JTA2

Jitter & Timing Analysis

Operator's Guide

December 2003

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JTA2-OM-E Rev A
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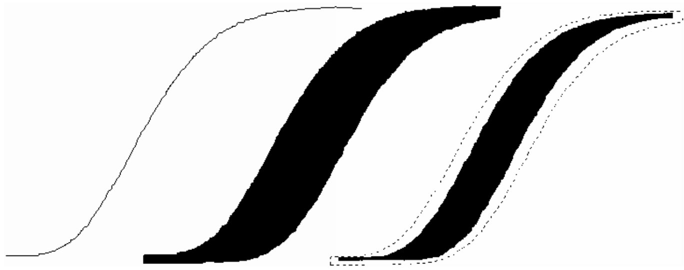
ACCESSING JTA2

To access JTA2's special features, you must first purchase and install the option. Once installed, JTA2's math and parameter selections will appear in the Math and Measure menus.

TIMING FUNCTIONS

JitterTrack, PersistenceHistogram and PersistenceTrace are timing functions in LeCroy's JitterPro and JTA jitter and timing analysis packages. The JitterTrack feature is key to identifying the source of excessive jitter or non-normal jitter characteristics. A timeline of signal jitter that is synchronous with the signal under test allows you to view patterns that would remain invisible using other systems, zoom to areas containing maximum jitter, and troubleshoot the problem. PersistenceHistogram is the ideal quantitative "companion" to persistence display. It histograms a horizontal or vertical slice of the persistence waveform. Utilizing average, sigma, and range settings, PersistenceTrace computes a vector trace from a bit map to give insight into edge details down to a few picoseconds.

- **JitterTrack** graphically plots as a function of time the amplitude of the waveform attributes **Cycle-to-Cycle** variation, **Duty Cycle**, **Interval Error**, **Period**, **Width**, and **Frequency**. Interval Error, for example, calculates the timing error of a signal compared with an ideal, expected interval defined by a user-specified reference frequency, the most common estimator of jitter. "The short-term variations of a digital signal's significant instants, from their ideal positions in time," are plotted. This is the perfect tool for characterizing clocks in synchronized telecom networks such as SONET and SDH. A special **data** function, available for most of these attributes, enables work on random data streams.
- **Persistence Histogram** analyzes a vertical or horizontal slice of a persistence map of multiple waveforms. The resultant bar chart shows a numerical measurement of the timing variations of a signal, which are observed qualitatively in the persistence display of the signal. A typical application is characterizing the jitter in a communications signal eye diagram.
- **Persistence Trace** is a method for displaying the data acquired from multiple sweeps of a waveform. A vector trace is computed, based on the bit map of the underlying multiple signal acquisitions. Detail is then represented in a choice of three graphic forms, each representing a different characteristic of the waveform. Insight into edge details is given down to a few picoseconds — valuable in applications such as the examination of fast signal transitions.



TIMING PARAMETERS

Timing parameters can also be used to measure cycle-to-cycle jitter, the width of positive and negative pulses, the duty cycle of either polarity, and an infinite number of cycles on long records. Pulses or cycles can be counted using one of these parameters.

As interpolation filtering is applied to signal edges in the vicinity of measurement points, timing parameters operate on acquired waveform levels that may be selected in either volts or percentage of signal amplitude. Each parameter calculation is performed over all cycles or edges present in the input signal, without limitations.

Statistical Tools

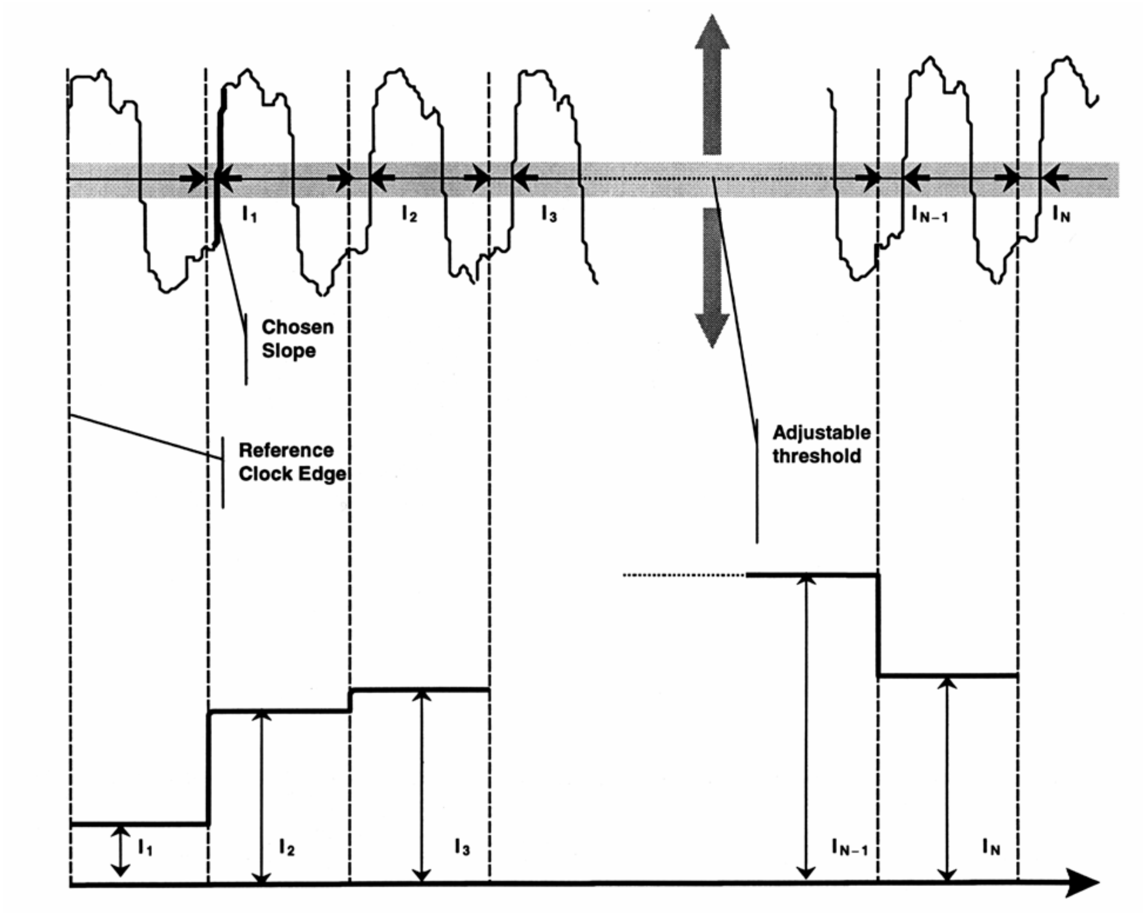
The information obtained from applying timing parameters can then be analyzed using the statistical tools, histograms and trends:

- **Histograms** characterize and present as a bar chart the statistical distribution of a timing parameter's set of values. In addition, there are 18 statistical histogram parameters, which operate directly on the histogram.
- **Trends** represent the evolution of timing parameters in line graphs whose vertical axes are the value of the parameter, and horizontal axes the order in which the values were acquired.

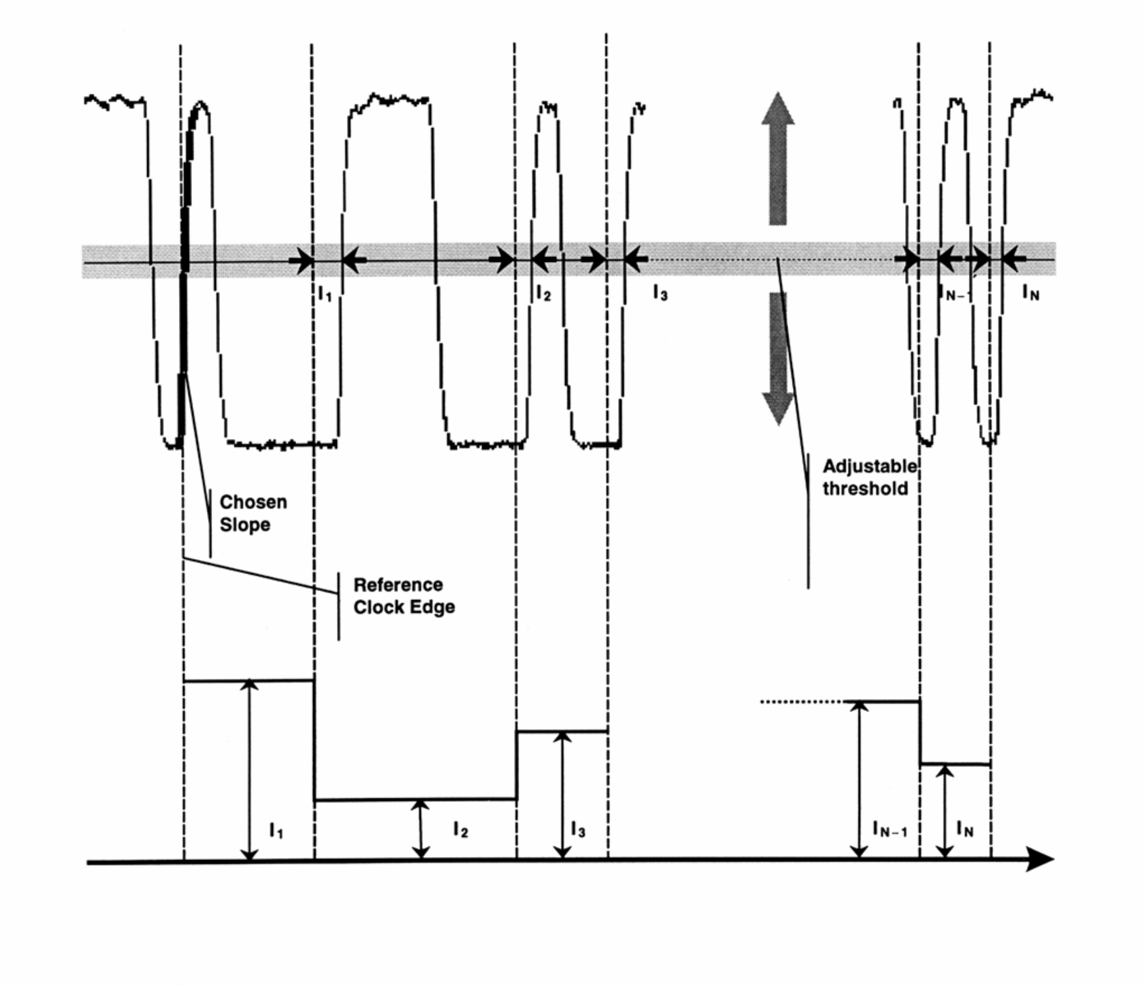
HOW JITTERTRACK WORKS

Using "Clock" or "Data"

Use this function to plot as a bar chart the evolution over time of this and five other waveform attributes in simple steps.



How JitterTrack's Interval Error works when "Clock" Mode is selected



When "Data" Mode is selected.

1. Set the desired reference clock frequency for an ideal position against which the signal is to be compared, or use "Find Frequency."
2. Specify the level at which the jitter measurement is to be made, as well as the rising or falling edge on which the measurement is to start.
3. Timing errors are graphically revealed.

WHEN TO USE JITTERTRACK

The JitterTrack Function charts the evolution in time of these waveform attributes:

- Cycle-to-Cycle deviation
- Duty Cycle
- Interval Error
- Period
- Pulse Width
- Frequency

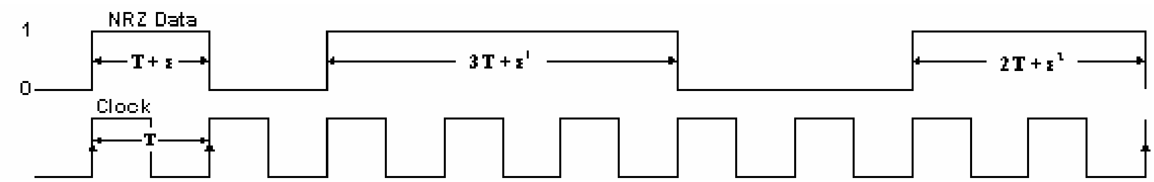
Each is time-correlated to its source trace and contains the same number of points as the waveform.

JitterTrack or Trend?

Whether it is more appropriate to use JitterTrack or the statistical tool, Trend will largely depend on the application, as well as the other factors set out in the tables below. While JitterTrack sample points are evenly spaced in time, those of Trend are not. Trend plots any parameter available in the instrument against its event count, as in a scatter or an XY diagram.

Characteristic	Trend	JitterTrack
Representation	parameter Value vs. Events	attribute value vs. time
Attributes or Parameters Supported	all parameters	Cycle-Cycle Period Duty Cycle Width Interval Error Frequency
Behavior	cumulative over several acquisitions up to 1 million events	non-cumulative (resets after every acquisition) unlimited number of events

When you need to	Use…
monitor the evolution of a waveform parameter or attribute over several acquisitions...	***Trend*** - Jitter works only on one acquisition at a time
time-correlate an event and a parameter value...	***JitterTrack***
monitor an evolution in the frequency domain...	***JitterTrack*** - Trend points are not evenly spaced in time and therefore cannot be used for FFT (Fast Fourier Transform).
monitor JTA parameters...	***Trend***



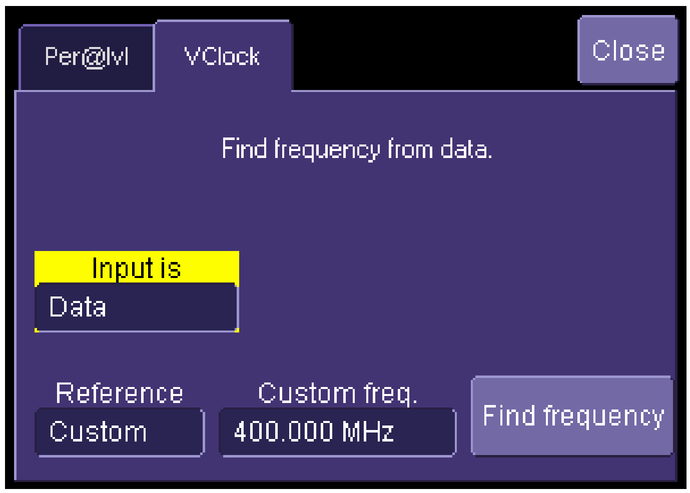
Random NRZ (Non-Return to Zero) data stream and its corresponding clock signal.

CLOCK OR DATA?

For most waveform attributes, JitterTrack offers the choice of Clock or Data modes for measuring clock signals or data streams. "Data" should be used (where available) when the pulse widths, intervals, periods or other significant instants being measured are randomly distributed and contain multiples of the clock period.

On the one hand, apart from jitter, clock signals ought to be regular. On the other hand, data streams by their very nature have irregular pulse widths.

A clock signal is normally required to characterize jitter. But such a signal will not be available if the waveform being measured is a data stream, whose very randomness hides the clock signal. To overcome this, JitterTrack provides both Clock *and* Data modes. Selecting **Data** from the VClock dialog gives the superior timing resolution through normalization (see table) required for correctly measuring jitter in data signals.



The diagram on the previous page shows a data stream in relation to its clock signal. It illustrates how data pulses contain, within themselves, multiples of their clock-signal pulse widths. Analyzing the positive pulses in the data stream, we observe a great variance between each sample in, for instance, the range T to $3T$. In fact, it is the small variations (the jitter) that are important. And they could be normalized if clock frequency, and clock frequency over pulse width, were known. This normalization, provided by JitterTrack, reduces pulse variations and increases timing resolution so that errors (ε) can be clearly observed. It does this by reducing the jitter range, dividing each measurement equal to n $\times$ T by n.

Comparing a Random Data Stream Analyzed Using Clock and Data Modes.

Modes	CLOCK	DATA
Jitter Range	$3T + \varepsilon$	$\varepsilon << 3T$
Resolution	coarse	fine

SETTING UP JITTER MEASUREMENTS

Jitter Math Setup

1. Touch **Math** in the menu bar, then **Math Setup...** in the drop-down menu.
2. In the "Math" dialog, touch an unused **Fx** button to simply make a selection from the **Select Math Operator** menu. Or, touch an **Fx** tab 

for more setup options.

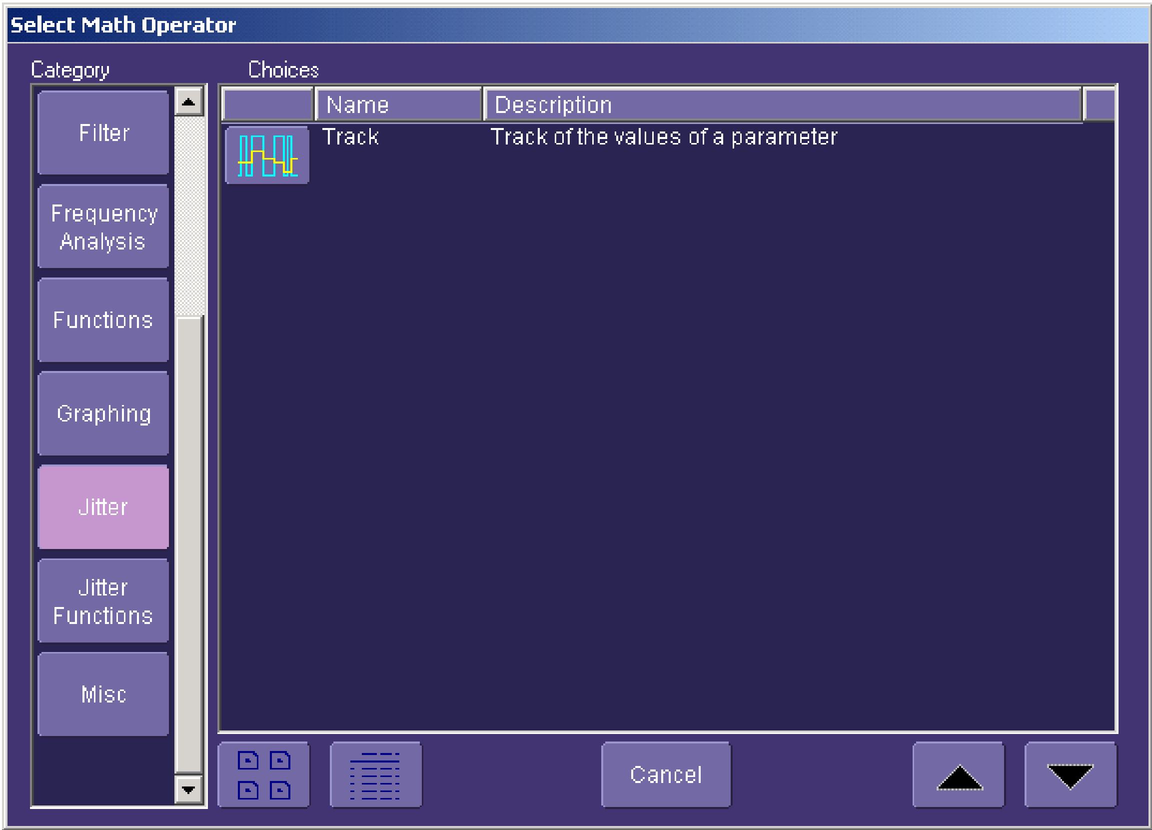
Note: By default, unused **Fx** positions are designated as zooms of C1. However, the traces are disabled, as indicated by an unchecked **On** box alongside the **Fx** button:

3. Touch the **Jitter Functions** button in the **Select Math Operator** menu for a list of persistence functions.

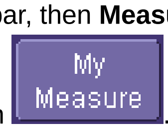
4. Touch a persistence function. The **Select Math Operator** menu closes, and the trace is automatically enabled.

JitterTrack

If you want to enable JitterTrack in addition to (or instead of) a persistence function trace, touch the **Jitter** button in the **Select Math Operator** menu, then the **Track** button. The **Select Math Operator** menu closes, and the JitterTrack is automatically enabled.

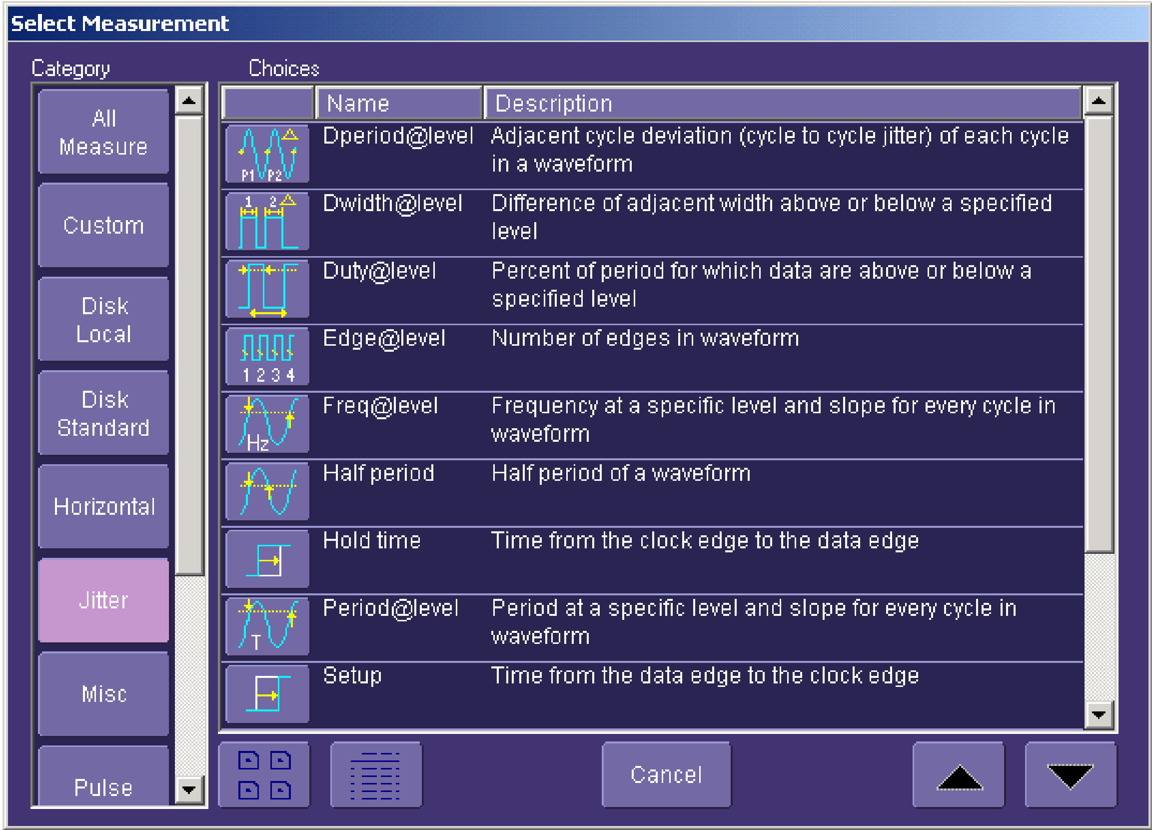


Jitter Parameters Setup

1. Touch **Measure** in the menu bar, then **Measure Setup...** in the drop-down menu.
2. Touch the **My Measure** button 

.
3. In the "Measure" dialog, touch an unused **Px** button to simply select a jitter parameter from the **Select Measurement** menu. Or, touch a **Px** tab for more setup options.
4. Touch the **Jitter** button in the **Select Measurement** menu; a list of persistence functions

appears.



5. Touch a parameter. The setup dialog for the Px position you selected opens automatically. A mini-dialog also opens to the right of the main dialog, giving you more setup options for the selected parameter.

WHEN TO USE PERSISTENCE HISTOGRAMS

The Persistence Histogram function builds a histogram from a persistence map to reveal the features that are only visible when several acquisitions have been superimposed on one another. In contrast to this, the histogram as statistical tool simply graphs waveform parameters such as amplitude, frequency, or pulse width on an acquisition or series of acquisitions.

Both Histogram and Persistence Histogram bar charts are divided into intervals, or bins. While each bin in the histogram bar chart contains a class of similar parameter values, the Persistence Histogram analyzes both vertical and horizontal "slices" of the persistence map. Vertically, each bin contains a class of similar amplitude levels; horizontally, each bin contains a class of similar time values.

For a Histogram of	**Use**
a crossover point in time or in amplitude on an eye diagram	Persistence Histogram (Vert. and Horiz. Slices)
cumulative jitter on an eye diagram	Persistence Histogram (Horiz. Slice)
signal-to-noise ratio on an eye diagram	Persistence Histogram (Vert. Slice)
the different interval widths present in a long data stream	Histogram (of Timing Parameter *p@lv*)
cumulative jitter on a long record of a clock signal	Histogram (of Timing Parameter *tie@lv*)
cycle-to-cycle jitter	Histogram (of *Δp@lv*)

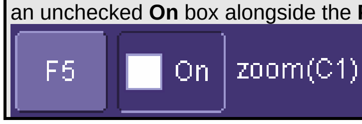
SETTING UP PERSISTENCE HISTOGRAMS

Selecting the Math Function

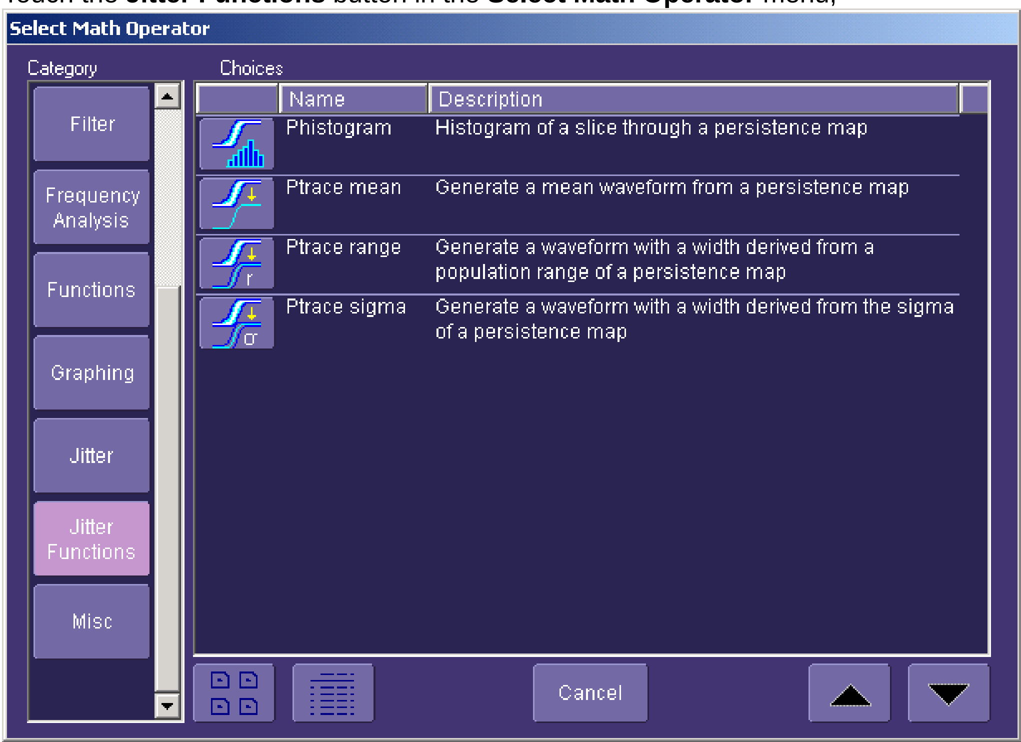
1. Touch **Math** in the menu bar, then **Math Setup...** in the drop-down menu.
2. In the "Math" dialog, touch an unused **Fx** button to simply make a selection from the **Select Math Operator** menu. Or, touch an **Fx** tab 

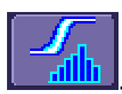
for more setup options.

Note: By default, unused **Fx** positions are designated as zooms of C1. However, the traces are disabled, as indicated by an unchecked **On** box alongside the **Fx** button:



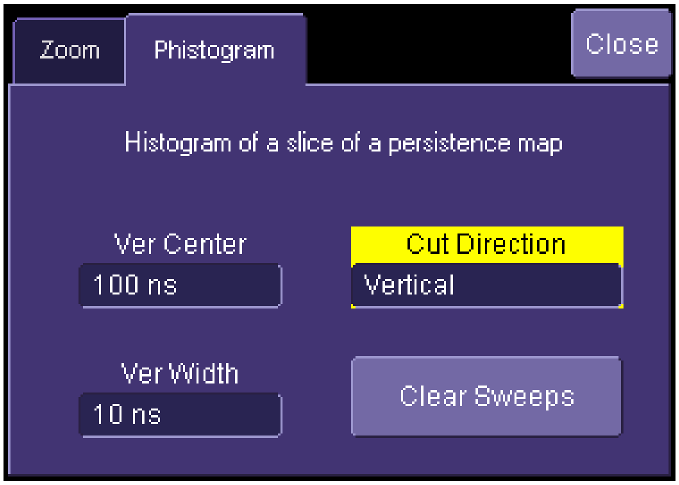
3. Touch the **Jitter Functions** button in the **Select Math Operator** menu,



then touch the **Phistogram** button . A setup mini-dialog opens to the right of the main dialog.

Setting Up the Histogram

The mini-dialog contains setup fields for your histogram.



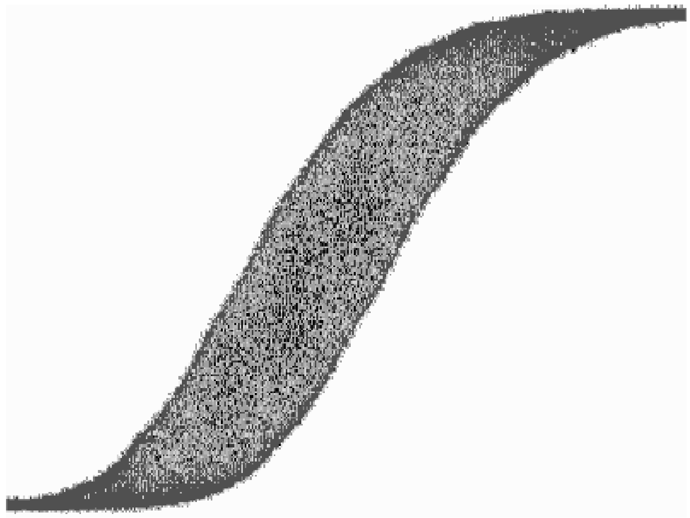
Selecting the Cut

Touch inside the **Cut Direction** field 

and select either **Vertical** or **Horizontal**. If you choose to cut a vertical slice, the units of the center and width of the slice are given in nanoseconds. If you choose a horizontal cut, the units of the center and width of the slice are given in millivolts.

HOW TO TRACE PERSISTENCE

A persistence waveform created by turning on persistence is show here. From this waveform, you can create three types of shapes on which waveform processing can be performed.



From left to right are shown Average, Range, and Sigma

An Innovative Visual and Processing Tool

With this timing function, not only can waveform noise and jitter be displayed but further processing can also be done.

Persistence Trace generates special graphic representations of the persistence waveform on which further processing, such as the application of parameters and even Pass/Fail testing, can be performed.

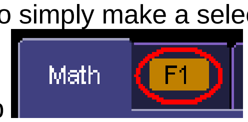
JTA2 Option

Displaying data acquired from multiple sweeps of the waveform, Persistence Trace computes a vector trace based on the bit map of the underlying signal acquisitions. Detail is then shown in a choice of three shapes: **average**, **range**, and **sigma**. These are created without destroying the underlying data, allowing the display of analytical results from raw data.

Typical applications of Persistence Trace are given in this table:

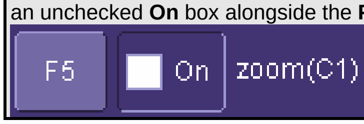
If you want to	**Use**
see edge detail in a fast signal	average
eliminate noise on a persistence trace	average
assess typical noise on a persistence trace	sigma
assess worst case noise on a persistence trace and use it to create a tolerance mask	range

To Set Up Trace Persistence

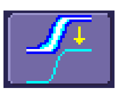
1. Touch **Math** in the menu bar, then **Math Setup...** in the drop-down menu.
2. In the "Math" dialog, touch an unused **Fx** button to simply make a selection from the **Select Math Operator** menu. Or, touch an **Fx** tab 

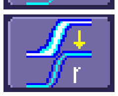
for more setup options.

Note: By default, unused **Fx** positions are designated as zooms of C1. However, the traces are disabled, as indicated by an unchecked **On** box alongside the **Fx** button:



3. Touch the **Jitter Functions** button in the **Select Math Operator** menu, then touch one of the Persistence Trace buttons:

 **Ptrace Mean**

 **Ptrace Range**

 **Ptrace Sigma**

A setup mini-dialog opens to the right of the main dialog, offering the following additional setup options:

Function	Options	How It Works
Ptrace Mean	Clear Sweeps	For each vertical time slice on the persistence map, Ptrace Mean calculates and plots a trace corresponding to the map's mean value. Single-shot signals sampled at or above 2 GS/s and accumulated in the persistence map can be traced at a resolution of 10 ps (100 GS/s equivalent sampling). The persistence trace average can be further analyzed using the instrument's standard parameters, such as rise time.
Ptrace Range	Clear Sweeps, **% population** range. A percentage of the population of the persistence map can be chosen from which the envelope will be formed, enabling exclusion of infrequent events (artifacts).	For each vertical time slice on the persistence map, Ptrace Range calculates and plots an envelope corresponding to the map's range. The range can then be used in further processing: for example, as a source for Pass/Fail masks.
Ptrace Sigma	Clear Sweeps, **Scale to** standard deviations. This allows you to select a sigma from 0.5 to 10.0, which expands those parts of the sigma envelope representing waveform regions with the most jitter. This is useful for making a tolerance mask.	For each vertical time slice on the persistence map, Ptrace Sigma calculates and plots an envelope corresponding to the map's standard deviation. Multiples of sigma can also be done using sigma. The sigma can be used in further processing; for example, as a source for Pass/Fail masks.

CHOOSING A TIMING PARAMETER

This table lists the Jitter and Timing Analysis (JTA) parameters and the tasks that they can perform. Additional analysis and processing of the waveform can be carried out by activating Statistics and using histogram parameters. For some parameters, one of the variants of JitterTrack can perform the same task.

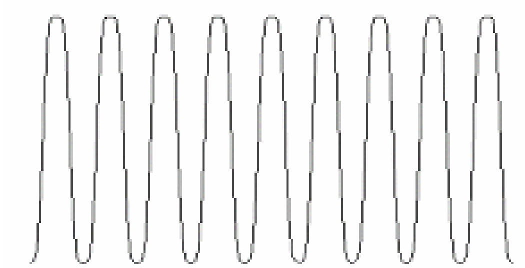
If You Want To	Use This Timing Parameter	For Further Processing	Or JitterTrack
measure accuracy of clock, period or frequency	p@lv freq@lv	Statistics On or use Histogram	Period Jitter Frequency Jitter
measure pulse width accuracy	wid@lv	Statistics On or use Histogram	Width Jitter
measure adjacent cycle deviation	Dp@lv	Statistics On or use Histogram	Cycle-to-Cycle Jitter
count number of edges in a waveform	edge@lv	---	---
measure duty cycle	duty@lv	Statistics On or use Histogram	Duty Cycle Jitter
measure time interval error	tie@lv	Statistics On or use Histogram	Interval Error Jitter
measure n-cycle	n-cycle@lv	---	N-Cycle Jitter
measure skew	skew	---	Clock Skew
measure setup	setup	---	Setup
measure hold	hold	---	Hold

HOW TO USE THE TREND TOOL

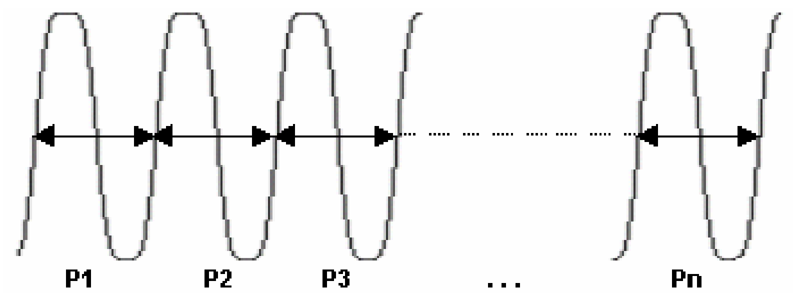
The Basic Idea

The Trend statistical tool displays the evolution of a timing parameter over time, in the form of a line graph. The graph's vertical axis is the value of the parameter; its horizontal axis is the order in which values are acquired.

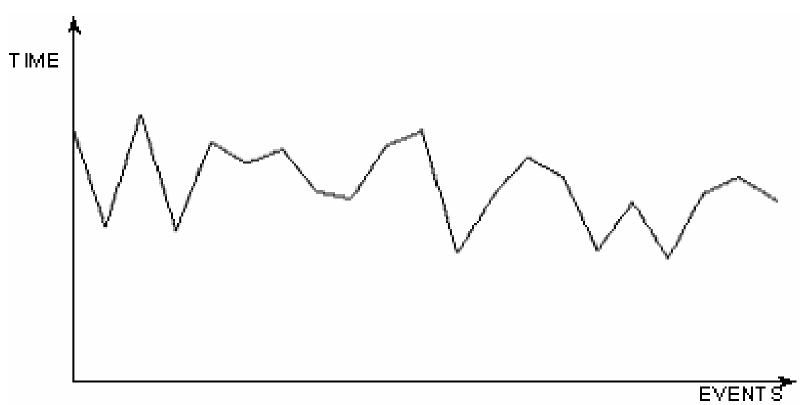
- **Display the waveform to be analyzed.**



- **Apply a timing parameter: period at level (p@lv), for example.**



- **Plot the trend of the parameter.**

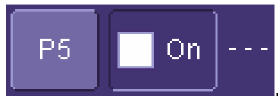


To Set Up and Configure Trend

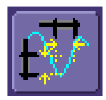
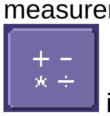
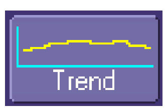
Parameter Setup

Before a Trend can be plotted, the timing parameter must be selected, as follows:

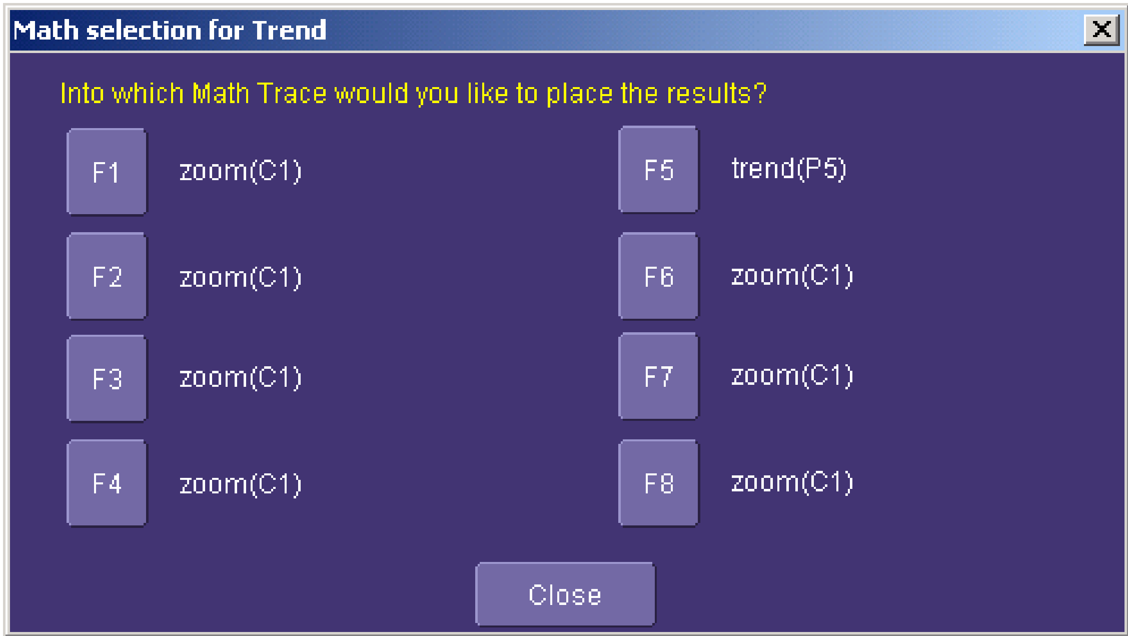
1. Touch **Measure** in the menu bar, then **Measure Setup...** in the drop-down menu.
2. In the "Measure" dialog, touch the **My Measure** button 

.
3. Touch an unused "Px" button: 

. The **Select Measurement** menu opens.
4. Touch the Jitter button 

on the **Select Measurement** menu and select a Jitter parameter. The setup dialogs for the Px position open.
5. Touch the **Measure On Waveforms** button  if you want to make a direct measurement on the source waveform. Or touch the **Math On Parameters** button  if you want to make a measurement on the result of two other parameters that have been added, subtracted, multiplied, or divided. If you want to use this feature, you must have first set up those other two parameters.
6. Touch inside the **Source1** field and select a channel or memory waveform on which to make the parameter measurement. If you are performing **Math On Parameters**, Touch inside each of the **Source1** and **Source2** fields and select the source parameters.
7. Touch the **Trend** button 

at the bottom of the dialog. A **Math Selection for Trend** pop-up menu opens from which you must select a math trace to display the trend.



8. A second setup dialog opens to the right of the main with more setup options. The options offered depend on the parameter you chose, but all include **Level is**, **Percent Level**, **Slope**, and **Hysteresis**. A **Find Level** button is also provided in this mini-dialog.

Option Field	Settings
Level Is	Percent Absolute
Percent Level	0 to 100%
Slope	Positive Negative
Hysteresis	0 div to 10 div

Note: The **Hysteresis** selection imposes a limit above and below the Level, which precludes measurements of noise or other perturbations within this band. The width of the band is specified in milli-divisions.

Guidelines for Use

1. Hysteresis must be larger than the maximum noise spike you want to ignore.
2. The largest value of hysteresis usable is less than the distance from the level to the closest extreme value of the waveform.
3. Unless you know the largest noise and closest extreme level that will ever occur on any cycle, leave some margin on both sides of the level.

Math Setup

Now that the parameter setups are done, you have to set up the Trend math function.

1. Touch **Math** in the menu bar, then **Math Setup...** in the drop-down menu.
2. In the "Math" dialog, touch the **Fx** tab 

for the math trace you chose to display the trend.
3. Touch the "Trend" tab 

in the setup dialog to the right of the main setup dialog. Touch inside the **Values to Trend** data entry field and enter a value from 20 to 20,000, using the pop-up numeric keypad.
4. You can touch the **Find Center and Height** button to automatically locate the center of the Trend waveform and to scale it to fit within the grid, without affecting zoom and position settings. Or you can enter specific values by touching inside the **Center** and **Height** data entry fields and typing in values, using the pop-up numeric keypad.
5. You can also touch the **Enable Auto Find** checkbox 

if you want the instrument to continuously self-adjust Center and Height.

HISTOGRAM AND TREND CALCULATION

With the instrument configured for Histograms or Trends, the timing parameter values are calculated and the chosen function performed on each following acquisition. The Histogram or Trend values themselves are calculated immediately after each acquisition.

The result is a waveform of data points that can be used the same way as any other waveform. Other parameters can be calculated on it, it can be zoomed, serve as the **x** or **y** trace in an **XY** plot, or used in cursor measurements.

Acquisition Sequence

The sequence of events for acquiring Histogram or Trend data is:

1. Trigger
2. Waveform Acquisition
3. Parameter Calculations
4. Histogram Update
5. Trigger Re-arm

If the timebase is set in non-segmented mode, a single acquisition occurs prior to parameter calculations.

However, in segment mode an acquisition for each segment occurs prior to parameter calculations. If the source of the Histogram or Trend data is a memory, storing new data to memory effectively acts as a trigger and acquisition. Because updating the screen can take significant processing time, it occurs only once a second, minimizing trigger dead-time. (Under remote control, the display can be turned off to maximize measurement speed.)

Parameter Buffer

The instrument maintains a circular parameter buffer of the last 20,000 measurements, including values that fall outside the set histogram range. If the maximum number of events to be used in a histogram or trend is a number **N** less than 20,000, the histogram will be continuously updated with the last **N** events as new acquisitions occur. If the maximum number is greater than 20,000, the histogram or trend will be updated until the number of events equals **N**. Then, if the number of bins or the histogram or trend range is modified, the instrument will use the parameter buffer values to redraw the histogram with either the last **N** or 20,000 values acquired, whichever is the lesser. The parameter buffer thereby allows histograms or trends to be redisplayed using an acquired set of values and settings that produce a distribution shape with the most useful information.

In many cases the optimal range is not readily apparent, so the instrument has a powerful range finding function. If required, it will examine the values in the parameter buffer to calculate an optimal range and redisplay the histogram or trend using it. The instrument will also give a running count of the number of parameter values that fall within, below, and above the range. If any fall below or above the range, the range finder can then recalculate using these parameter values, while they are still within the buffer.

Parameter Events Capture

The number of events captured per waveform acquisition or display sweep depends on the type of parameter. Acquisitions are initiated by the occurrence of a trigger event. Sweeps are equivalent to the waveform captured and displayed on an input channel.

For non-segmented waveforms, an acquisition is identical to a sweep, but for segmented waveforms an acquisition occurs for each segment and a sweep is equivalent to acquisitions for all segments. Only the section of a waveform between the parameter cursors is used in the calculation of parameter values and corresponding histogram events.

The following table provides a summary of the number of Histogram or Trend events captured per acquisition or sweep for each parameter and for a waveform section between the parameter cursors.

Parameter	Number of Events Captured
Timing Parameters: p@lv, freq@lv, wid@lv, ∆ p@lv, edge@lv, duty@lv, tie@lv, skew@lv, setup@lv, hold@lv	Unlimited number of events per acquisition
data	All data values in the region analyzed
duty, freq, period, width	Up to 49 events per acquisition
ampl, area, base, cmean, cmedian, crms, csdev, cycles, delay, dur, first, last, maximum, mean, median, minimum, nbph, nbpw, over+, over-, phase, pkpk, points, rms, sdev, ∆ dly, ∆ t@lv	One event per acquisition
f@level, f80-20%, fall, r@level, r20-80%, rise	Up to 49 events per acquisition

Zoom Traces and Segmented Waveforms

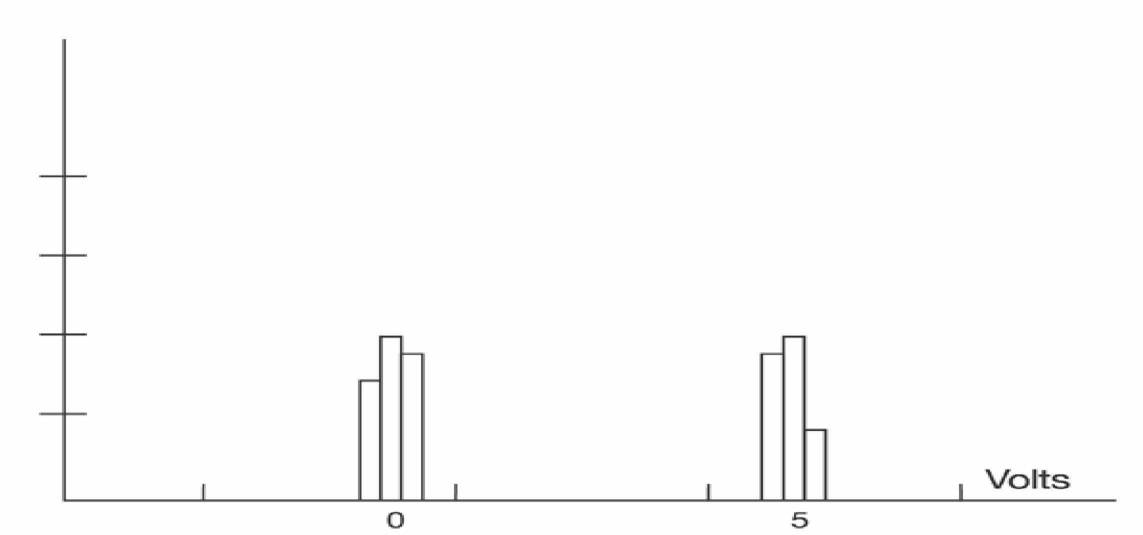
Histograms and Trends of zoom traces display all events for the displayed portion of a waveform between the parameter cursors. When dealing with segmented waveforms, and when a single segment is selected, the histogram or trend will be recalculated for all events in the displayed portion of this segment between the parameter cursors.

Histogram Peaks

Because the shape of histogram distributions is particularly interesting, additional parameter measurements are available for analyzing these distributions. They are generally centered on one of several peak value bins, known (with its associated bins) as a histogram peak.

Example

A histogram of the voltage value of a five-volt amplitude square wave is centered on two peak value bins: **0 V** and **5** ***V*** (see figure). The adjacent bins signify variation due to noise. The graph of the centered bins shows both as peaks.



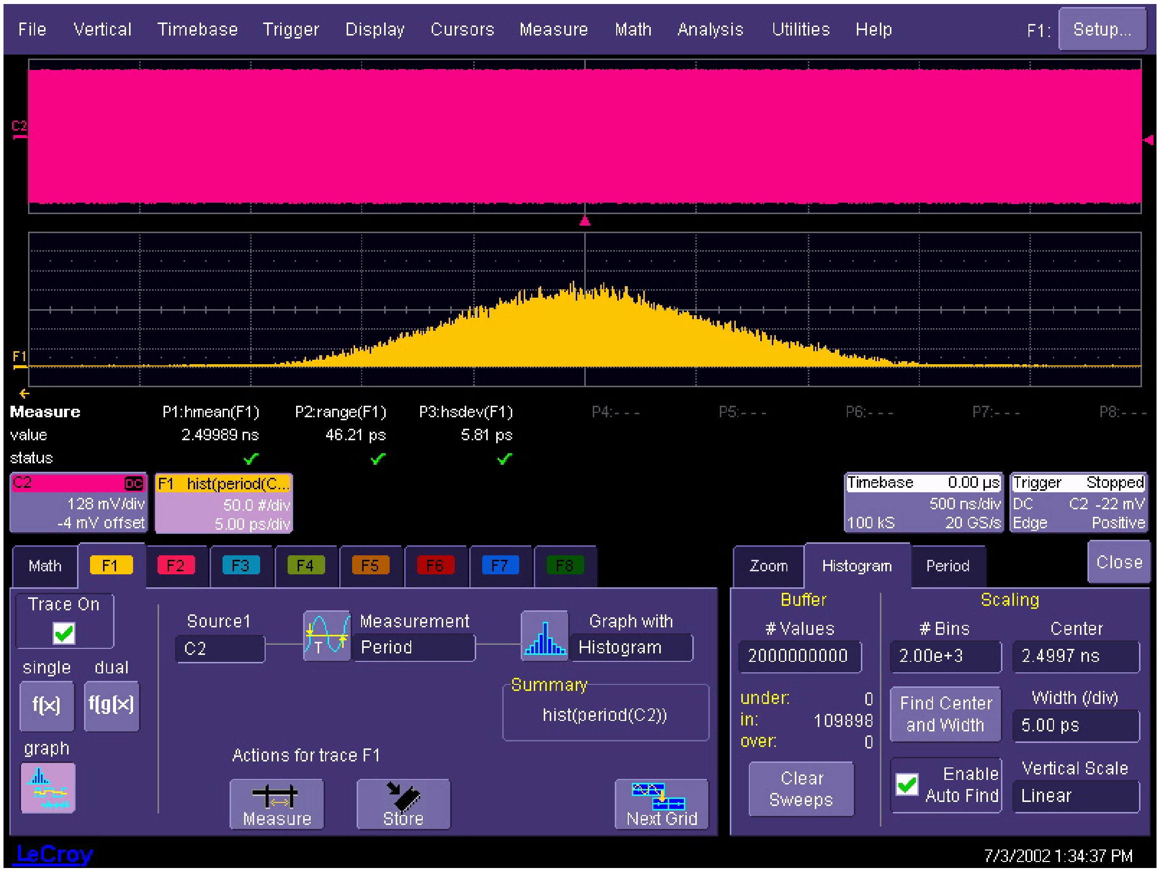
Determining such peaks is very useful because they indicate dominant values of a signal. However, signal noise and the use of a high number of bins relative to the number of parameter values acquired can give a jagged and spiky histogram, making meaningful peaks hard to distinguish. The instrument analyzes histogram data to identify peaks from background noise and histogram definition artifacts such as small gaps, which are due to very narrow bins.

Binning and Measurement Accuracy

Histogram bins represent a sub-range of waveform parameter values, or events. The events represented by a bin may have a value anywhere within its sub-range. However, parameter measurements of the histogram itself, such as **average**, assume that all events in a bin have a single value. The instrument uses the center value of each bin's sub-range in all its calculations. The greater the number of bins used to subdivide a histogram's range, the less the potential deviation between actual event values and those values assumed in histogram parameter calculations.

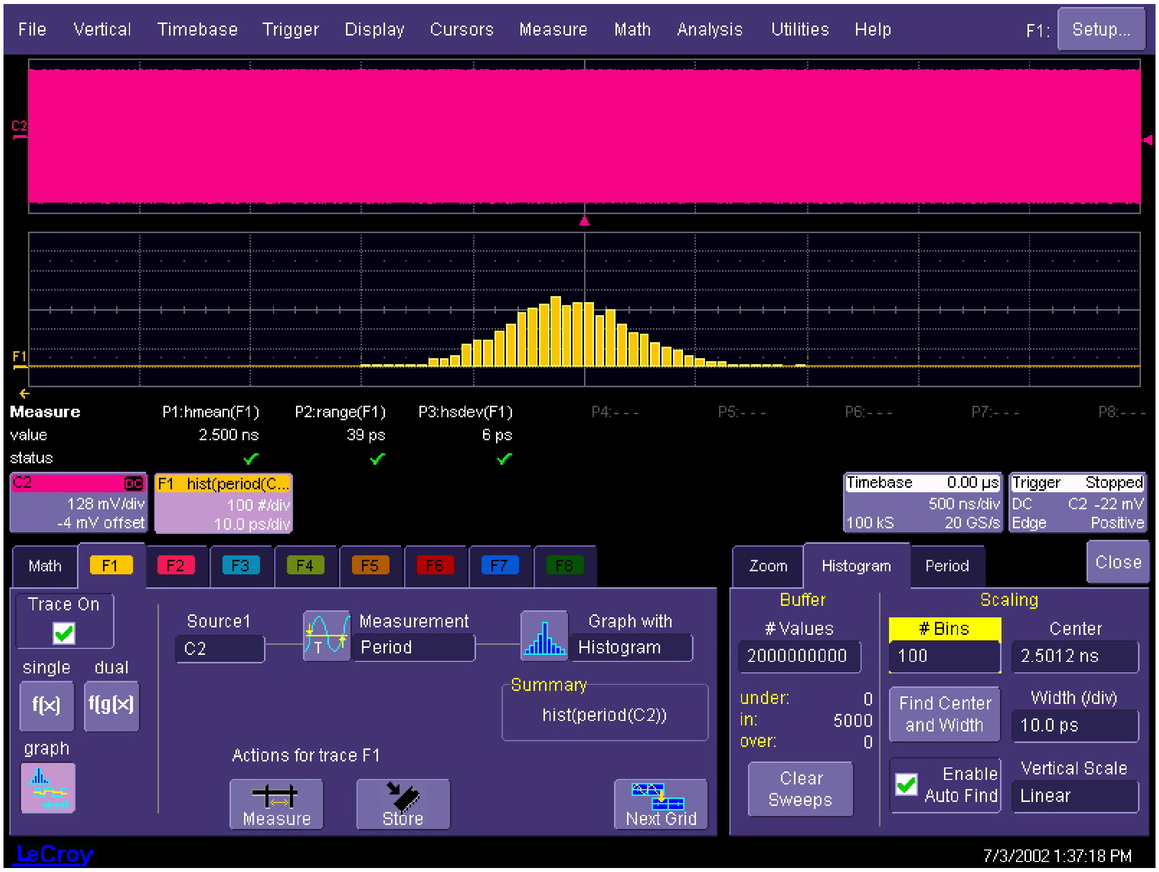
Nevertheless, using more bins may require a greater number of waveform parameter measurements to populate the bins sufficiently for the identification of a characteristic histogram distribution.

The next figure shows a histogram display of 17,999 parameter measurements divided or classified into 2000 bins. The standard deviation of the histogram sigma is 6.750 ps.



The instrument's parameter buffer is very effective for determining the optimal number of bins to be used. An optimal bin number is one where the change in parameter values is insignificant, and the histogram distribution does not have a jagged appearance. With this buffer, a histogram can be dynamically redisplayed as the number of bins is modified by the user. In addition, depending on the number of bins selected, the change in waveform parameter values can be seen.

In the next figure, the histogram shown in the previous figure has been recalculated with 100 bins. Note how it has become far less jagged, while the real peaks are more apparent. Also, the change in sigma is minimal (6.750 ps compared with 6.8 ps).


File
Vertical
Timebase
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Cursors
Measure
Math
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Utilities
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F1:
Setup...
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P1:hmean(F1)
P2:range(F1)
P3:hsdev(F1)
value
2.500 ns
39 ps
6 ps
status
C2
128 mV/div
-4 mV offset
F1 hist(period(C...
100 #/div
10.0 ps/div
Timebase 0.00 µs
500 ns/div
100 kS 20 GS/s
Trigger Stopped
DC C2 -22 mV
Edge Positive
Math
Zoom
Histogram
Period
Close
Trace On
single
dual
graph
Source1
C2
Measurement
Period
Graph with
Histogram
Summary
hist(period(C2))
Actions for trace F1
Measure
Store
Next Grid
Buffer
Values
2000000000
under: 0
in: 5000
over: 0
Clear Sweeps
Scaling
Bins
100
Center
2.5012 ns
Find Center and Width
Width (/div)
10.0 ps
Enable Auto Find
Vertical Scale
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