HISTOGRAM

FOR THE SIA-3000

Applications of Histogram tool

- Display a histogram of the samples taken during a single burst of measurements (such as Period+, Period-, Pulse Widths).
- Analyze long-term signal integrity in a short test time.
- Separates the Gaussian Random jitter and Deterministic jitter components.
- Obtain accurate values for Random Jitter (RJ), Deterministic Jitter (DJ), and Total Jitter (TJ).

Introduction

The focus of this guide is to familiarize the user with the basic Histogram tool to allow quick and easy measurements and interpretation of results. Refer to the SIA-3000 User's Manual and the VISI help files for more information.

Theory of Operation

The Histogram tool makes time measurements of different clock parameters (Period+, Period-, Pulse Widths, etc). The time measurements are asynchronously sampled (without a trigger) at random intervals to give a solid, statistical population. The randomization ensures that no jitter is masked out by a constant sampling rate. The time measurements are displayed as a Histogram; measured values are on the x-axis and number of hits is on the y-axis. The Histogram tool also incorporates the TailFit™ algorithm which separates the jitter into Random and Deterministic components (RJ and DJ). When operating in TailFit™ mode, a Bathtub Curve provides an accurate estimation of Total Jitter (TJ) or long-term signal integrity. Note that TailFit™ is available only with the Advanced Clock VISI software module.

Histogram Panel

Dialog Bar
Contains tool settings menus.

Plot area
Zoom in—hold down left mouse button, expand zoom box over area of interest.
Zoom out—double click left mouse.

VISI Panel
Cursor coordinates - Displayed in the box at lower right portion of the VISI Panel. Units are same as those in plot.

Statistics View
"Normal" shows data from the most recent run. "Accumulated" shows data collected from multiple runs (using Cycle). "Hits" shows the samples per histogram.

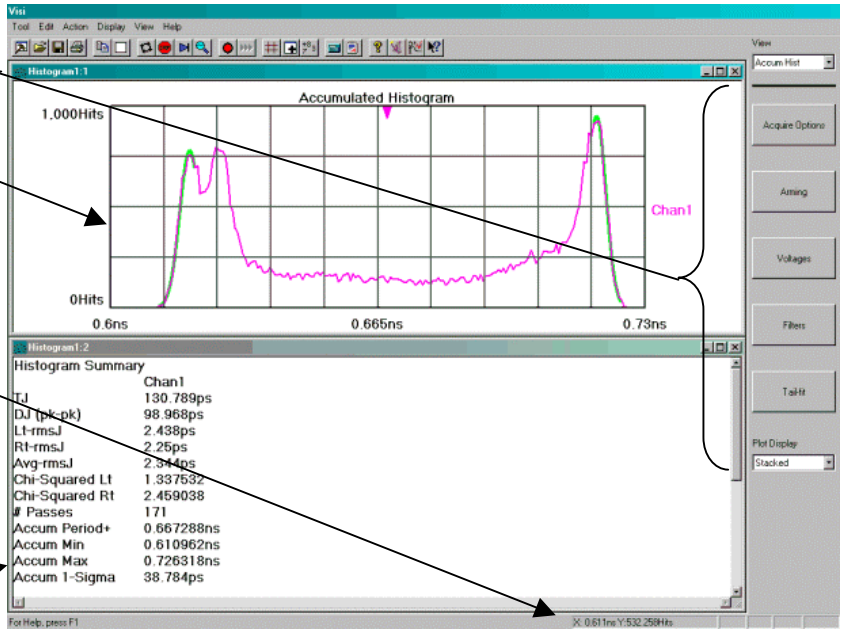

Figure 1. Histogram Plot

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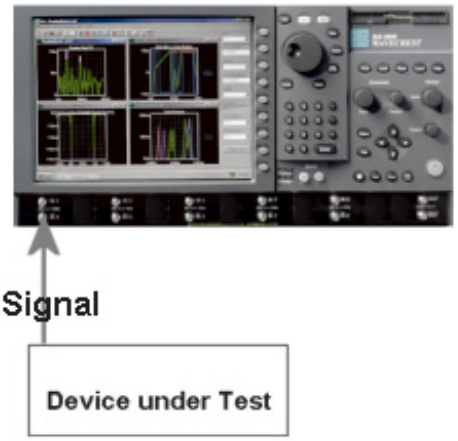
Making a Measurement

On the Dialog bar menu along the right side of the initial VISI screen, select Clock then Histogram. The Dialog Bar menu default settings allow users under most conditions to immediately begin making measurements.

- Verify that a signal is connected to an input channel
- Go to the "Acquire Options" menu and select "Channel". In the dialog box, check the channel to be used.
- On the Front Panel or on the top toolbar press "Pulse Find". Verify the voltage levels and close the Pulse Find box.
- On the Front Panel or on the Tool Bar, press the "Single/Acquire" button or press the "Run" button to accumulate a continuous series of measurements.
- Press the "Single/Acquire" button or the "Disable All" button to stop the cycling process.



If the histogram distribution is Multimodal as in Figure 2, the 1-sigma value doesn't accurately reflect the Random component of jitter. This is because the cause of a non-Gaussian distribution is Deterministic. Therefore, in the presence of DJ, the 1σ value cannot be used as the true RJ value.

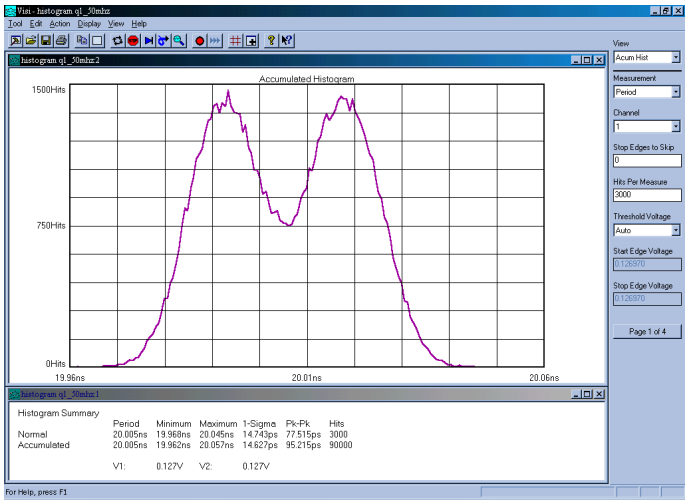


Figure 2. Histogram without TailFit™

The Histogram tool produces three different views: Accum, Max, Bathtub and Summary. The "Accum" view (see Figure 2) puts all measurements from multiple acquisitions into one histogram. The "Max" view (see Figure 3.) is useful to see low frequency or low probability events as outliers. Rather than auto-scaling all measurements into one histogram the most recent histogram is shown in addition to the maximum extents of all previous histograms. Period drift or wander can be seen in this view.

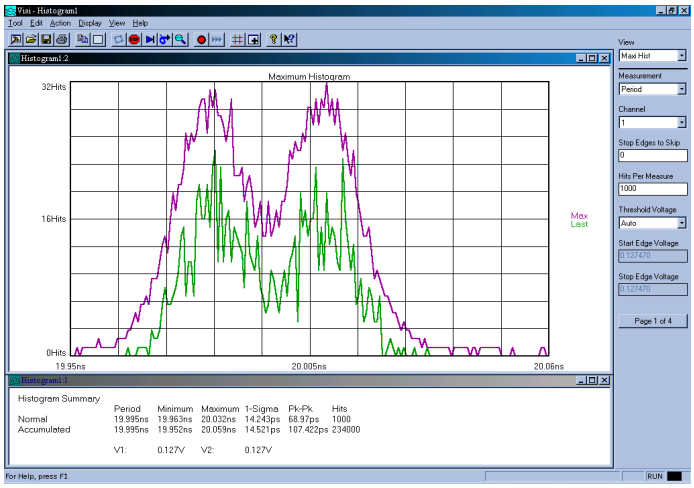


Figure 3. Histogram using Maxi View

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Enabling TailFit™ and Taking a measurement.

While in the Histogram tool, go to the Tail-Fit Menu of the Dialog Bar. In the “Tail-Fit” pull-down menu select “Enabled”. The standard Tail-Fit method will not return a result until a number of statistical requirements are met. Therefore, the user should enable the “Stop on Success” option by selecting “ON”. To make a measurement, press the Run/Cycle button .

The TailFit™ algorithm is used to separate and accurately quantify the Random and Deterministic components of Jitter. Random jitter is naturally modeled by a Gaussian function (bell shaped distribution). Therefore, the tail of a histogram distribution reflects the random jitter process which has a Gaussian-type distribution. The TailFit™ algorithm identifies a Gaussian curve with a symmetrical tail region to that of the distribution under evaluation. Two gaussian curves are fitted against each of the tail regions of the distribution until optimal matches are found. As demonstrated in Figure 4, the matched Gaussian distributions are not necessarily the same for each tail. The rms ($1\sigma_L$ for the left side) of the matched curve is used as the standard deviation multiplier for that particular tail. The left and right rms values are found and averaged to provide an avg rmsJ value. Once the random component is quantified, a total DJ value can be determined.

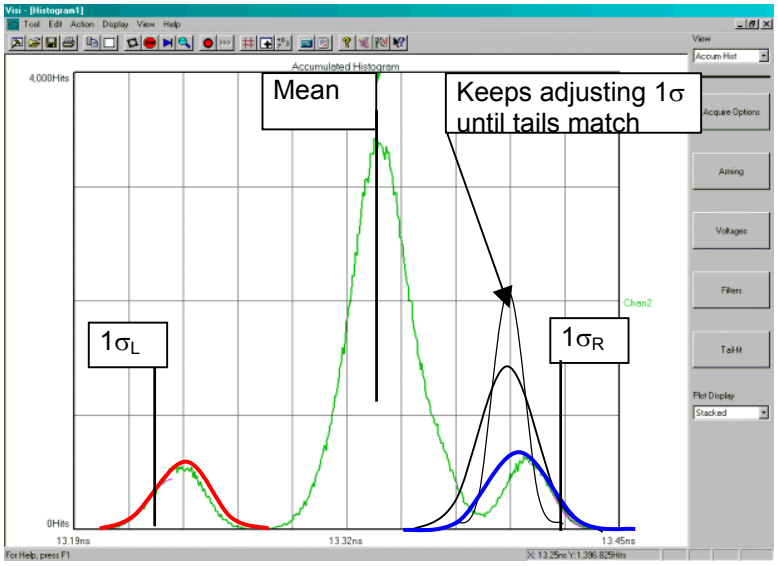

Figure 4. Tail-Fit Algorithm

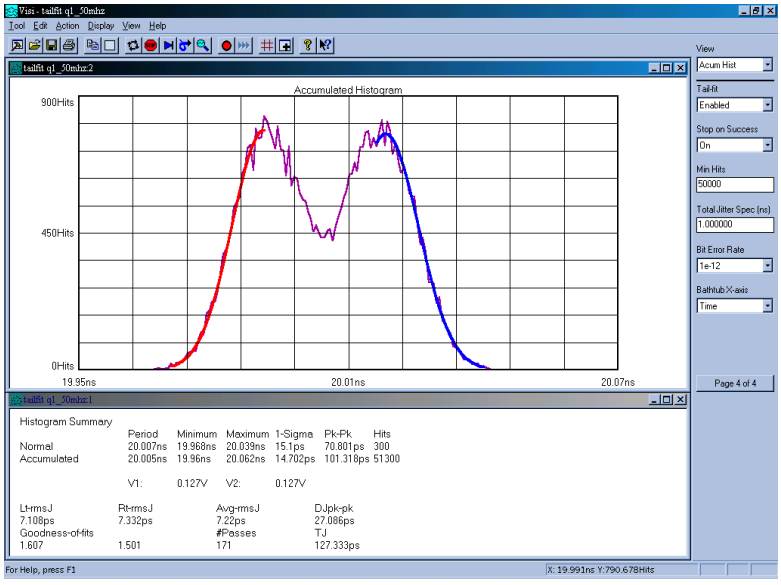

Figure 5. Histogram with TailFit™ enabled

Both Figures 3 and 5 have about the same 1-sigma and Pk-Pk values, but Figure 5 separates the jitter into its individual components. A DJ value is now displayed in the statistics window. RJ is displayed as Left-side (Lt-rmsJ), Right-side (Rt-rmsJ), and Average (Avg-rmsJ) which can be used if the left and right RJ’s are different. Note that the 1-sigma value is larger than the Avg-rmsJ which represents the true random component. A Total Jitter (TJ) value is now present in the statistics window; it is derived from the bathtub curve below.

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Bathtub Curve View

Figure 6 shows a Bathtub Curve also referred to as an “error probability density plot”. This plot is derived from a convolution of DJ and RJ values from TailFit™. The plot shows a view of the long-term reliability of the signal under test. Total Jitter (TJ) is extracted directly from this plot and is a pk-pk value at a specific bit error rate or number of clock cycles. The TJ value is read from the curve at the point that the color turns to gray.

The Y-axis in these examples represents a number of cycles of the clock. Figures 6 & 7 show a clock’s TJ calculated to 10^{12} cycles or $10*10^{3}$ seconds of a 50MHz clock. In Figure 6, the specification is set to 1000 ps, so that at 10^{12} cycles or $10*10^{3}$ seconds, Total Jitter (TJ) =127.333ps.

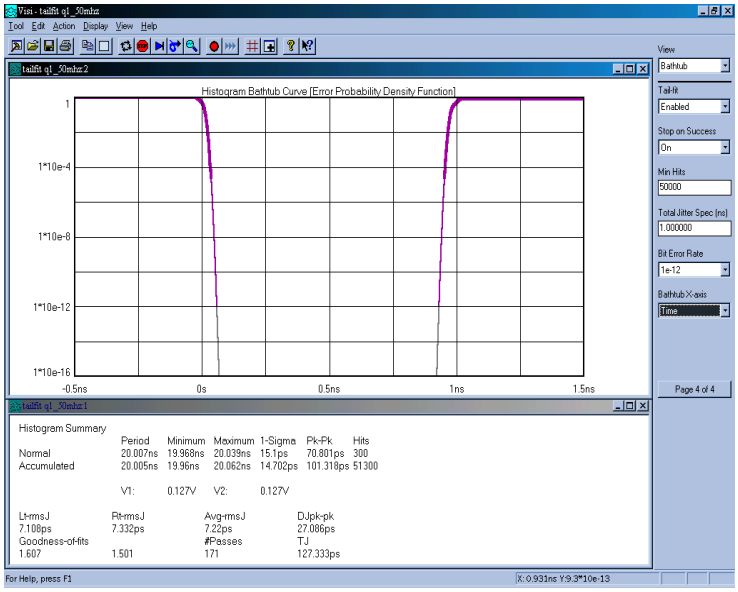

Figure 6. Bathtub Curve

A specification failure would be indicated if the lines met above the “bit error rate” set in the dialog menu. In Figure 7, the spec is set to 120ps (for the same clock used in Figure 6). Note that this plot shows TJ=120ps, since the actual TJ=127.333ps the clock failed the 120ps spec. The plot indicates that the device under test is predicted to fail the spec at just over 1^10e-11 seconds.

The use of TailFit™ and the Bathtub curve view makes it possible for the user to determine not only if the device under test passes, but also how much margin remains before a specification would be violated.

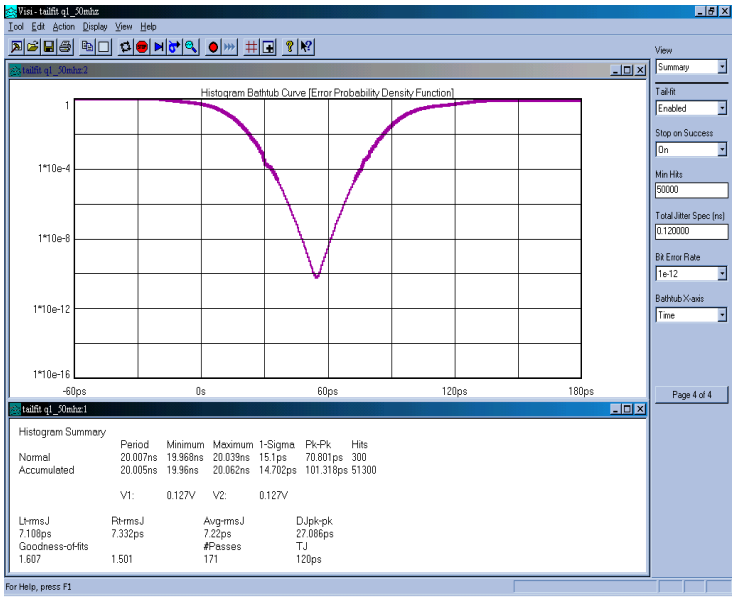

Figure 7. Bathtub Curve showing specification failure

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Bathtub Curve Interpretation

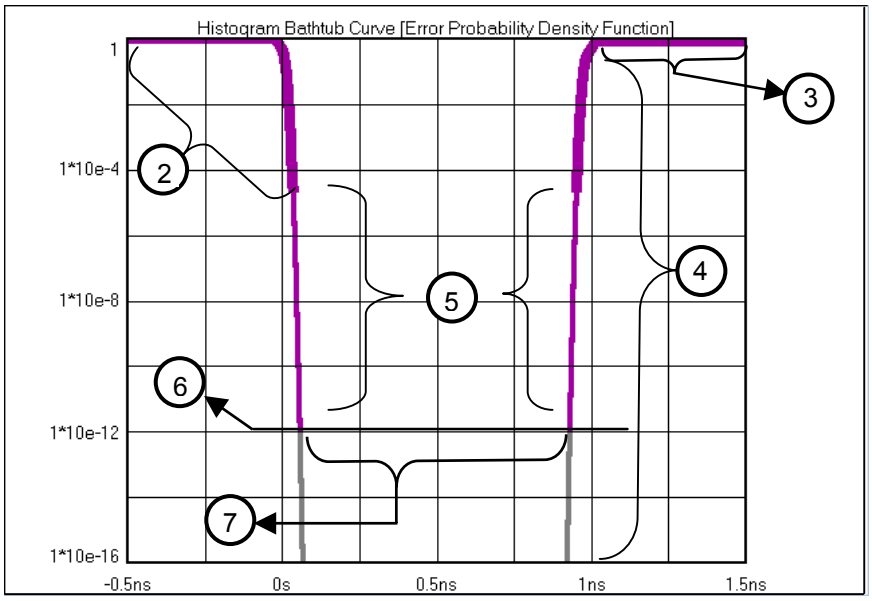

Figure 8. Bathtub Curve Interpretation

1) The lines on this plot are inversely proportional to the TailFit™ curves in Figure 5. Here, the left line corresponds to the right tail-fit, and the right line corresponds to the left tail-fit.

2) The thick portion of both lines represents data that has actually been acquired.

3) The portion of the thick colored line prior to the line's final downward turn represents the deterministic component. This is symbolic of the bounded nature of DJ, since DJ does not grow over time.

4) The vertical portion of the lines represents the random component. The stretching of the lines downward along the Y-axis demonstrates the unbounded nature of RJ and how it grows over time.

5) The thin portion of the colored line represents data from the TailFit™ extrapolation.

6) The point at which the lines become gray signifies the specific number of cycles of the clock or bit error rate set in the Tail-Fit Menu. It is at this point, where the TJ value is calculated.

7) The area between the lines can be compared to the eye opening, or the amount of margin above a specification. The amount of opening or margin is directly proportional to the amount of jitter present. If at this point, the right and left lines have NOT met, the signal has passed its Jitter Spec. The "Total Jitter Spec" is selected in the "Tail-Fit" Menu.

Additional Bathtub Curve Notes

- The deterministic component of jitter pushes the lines together.
- The Random component of jitter affects the slope of lines.
- The plot's right line represents short cycles of a clock in a clock application or short pulses in a dataCOM application.
- The plot's left line represents long cycles of a clock in a clock application or long pulses in a dataCOM application.

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Rise / Fall time Measurements – Voltage Threshold Settings

If you use the Histogram tool to measure Rise or Fall times you may want to select 20-80% or 10-90%. As noted in the Voltages Menu of the Dialog Bar, setting the threshold voltage to "Auto" during a Rise or Fall time measurement sets the threshold voltage to the 20-80% or 10-90% points of the input signal.

Users may select either of these two settings by going to Edit along the top of the Visi screen and selecting Configuration... This will open the Configuration menu window. Next, go to the pull down tab labeled Rise/Fall % (see circled section of Figure 9) and select either the 20-80% or 10-90% points. Before closing this window, press the Apply button to activate any changes that may have been made. The "Auto" voltage threshold setting used during a Rise / Fall time measurements will default to the setting in the Configuration menu.

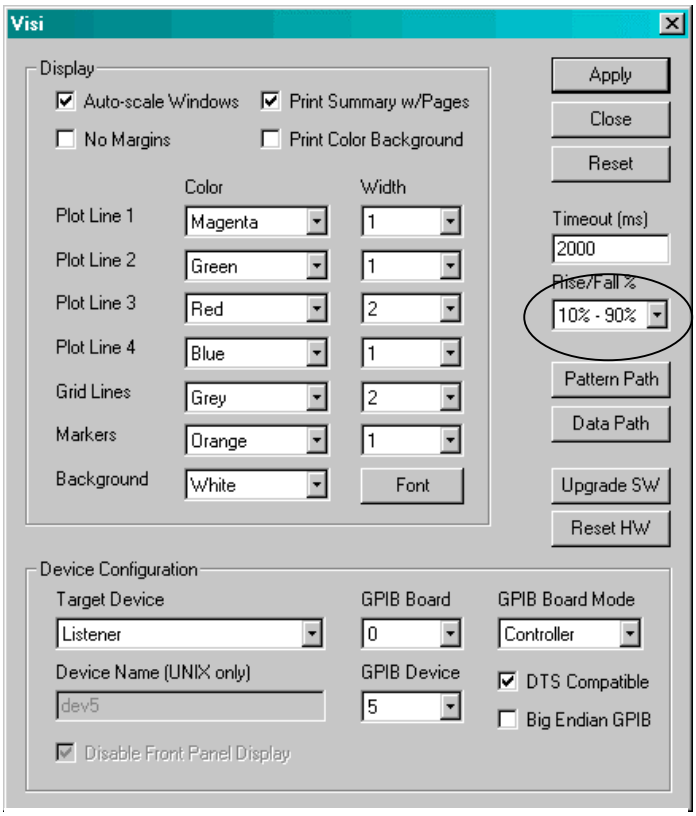

Figure 9. Edit Configuration Menu.

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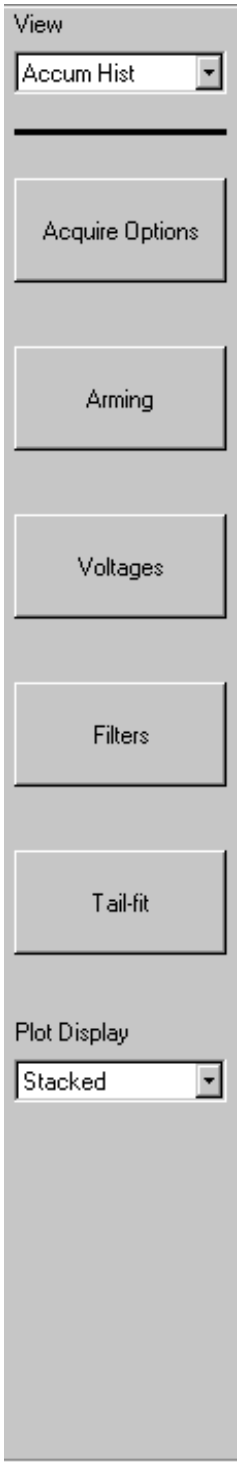
Dialog Bar Details

The next section provides a detailed description of all of the Dialog Bars and associated Menus. Specific controls are described.

Histogram Main Menu



View
The View pull-down menu provides several different ways to see the acquired measurement data. "Accum Hist" displays all accumulated measurements (when Run is pressed). "Max Hist" shows the most recent histogram with an 'envelope' of all previous measurements; it is useful to detect outliers or wander. "Bathtub" shows the TJ at a specific time. "Summary" shows a text output of the acquired values.

Acquire Options
Opens the Acquire Options Menu. Choose channels, sample size, etc.

Arming
Opens the Arming Menu.

Voltages
Opens the Voltages Menu. Select to use pulsefind or to set User Volts to specify the threshold voltage.

Filters
Opens the Filters Menu. Settings allow time filters which will discard measurements outside of a time window.

Tail-Fit
Opens the Tail-Fit Menu.

Plot Display
If measurements on more than one channel are made, this will display the plots for each channel separately(stacked) or on top of each other(overlayed).

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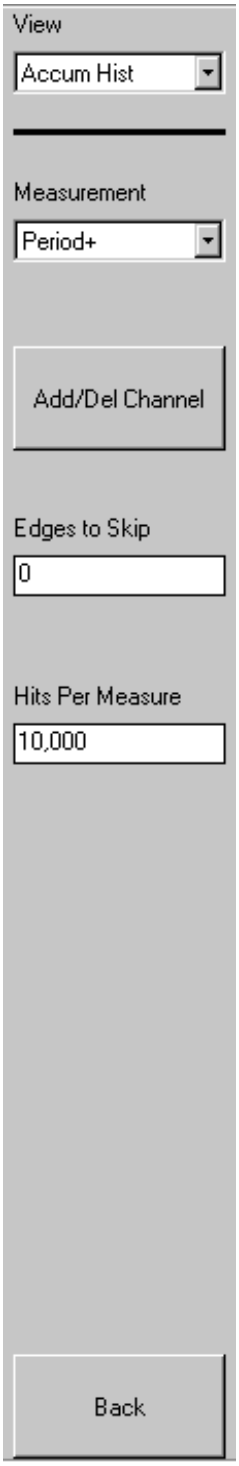
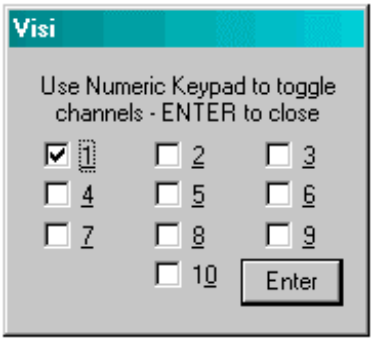
Acquire Options Menu



Measurement
Select primary measurement configuration for the unit: Rise time, Fall time, PW+, PW- and Period.



Add/Del Channel
Choose one or more channels to make a measurement. Use the keypad on the SIA-3000 Front panel to select or deselect channels. Press Enter when complete.

Edges to Skip
Will determine the number of edges to skip before the time measurement stops. When measuring Period, a value of zero will create a histogram of single period measurements. A value of one will create a histogram of double period measurements, etc. Thus, when skipping one edge, the mean measurement would be doubled.

Hits Per Measure
Determines the number of time measurements, or samples, that will be made for one histogram.

Back
Returns to Previous Menu.

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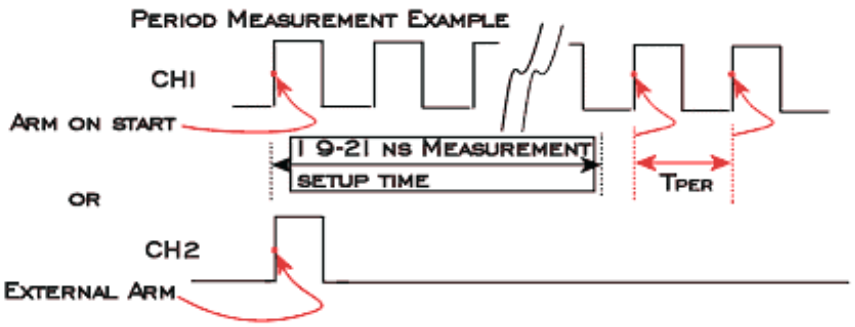
Arming Menu

Arm Delay (19-21ns)
The arm delay sets the minimum time from an arm event to the first measurement edge. As the diagram below shows, there is a user selectable 19 to 21 ns delay from the Arm event to the first measurement. See Example below.



Arming Mode

An arm is required to make every measurement.

- The “Arm on Stop” selection will use an edge from the currently chosen measurement channel. 'Stop' refers to using an edge type (rising or falling) that begins the.
- The “Arm on Start” selection will use an edge from the currently chosen measurement channel. 'Start' refers to using an edge type (rising or falling) that begins the measurement.
- The “External Arm” selection will use an edge from a channel different than the one(s) chosen to make the measurement(s). When 'External Arm' is selected, you will be able to select a channel and edge to be used to arm the measurement. Once armed, the SIA-3000 measures edges after the Arm Delay has elapsed.

Arm Number
When External Arm is selected, Arm Number allows you to choose a channel to be used as the Arm.

Arming Edge
Choose the edge type to arm the measurement. This is only available with External Arm.

Back
Return to Previous Menus.

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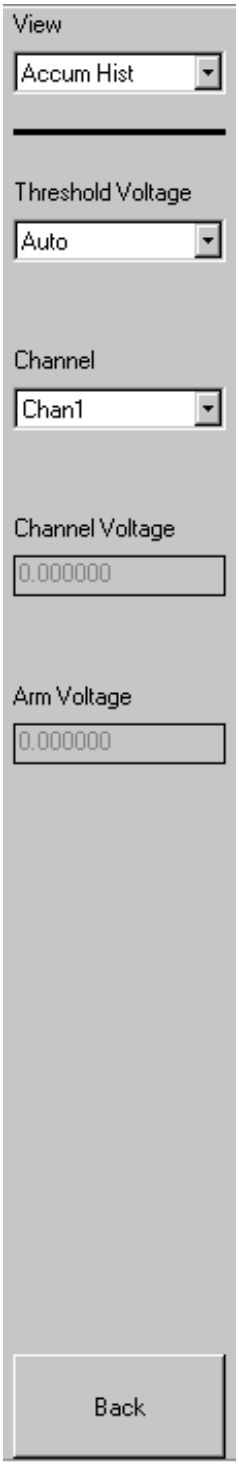
Voltages Menu



Threshold Voltage
When set to Auto, the start and stop threshold reference voltages are based on the minimum and maximum pulse level found on each channel. For all measurements, except Rise or Fall time, the 50% point is used. Rise/Fall time measurements are made according to the 10-90 or 20-80 setting in the Edit/Configuration menu.
The voltages are shown in the voltage display boxes after a pulsefind is completed. Select "User" to manually enter threshold voltages in the voltage display boxes. A pulsefind cannot be performed when User Volts is selected.

Channel
When "Threshold Voltage" is set to AUTO, use the "channel" control to view the threshold voltages derived from PULSEFIND. Voltages are displayed under “Channel Voltage", and "Arm Voltage".

When "Threshold Voltage" is set to USER VOLTS, use the "channel" control to view the threshold voltages and specify or change the threshold voltages to be used for the measurement on that channel.

Channel Voltage
Displays the Channel threshold voltage in AUTO. In USER VOLTS, the voltage can be set here.

Arm Voltage
Displays the Arm threshold voltage in AUTO. In USER VOLTS, the voltage can be set here.

Back
Returns to the previous menu.

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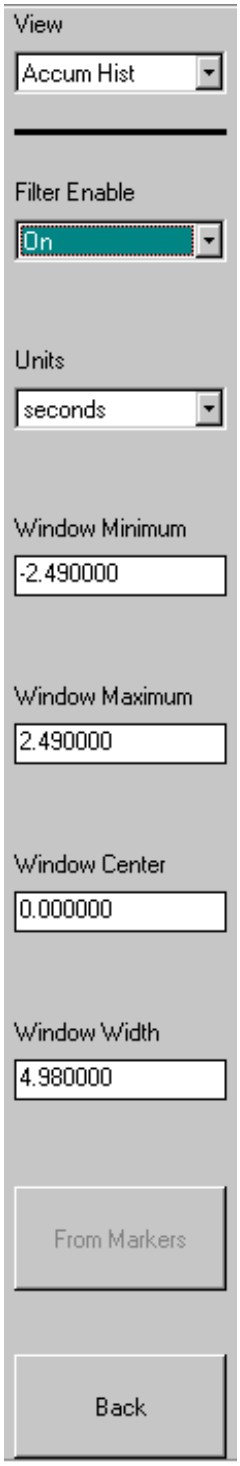
Filters Menu



Filter Enable
Enables/disables time and range filtering.

The Window Filter is a post-processing filter that discards measurements acquired outside of the filter parameters. The summary window will show the statistics from the measurements within the filter window and the histogram view will display the filtered region. The filter does not change the number of samples that fall within the filtered area, so the Hits Per Edge reflects the total unfiltered histogram. To increase the number of samples falling in the filtered area, the Hits Per Edge will have to be increased. For example, if there are two roughly equal distributions displayed without filters and the hits per edge is set to 1000, the probability of a value occurring in either distribution is equal. Therefore, the filtered data may contain approximately 500 hits.

The window filter can be enabled in three different ways: choose “Window Minimum” and “Window Maximum”; choose “Window Center” and “Window Width”; or enable markers and choose “From Markers”.

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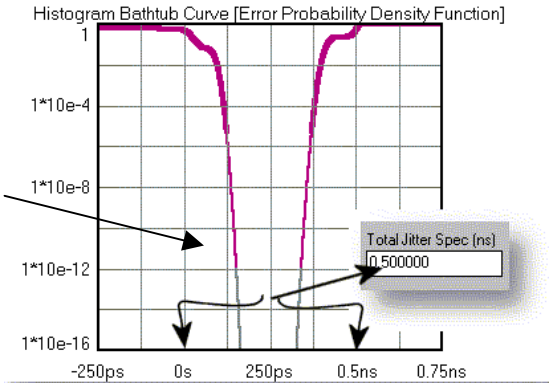
Tail-Fit Menu

Tail-Fit
Pull-down menu list for enabling/disabling tail-fit feature. When Tail-fit is enabled, Random Jitter and Deterministic Jitter can be separated in order to calculate Total Jitter. To accurately predict long-term clock performance, Tail-fit is necessary when the histogram is not Gaussian. Force-fit will force a Tail-fit after a set number of samples; this setting may not provide the best fit and is generally used in a production environment when a fixed test time is required.

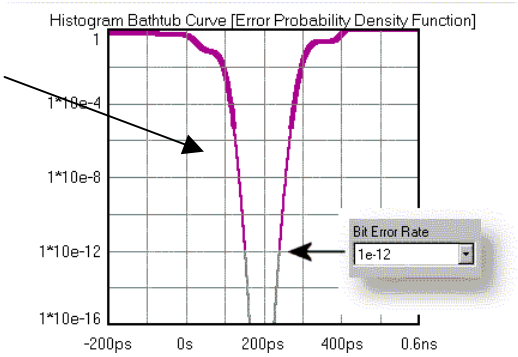
Stop on Success
The Tailfit option has certain quality requirements that must be met in order to successfully separate RJ and DJ. If there is a large DJ component, this may require several passes. Enable this option and then use Cycle in order to accumulate until the requirements are met.

Min Hits
A Tailfit is not attempted until the number of hits specified is acquired.

Total Jitter Spec(ns)
The width used in the Bathtub View to assess the Error Probability in nanoseconds. Different specs will yield different bathtub curves without reacquiring measurements.



Bit Error Rate
Determines the Bit Error Rate to be used when extracting total jitter from the Bathtub Curve. The default value is 1e-12. This setting has a direct effect on the TJ value that is calculated. For example, TJ at 1e-6 will be lower (smaller) than TJ at 1e-12.



Bathtub X-axis
Displays spec in time or UI

Bathtub Y-axis
Displays axis in time or BER

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Summary

The Histogram tool without the TailFit™ enabled provides very basic statistical information (1-Sigma and Pk-Pk). With the TailFit™ algorithm activated, critical data can be obtained, enabling the user to separate and quantify the individual components of jitter (RJ and DJ). From this information, a TJ value can be extrapolated. This provides a more realistic view of the long-term effects of jitter on signal integrity. The TailFit™ algorithm and Bathtub curve view are also available in all dual channel measurements (The Propagation Delay and Skew tools) and dataCOM tools.

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