.

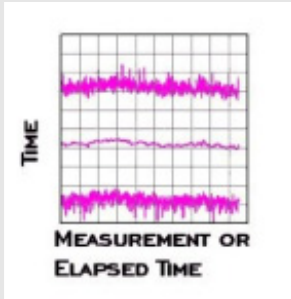


**Figure 6 - FFT shows jitter frequencies and amplitudes. Analysis of 2GHz clock from Figure 3. Shows jitter at ~62kHz.**

This 1-clk FFT view shows jitter components lower than 100kHz. This tool is useful when very low frequency jitter or wander may be suspected. The example in Figure 6 shows that we can see a Periodic jitter component at ~62kHz on the 2GHz clock signal; this jitter was added to the clock signal for the purposes of displaying the capabilities of the tool.

We have now identified low frequency jitter, but there may be other factors that affect the timing stability such as drift due to temperature or voltage changes.

**STRIP CHART  
MIN/MEAN/MAX VIEW**



TO MEASURE:

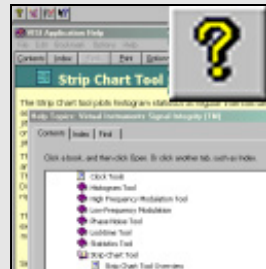


ON:




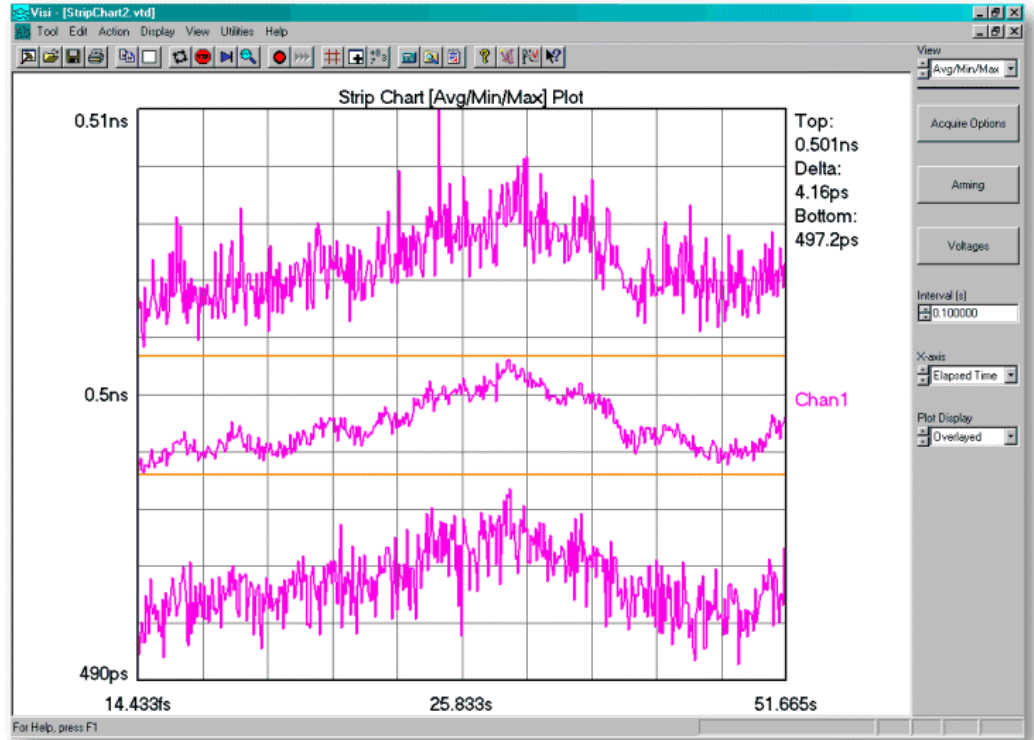
FOR MORE  
INFORMATION ON THIS  
TOOL, REFER TO:

**VISI ONLINE HELP**



**Analyze long-term drift/wander or effects of temperature change or supply voltage change on mean measurement values**

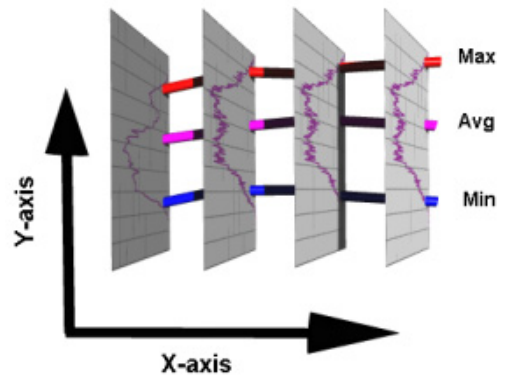
- From the main menu, press **Clock**, then **Strip Chart** to open the tool.
- The default interval between histogram measurements is 0.1seconds.
- Press the RUN button on the front panel or the top menu  to run continuously.



**Figure 7 - Shows drift of period by logging histogram statistics at user defined intervals**

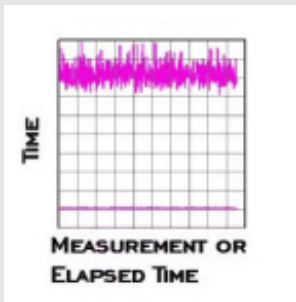
Figure 7 shows the results of “logged” histogram values. The Strip Chart tool allows histograms to be performed at regular intervals chosen by the user. In other words, when a histogram is performed, the tool waits for a specified time interval and then performs another histogram measurement (see Figure 8). The Max, Average, Min values are displayed relative to when the histogram was created. This tool is useful to plot the effects of environmental changes such as temperature, Vcc, or ground changes. By enabling Markers in Figure 7, we can see the total deviation of the mean period measurement—4.16ps over the total acquisition time—51.6 seconds on the x-axis.

Long term studies of environmental effects on timing parameters can be performed using this tool.



**Figure 8 - Shows Histogram values plotted relative to time of acquisition**

**STRIP CHART  
1-SIGMA/PK-PK  
VIEW**



To MEASURE:



ON:




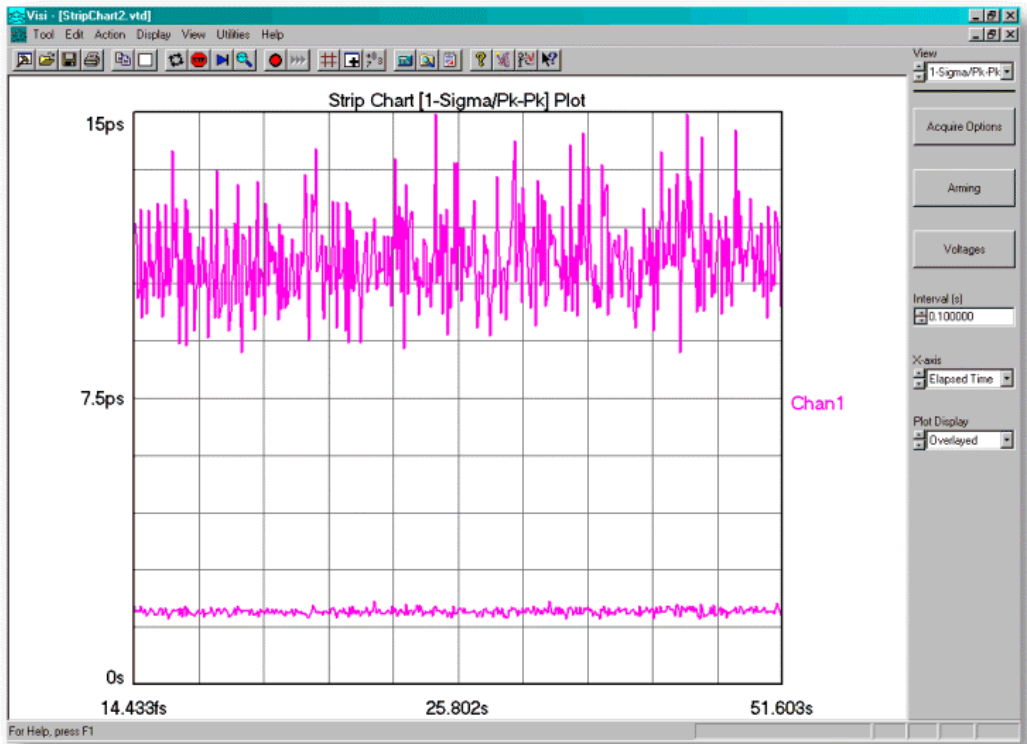
FOR MORE INFORMATION ON THIS TOOL, REFER TO:

**VISI ONLINE HELP**



**Analyze long-term drift/wander or effects of temperature change or supply voltage change on the 1-sigma and Peak-to-peak values of histograms**

- While still in the Strip Chart tool, change the view from “Avg/Min/Max” to “1-Sigma/Pk-Pk”. The default interval between histogram measurements is 0.1seconds.
- Press the RUN button on the front panel or the top menu .



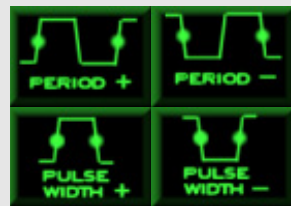
**Figure 9 - Shows the change of 1-sigma and Pk-Pk values by logging histogram statistics at user defined intervals.**

Figure 9 shows the results from the same tool, but a different view of the measurements from Figure 7. In this case, the 1-sigma and Peak-to-Peak values are plotted relative to when the histogram was created. This specific example shows that as the mean (from Figure 7) changes, the 1-sigma and Peak-to-Peak values of the histograms remain level. In some cases, as temperature or supply voltage to the part are varied, the period mean will remain constant, but the jitter will increase. This plot would show that effect. If the histogram grew in width with the addition of DJ or RJ, the Pk-Pk and 1-sigma lines would trend upwards across the plot.

## STATISTICS: DUTY CYCLE/ FREQUENCY COUNT

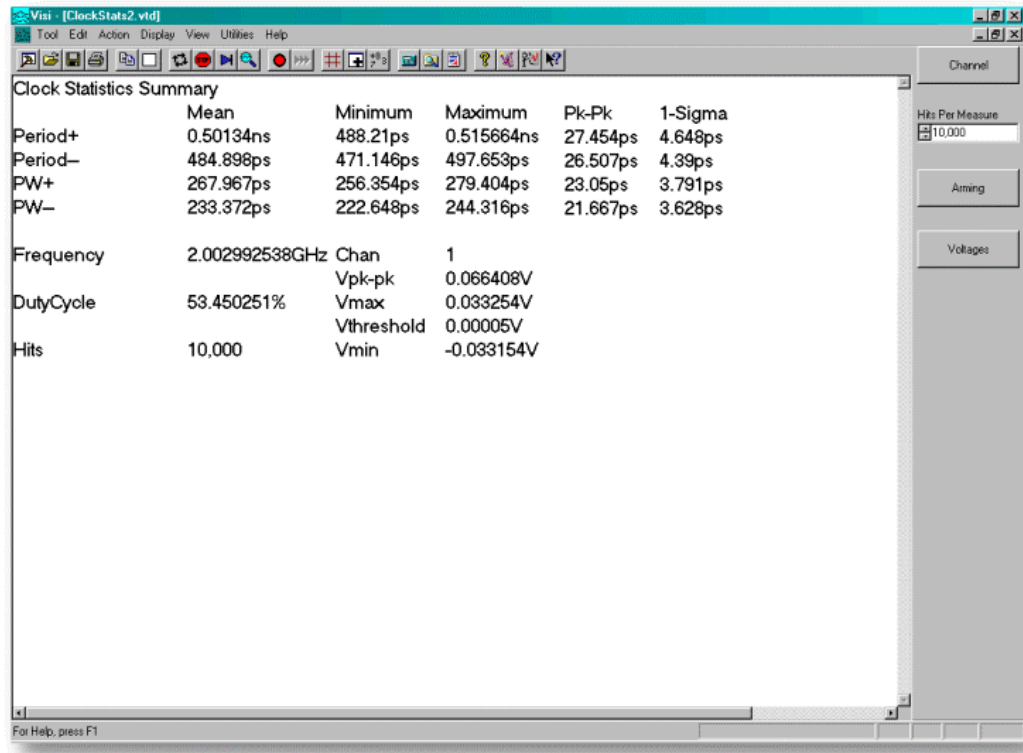
Clock Statistics Summary			
	Mean	Minimum	Maximum
Period+	0.50134ns	488.21ps	0.515664ns
Period-	484.898ps	471.146ps	497.653ps
PW+	267.967ps	256.354ps	279.404ps
PW-	233.372ps	222.648ps	244.316ps
Frequency	2.002992538GHz	Chan	1
DutyCycle	53.450251%	Vpk-pk	0.066408V
Hits	10,000	Vmax	0.033254V
		Vthreshold	0.00005V
		Vmin	-0.033154V

## TO MEASURE:



## Measure Duty Cycle and Frequency

- From the main menu, press **Clock**, then **Statistics** to open the tool.
- Press SINGLE/STOP button on the front panel or the top menu or Press the RUN button on the front panel or the top menu .

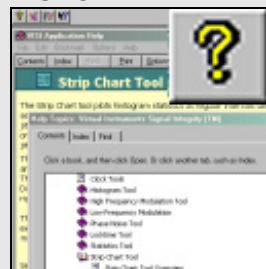


**Figure 10 - Shows statistics from histogram measurements of Period +, Period-, Pulswidth +, Pulswidth -, Duty Cycle, and Frequency Counter.**

The Statistics tool is valuable in that it is the only tool to show Duty Cycle and Frequency Counter information. Additionally, it shows the basic statistics of histograms of all measurements of Period +, Period -, PW +, PW-. It is important to remember, though, that while the raw statistics may convey some information, the plot views convey so much more. Before accepting any values from this tool “as is” you should also perform at least a histogram analysis of the measurement and understand the graphical results.

FOR MORE  
INFORMATION ON THIS  
TOOL, REFER TO:

## VISI ONLINE HELP







## CYCLE-TO-CYCLE ACCUMULATED VIEW

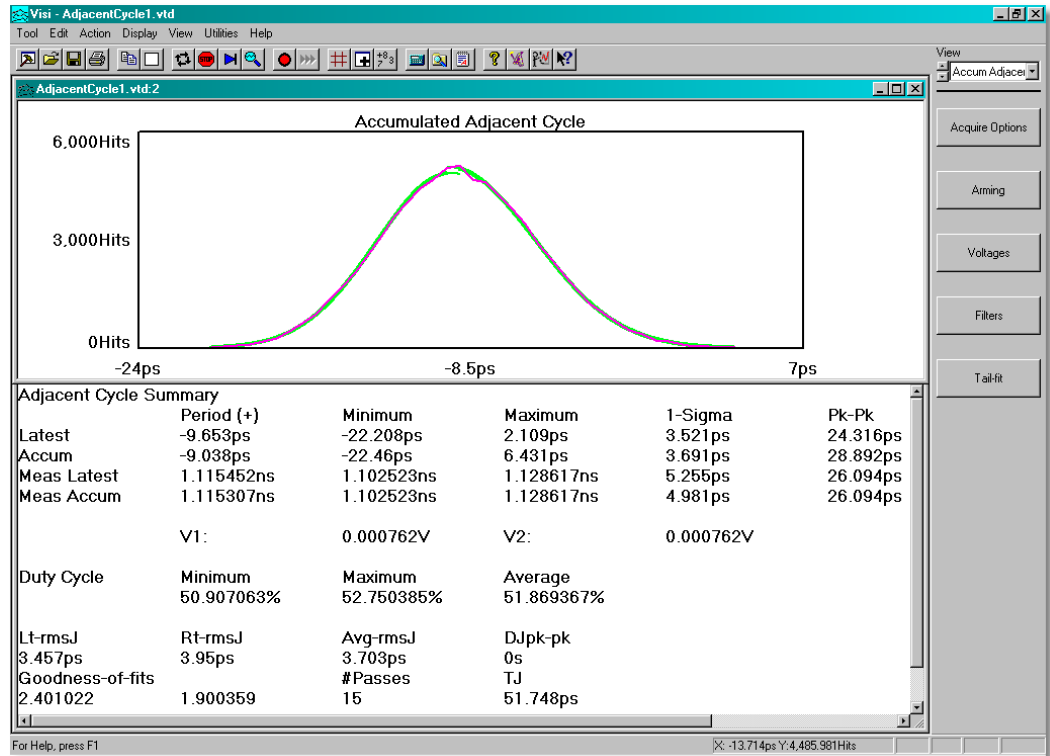


TO MEASURE:



## Measure Cycle to Cycle

- From the main menu, press **Advanced Clock**, then **Adjacent Cycle** to open the tool.
- Press **SINGLE/STOP** button on the front panel or the top menu  or Press the **RUN** button on the front panel or the top menu .

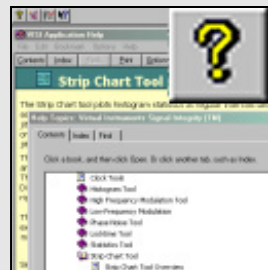


**Figure 11 - Shows statistics from histogram measurements of Cycle-to-Cycle (or the difference of two adjacent cycles), Period, and Duty Cycle.**

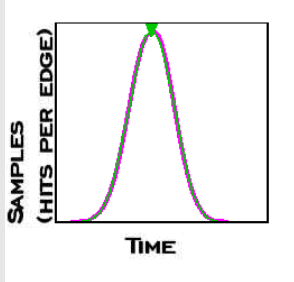
This tool can measure cycle-to-cycle, which is the difference between two adjacent cycles. Rising edges or falling edges can be measured and Tail-Fit™ can be performed on the resulting histogram.

FOR MORE INFORMATION ON THIS TOOL, REFER TO:

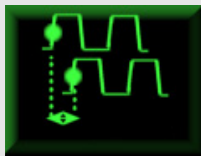
## VISI ONLINE HELP



**SKEW  
PROPAGATION  
DELAY**

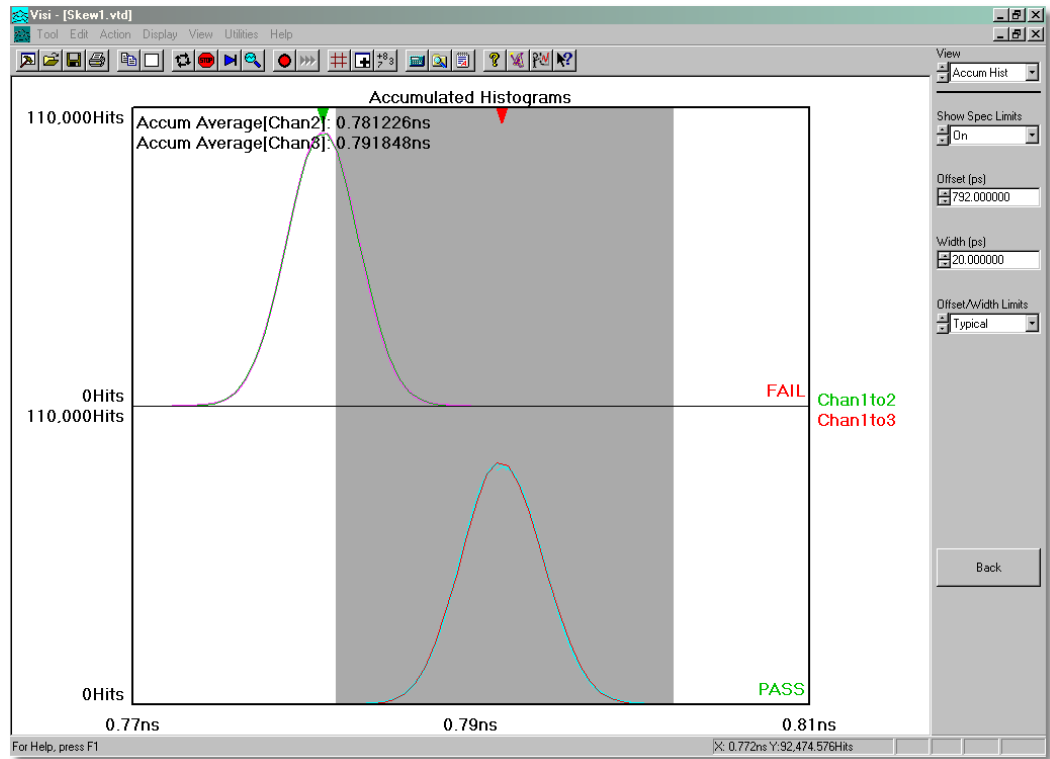


To MEASURE:



**Measure Skew or Propagation Delay**

- From the main menu, press **Chan to Chan** then **Propagation Delay and Skew** to open the tool.
- Press **SINGLE/STOP** button on the front panel or the top menu or Press the **RUN** button on the front panel or the top menu .



**Figure 12 - Shows statistics from histogram measurements of Skew or Propagation delay between two or more channels.**

This tool is useful for measuring the skew between two or more signals. One example is the propagation delay through a part from input to multiple outputs such as a clock fan out. The example above shows the skew referenced from Channel 1 to Channels 2 and 3. A window or guide can be enabled to quickly identify if all channels occur within a specified amount of time from one another.

FOR MORE  
INFORMATION ON THIS  
TOOL, REFER TO:

**VISI ONLINE HELP**



## Conclusion

The SIA-3000 provides the ability to measure and graphically display many different critical clock parameters. Using the tools described in this application note, a characterization or test engineer can understand the output of the part under test in just a few minutes. Each tool has additional capabilities not described in this application note. Most notably are DSP post-processing filters that can be enabled. For more details on these capabilities please refer to specific Quick Reference Guides or the online help. *WAVECREST* also provides software tools for advanced analysis of PLLs. The PLL analysis module can provide Transfer function, Poles and Zero, Bode Plot, Carrier Frequency, Damping Factor, Natural Frequency, PSD of Noise, Lock Range, Lock-in Time, Pull-in Time, Pull-out Range and Noise Bandwidth. This tool allows comparison of actual measurements to the design simulations.

These different analysis tools provide the flexibility to look at many different components of Signal Integrity. The SIA-3000 combines different hardware techniques with industry-accepted algorithms for the measurement of Deterministic, Random, and Total Jitter. These capabilities make the SIA-3000 the most complete and easy to use Signal Integrity Analysis system available today.

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