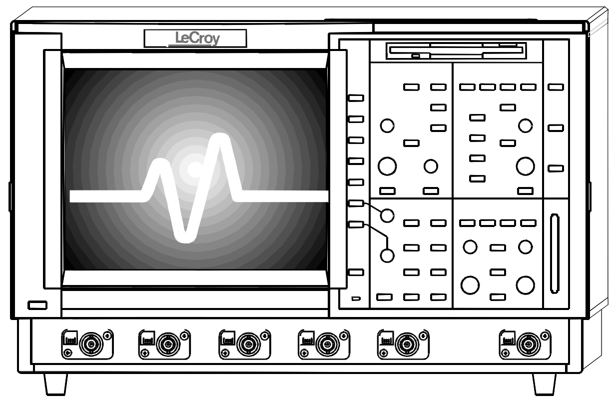

DDM & PRML

Operator's and Programming Manual

LeCroy Digital Oscilloscopes

Revision C — February 1997

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LCXXX-DDM/PRML-OM-E Rev C 0297

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What the Options Offer

The DDM and PRML waveform processing options for LeCroy's color digital oscilloscopes provide:

- **Waveform parameter measurements, allowing disk-drive measurements to be performed over selected waveform sections or an entire waveform**
- **Related mathematical functions for performing disk drive waveform analysis.**

DDM Option

This option offers a variety of waveform parameters.

The **Disk Drive** (**Disk–STD**) parameters — *see* Chapter 5 — provide standard disk drive measurements such as overwrite, **pw50** and track average amplitude (**TAA**).

The **Local** (**Disk–Local**) parameters — *see* Chapter 4 — offer amplitude, time, baseline and other measurements for disk drive waveform peak–trough pairs, allowing useful analysis beyond many standard disk drive measurements.

The option also offers a **Histogram Math** function and histogram parameters (*see* Chapter 3).

The value of **histograms** for use in data analysis, and in the interpretation of measurement results, is well known. The DDM option added to your oscilloscope provides this capability for waveform parameter analysis. Histograms of waveform parameter measurements can be created, statistical parameters determined, and histogram features quantified and analyzed.

Statistical parameters alone — such as mean, standard deviation and median — are usually insufficient for determining whether the distribution of measured data is as expected. Histograms provide an enhanced understanding of the distribution of measured parameters by enabling visual assessment of the distribution. Observations based on the histogram of a parameter can indicate:

1. Distribution type: normal, non-normal, etc. This is helpful in determining whether the signal behaves as expected.
2. Distribution tails and extreme values, which can be observed and may be related to noise or other infrequent and non-repetitive sources.
3. Multiple modes, which can be observed and could indicate multiple frequencies or amplitudes. These can be used to differentiate from other sources such as jitter and noise.

PRML Option

This enables correlation-based measurements. It includes a correlation-math function and two correlation-based parameters: auto-correlation signal–to–noise and non-linear transition shift. The non-linear transition shift parameter can be used to measure other correlation-based disk drive measurements such as overwrite. The correlation math function is capable of performing auto-correlation and cross-correlation calculations. As with histograms, the correlation-math function is assigned to a trace, and the correlation waveform can be displayed.

Parameter Measurements

Histograms of user-selected waveform parameters are created using the scope's Histogram Math function. This is done by defining a trace (**A**, **B**, **C**, or **D**) as a math function, and selecting "**Histogram**" as the function to be applied to the trace. As with other traces, histograms can be positioned and expanded using the **POSITION** and **ZOOM** knobs on the instrument's front panel.

Histograms are displayed based on a set of user settings, including bin width and number of parameter events. Special parameters are provided for determining histogram characteristics such as mean, median, standard deviation, number of peaks and most-populated bin.

This broad range of histogram options and controls provides a quick and easy method of analyzing and understanding measurement results.

The “**MEASURE**” “**Parameters**” menu — and with it, disk drive and histogram parameters — is accessed by pressing the **CURSORS/MEASURE** button, then selecting “**Parameters**” from the top menu appearing, as shown in *Figure 1.1*.

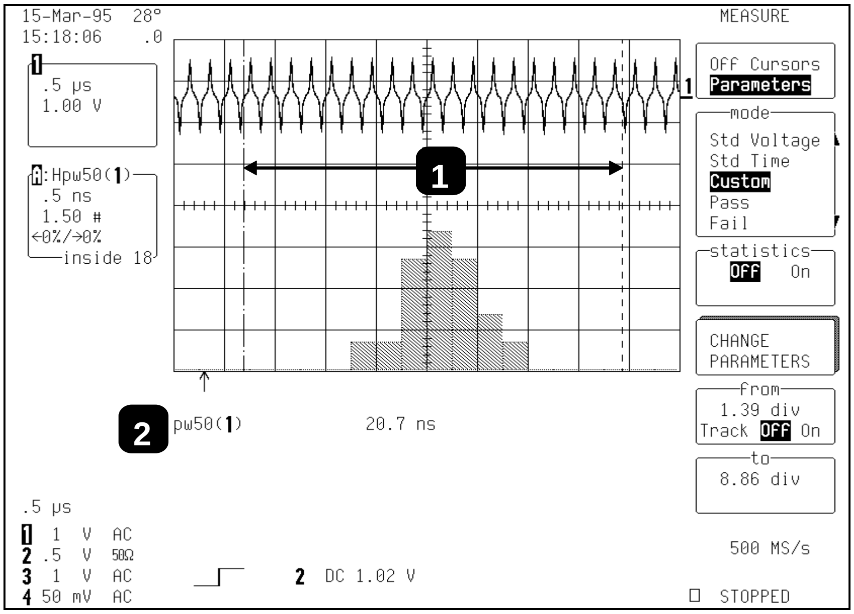


Figure 1.1

Parameters are used to perform waveform measurements for the section of waveform that lies between the parameter cursors (Annotation ❶ in this figure). The position of the parameter cursors is set using the “**from**” and “**to**” menus and controlled by the associated ‘menu’ knobs.

The top trace shows a disk drive test waveform. A **pw50** parameter measurement is being performed on the waveform (Annotation ❷) with a value of 20.7 ns as the calculated result. The bottom trace shows a histogram of the **pw50** parameter. Now, up to five parameters can be selected, with each displayed on its own line below the waveform display grid. Parameter measurements can then also be selected from the “**Category**” and “**measure**” menus using the corresponding menu buttons.

Categories are provided for related groups of parameter measurements. The "**Statistics**" category is provided for Histogram Parameters. After selection of a category, a parameter can be selected from the "**measure**" menu. Selection of parameters is done using the menu buttons or knobs. The parameter display line is selected from the "**On line**" menu.

Figure 1.2 shows the "**Disk–Std**" from "**Category**" and "**pw50**" from "**measure**" selected. The disk drive parameter categories available are "**Disk–Std**", "**Disk–Local**" and "**Disk–PRML**", corresponding to the Disk Drive, Local and PRML parameter groups. The **pw50** parameter is selected for Line 1 and the "**mode**" parameter for Line 2. The mode parameter provides the value of the histogram bin with the most events. No parameters are selected for Lines 3–5.

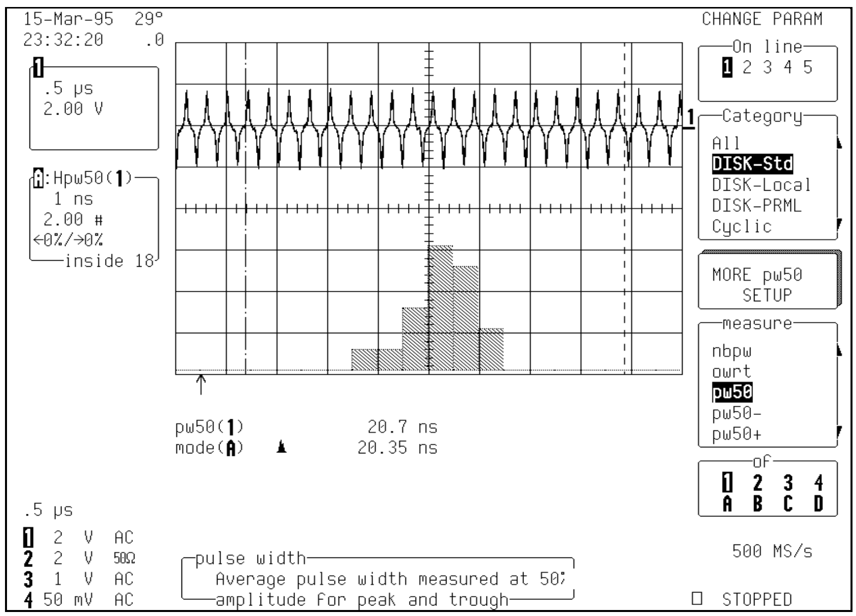


Figure 1.2

If a parameter has additional settings that must be supplied in order to perform measurements, the "**MORE 'xxxx' SETUP**" menu appears. The figure above shows how the "**pw50**" parameter requires the user to provide additional settings. But if no additional settings are required the "**DELETE ALL PARAMETERS**" menu will appear, and pressing the corresponding menu button results in all five lines of parameters being cleared.

The "**of**" menu determines which input channel ("**1**", "**2**", "**3**" or "**4**") or which trace ("**A**", "**B**", "**C**" or "**D**") a parameter measurement will be performed on.

Parameter Value Calculation and Display

When Persistence is *not* being used, the display for input channels shows the captured waveform of a single sweep.

For non-segmented waveforms, the display is the same as a single acquisition. For segmented waveforms the display shows the result of a single acquisition for all segments.

The value displayed for a chosen parameter depends on whether "**statistics**" is "**On**". And on whether the waveform is segmented. These two factors and the parameter chosen determine whether results are provided for a single acquisition (trigger) or multiple acquisitions. In any case, only the waveform section between the parameter cursors is used.

If the waveform source is a memory ("**M1**", "**M2**", "**M3**" or "**M4**") then loading a new waveform into memory acts as a trigger and sweep. This is also the case when the waveform source is a zoom of an input channel, and when a new segment or the "**All Segments**" menu is selected.

When "**statistics**" is "**Off**", the parameter results for the last acquisition are displayed. This corresponds to results for the last segment for segmented waveforms with all segments displayed. For **zoom** traces of segmented waveforms, selection of an individual segment gives the parameter value for the displayed portion of the segment between the parameter cursors. Selection of "**All Segments**" provides the parameter results from the last segment in the trace.

When "**On**", and where the parameter does *not* use two waveforms in calculating a result (∆dly, ∆t@lv, owrt and res), results are shown for all acquisitions since the **CLEAR SWEEPS** button was last pressed. If the parameter uses two waveforms, the result of comparing only the last segment per sweep for each waveform contributes to the statistics.

The statistics for the selected segment are displayed for **zoom** traces of segmented waveforms. Selection of a new segment or "**All Segments**" acts as a new sweep and the parameter calculations for the new segment(s) contribute to the statistics.

Depending on the parameter, single or multiple calculations can be performed for each acquisition. For example, the auto-correlation signal–to–noise (**acsn**) parameter performs 25 or more auto-correlation signal–to–noise calculations in producing a parameter value for a single acquisition. And the **period** parameter calculates a period value for each of up to the first 50 cycles.

When multiple calculations are performed, with "**statistics**" "**Off**" the parameter result shows the average value of these calculations. Whereas "**On**" displays the **average**, **low**, **high** and **sigma** values of all the calculations.

In the following chapters, a description of each of the various types of parameters is given. Also described are any mathematical operations performed in calculating values, the values returned by each parameter, and parameter setup details.

Theory of Operation

A statistical understanding of variations in parameter values is of great interest for many waveform parameter measurements. Knowledge of the average, minimum, maximum and standard deviation of the parameter may often be enough for the user, but in many other instances a more detailed understanding of the distribution of a parameter's values is desired.

Histograms provide the ability to see how a parameter's values are distributed over many measurements, enabling this detailed analysis. They divide a range of parameter values into sub-ranges called bins. Maintained for each bin is a count of the number of parameter values calculated — events — that fall within its sub-range.

While the range can be infinite, for practical purposes it need only be defined as large enough to include any realistically possible parameter value. For example, in measuring TTL high-voltage values a range of ± 50 V is unnecessarily large, whereas one of 4 V ± 2.5 V is more reasonable. It is this 5 V range that is subdivided into bins. And if the number of bins used were 50, each would have a sub-range of 5 V/50 bins or 0.1 V/bin. Events falling into the first bin would then be between 1.5 V and 1.6 V. While the next bin would capture all events between 1.6 V and 1.7 V. And so on.

After a process of several thousand events, the graph of the count for each bin — its histogram — provides a good understanding of the distribution of values. Histograms generally use the 'x' axis to show a bin's sub-range value, and the 'y' axis for the count of parameter values within each bin. The leftmost bin with a non-zero count shows the lowest parameter value measurement(s). The vertically highest bin shows the greatest number of events falling within its sub-range.

The number of events in a bin, peak or a histogram is referred to its population. *Figure 2.1* shows a histogram's highest population bin as the one with a sub-range of 4.3–4.4 V — to be expected of a TTL signal. The lowest value bin with events is that with a sub-range of 3.0–3.1 V. As TTL high voltages need to be greater than 2.5 V, the lowest bin is within the allowable tolerance. However, because of its proximity to this tolerance and the degree of the bin's separation from all other values, additional investigation may be desirable.

LeCroy DSO Process

LeCroy digital oscilloscopes generate histograms of the parameter values of input waveforms. But first, the following must be defined:

- The parameter to be histogrammed.
- The trace on which the histogram will be displayed.
- The maximum number of parameter measurement values to be used in creating the histogram.
- The measurement range of the histogram.
- The number of bins to be used.

Once these are defined, the oscilloscope is ready to make the histogram.

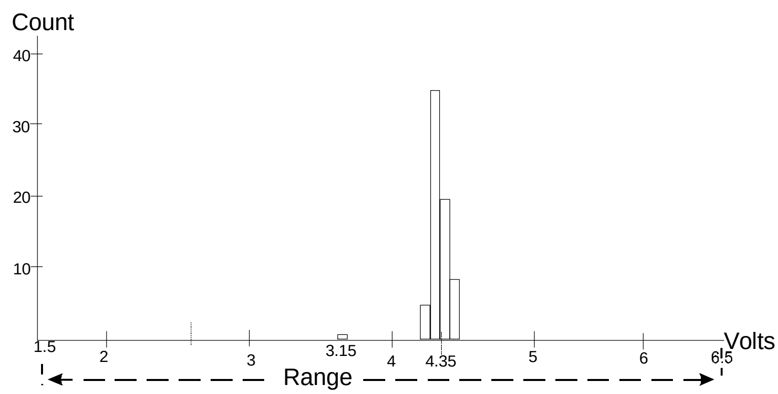


Figure 2.1

The sequence for acquiring histogram data is:

1. trigger
2. waveform acquisition
3. parameter calculation(s)
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 Sequence mode an acquisition for each segment occurs prior to parameter calculations. If the source of histogram 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 oscilloscope maintains a circular parameter buffer of the last
20 000 measurements made, including values that fall outside the set histogram range. If the maximum number of events to be used in a histogram 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 will be updated until the number of events is equal to 'N'. Then, if the number of bins or the histogram range is modified, the scope 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 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 scope 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 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 to include these parameter values, as long as they are still within the buffer.

Parameter Events Capture

The number of events captured per waveform acquisition or display sweep depends on the parameter type. Acquisitions are initiated by the occurrence of a trigger event. Sweeps are equivalent to the waveform captured and displayed on an input channel (1, 2, 3 or 4). For non-segmented waveforms an acquisition is identical to a sweep. Whereas 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, for each parameter and for a waveform section between the parameter cursors, a summary of the number of histogram events captured per acquisition or sweep.

Parameters (plus others, depending on options)	Number of Events Captured
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, Ddly, Dt@lv	One event per acquisition.
f@level, f80–20%, fall, r@level, r20–80%, rise	Up to 49 events per acquisition.

Histogram Parameters

Once a histogram is defined and generated, measurements can be performed on the histogram itself. Typical of these are the histogram's:

- Average value, standard deviation
- Most common value (parameter value of highest count bin)
- Leftmost bin position (representing the lowest measured waveform parameter value)
- Rightmost bin (representing the highest measured waveform parameter value).

Histogram parameters are provided to enable these measurements. Available through selecting "**Statistics**" from the "**Category**" menu, they are calculated for the selected section between the parameter cursors (*for a full description of each parameter, see Chapter 3*):

avg	average of data values in histogram
fwhm	full width (of largest peak) at half the maximum bin
fwxx	full width (of largest peak) at xx% the maximum bin
hampl	histogram amplitude between two largest peaks
hbase	histogram base or leftmost of two largest peaks
high	highest data value in histogram
hmedian	median data value of histogram
hrms	rms value of data in histogram
htop	histogram top or rightmost of two largest peaks
low	lowest data value in histogram
maxp	population of most populated bin in histogram
mode	data value of most populated bin in histogram
pctl	data value in histogram for which specified 'x'% of population is smaller
pks	number of peaks in histogram
range	difference between highest and lowest data values
sigma	standard deviation of the data values in histogram
totp	total population in histogram
xapk	x-axis position of specified largest peak.

Zoom Traces and Segmented Waveforms

Histograms 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 will be recalculated for all events in the displayed portion of this segment between the parameter cursors. But if "**All Segments**" is selected, the histogram for all segments will be displayed.

Histogram Peaks

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

Example

In *Figure 2.2*, a histogram of the voltage value of a five-volt amplitude square wave is centered around two peak value bins: 0 V and 5 V. The adjacent bins signify variation due to noise. The graph of the centered bins shows both as peaks.

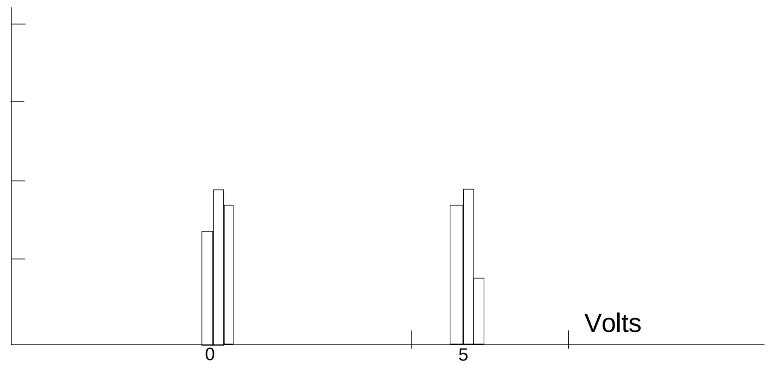


Figure 2.2

Determining such peaks is very useful, as 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 scope analyzes histogram data to identify peaks from background noise and histogram definition artifacts such as small gaps, which are due to very narrow bins.

*For a detailed description on how the scope determines peaks see the **pks** parameter description, Chapter 3.*

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 scope 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 performance of a greater number of waveform parameter measurements, in order to populate the bins sufficiently for the identification of a characteristic histogram distribution.

In addition, very fine-grained binning will result in gaps between populated bins that may make determination of peaks difficult.

Figure 2.3 shows a histogram display of 3672 parameter measurements divided into 2000 bins. The standard deviation of the histogram sigma (Annotation ❶) is 81.17 mV. *Note the histogram's jagged appearance.*

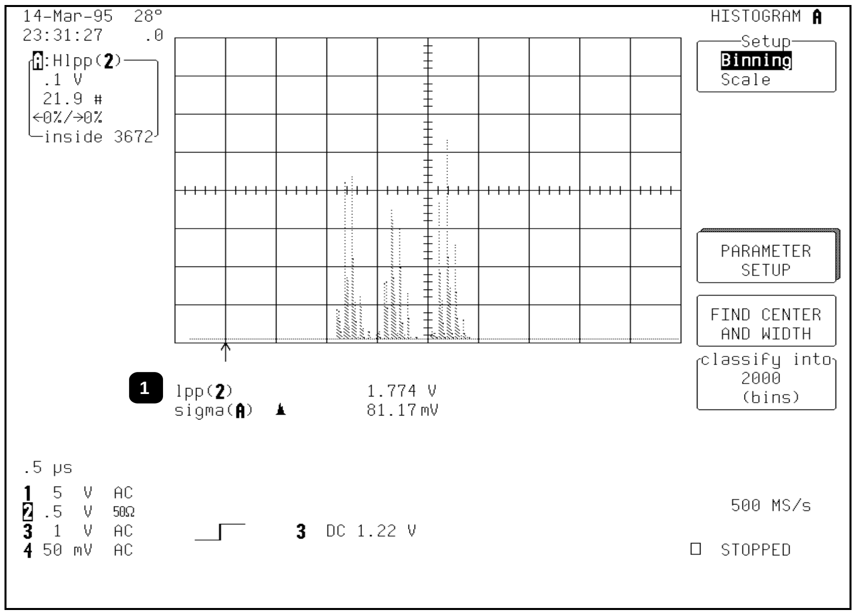


Figure 2.3

The oscilloscope's 20 000-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 *Figure 2.4* 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 (81.17 mV vs 81 mV).

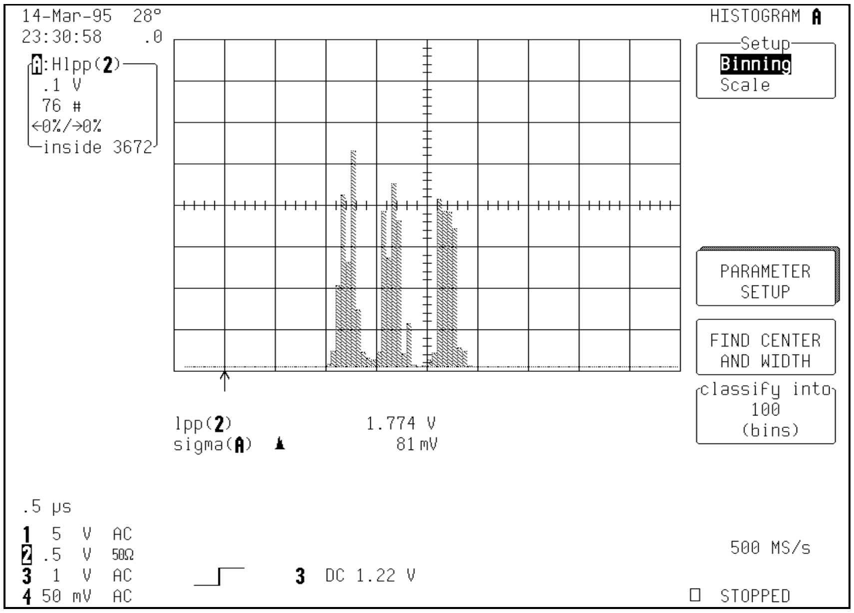


Figure 2.4

Creating and Analyzing Histograms

The following provides a description of the oscilloscope's operational features for defining, using and analyzing histograms. The sequence of steps is typical of this process.

Selecting the Histogram Function

Histograms are created by graphing a series of waveform parameter measurements. The first step is to define the waveform parameter to be histogrammed. *Figure 2.5* shows a screen display accompanying the selection of a frequency (**freq**) parameter measurement (*Annotation* ❶) for a sine waveform on Channel 1.

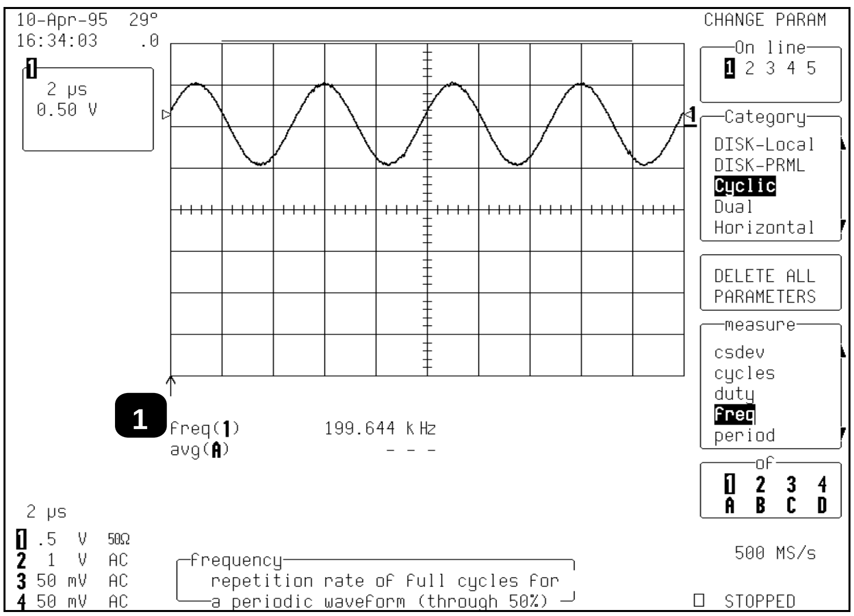


Figure 2.5

The preceding figure shows four waveform cycles, which will provide four freq parameter values for each histogram, each sweep. With a freq parameter selected, a histogram based on it can be specified.

But first the waveform trace must be defined as a histogram. This is done by pressing the **MATH SETUP** button. *Figure 2.6* shows the resulting display. To place the histogram on Trace **A**, the menu button corresponding to the "**REDEFINE A**" menu is pressed.

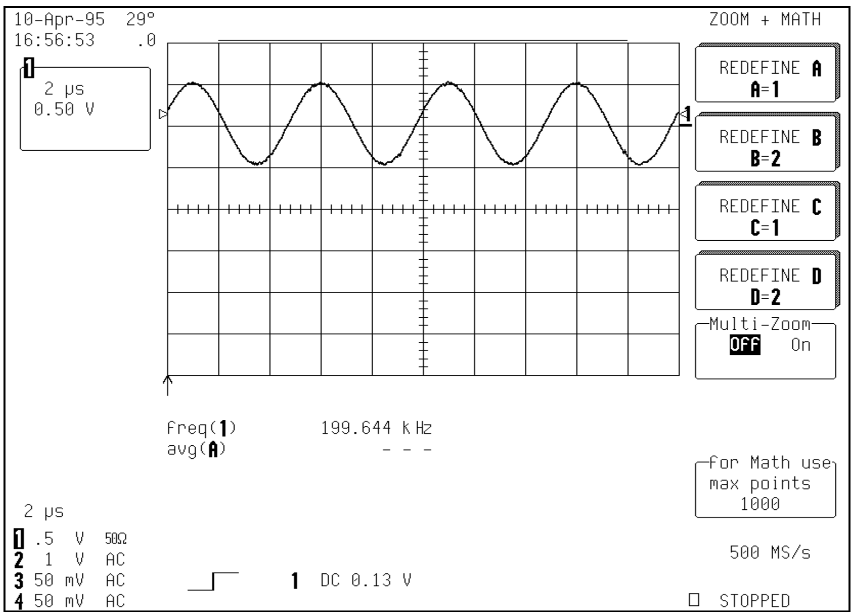


Figure 2.6

Once a trace is selected, the screen shown in *Figure 2.7* appears. Selecting "**Yes**" from the "**use Math**?" menu enables mathematical functions, including histograms.

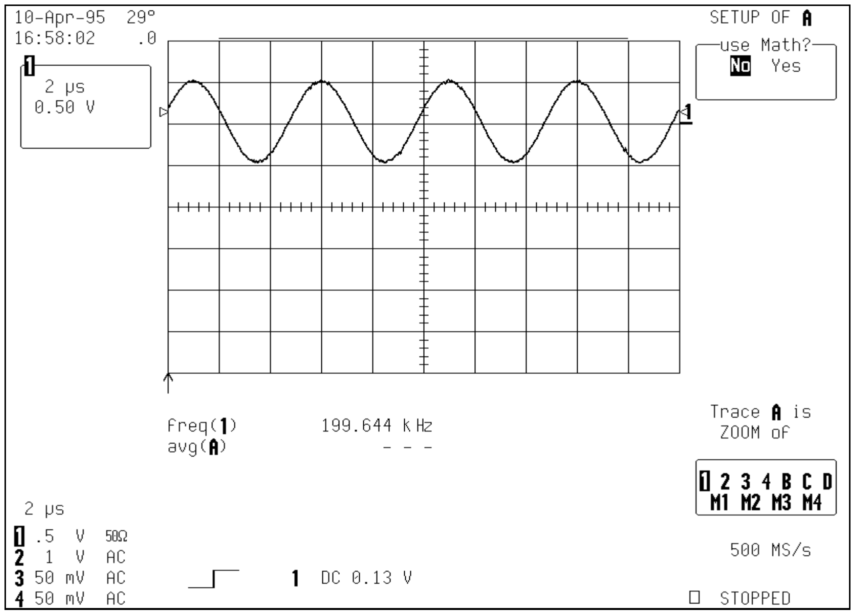


Figure 2.7

Histogram Trace Setup Menu

Figure 2.8 (*next page*) shows the display when "**Histogram**" is selected from the "**Math Type**" menu. Here, the freq parameter only has been defined. However, if additional parameters were to be defined, the individual parameter would need to be selected — by pressing the corresponding menu button or turning the associated knob until the desired parameter appeared in the "**Histogram custom line**" menu.

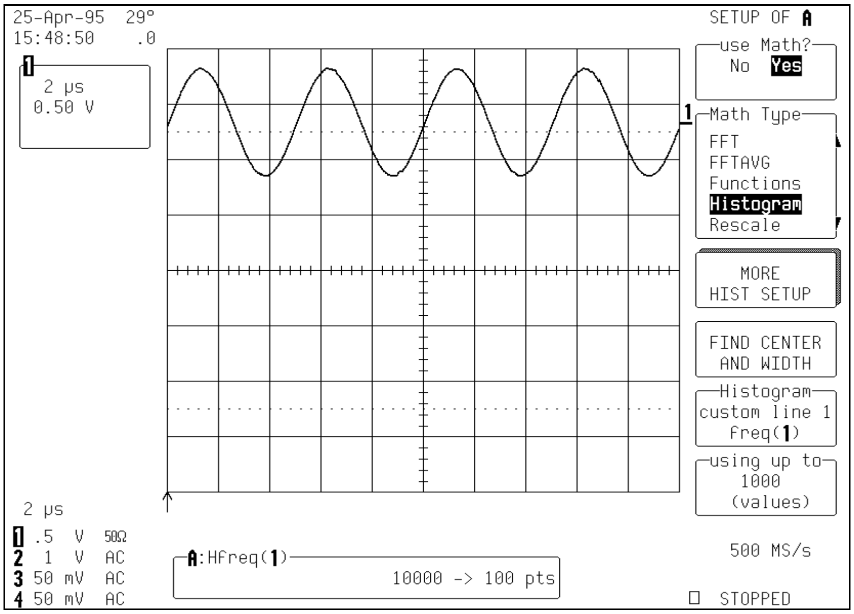


Figure 2.8

Each time a waveform parameter value is calculated it can be placed in a histogram bin. The maximum number of such values is selected from the "**using up to**" menu. Pressing the associated menu button or turning the knob allows the user to select a range from 20 to 2 billion parameter value calculations for histogram display.

To see the histogram, turn the trace display on by pressing the appropriate **TRACE ON/OFF** button, for a display similar that shown in *Figure 2.9*.

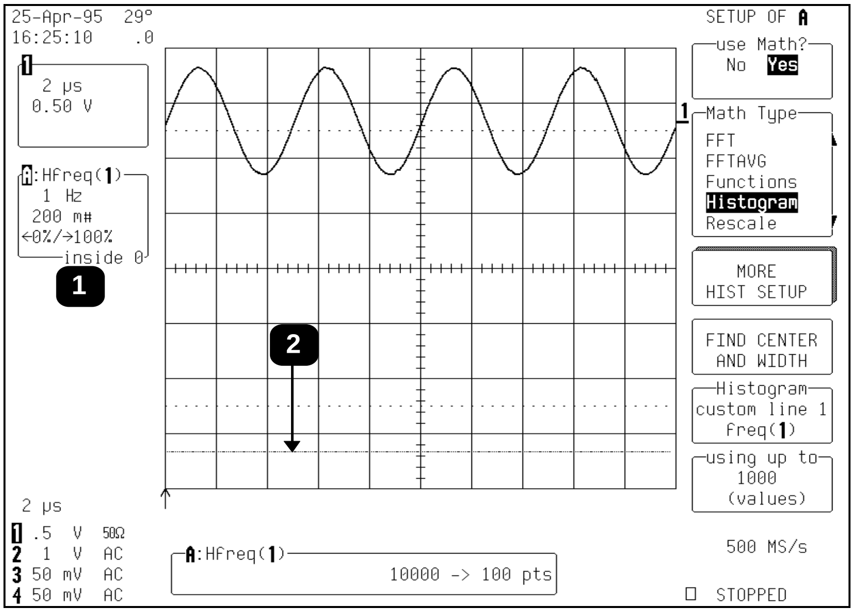


Figure 2.9

Each histogram is set by the user to capture parameter values falling within a specified range. As the scope captures the values in this range the bin counts increase. Values not falling within the range are not used in creating the histogram.

Information on the histogram is provided in the **Displayed Trace Field** (*Annotation* ❶) for the selected trace. This shows:

- The current horizontal per division setting for the histogram ("1 Hz" in this example). The unit type used is determined by the waveform parameter type on which the histogram is based.
- The vertical scale in #bin counts per division (here, "200 m").
- The number of parameter values that fall within the range ("inside 0")
- The percentage that fall below ("←0%")

- The percentage of values above the range ("100%→").

This figure shows that 100% of the captured events are above the range of bin values set for the histogram. As a result, the baseline of the histogram graph (*Annotation* ❷) is displayed, but no values appear.

Selecting the "**FIND CENTER AND WIDTH**" menu allows calculation of the optimal center and bin-width values, based on the up to the most recent parameter values calculated. The number of parameter calculations is chosen with the "**using up to**" menu (or 20 000 values if this is greater than 20 000). *Figure 2.10* shows a typical result.

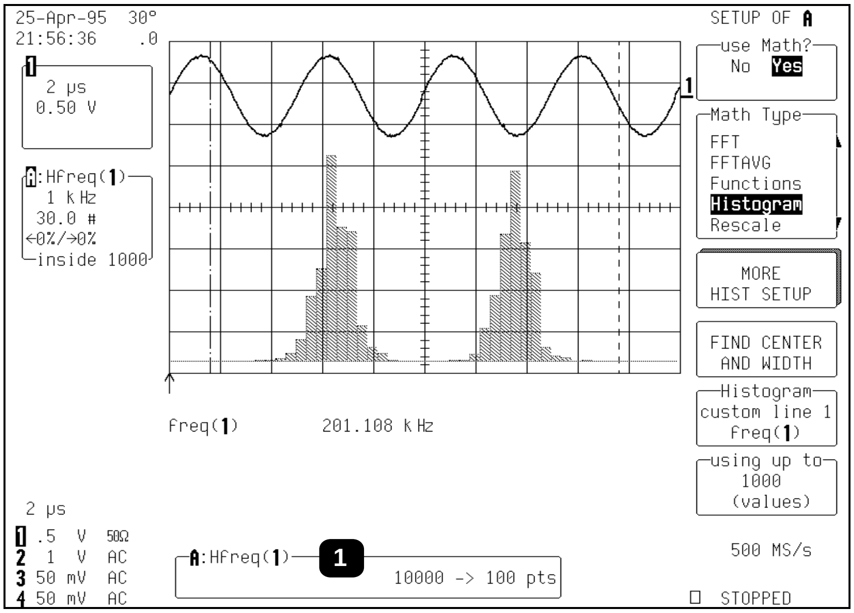


Figure 2.10

If the trace on which the histogram is made is not a zoom, then all bins with events will be displayed. Otherwise, press **RESET** to reset the trace and display all histogram events.

The **Information Window** (*Annotation* ❶) at the bottom of the previous screen shows a histogram of the **freq** parameter for Channel 1 (designated as "**A:Hfreq(1)**") for Trace A. The "**1000 ® 100 pts**" in the window indicates that the signal on Channel 1 has 1000 waveform acquisition samples per sweep and is being mapped into 100 histogram bins.

Selecting "**MORE HIST SETUP**" allows additional histogram settings to be specified, resulting in a display similar to that of *Figure 2.11*, below.

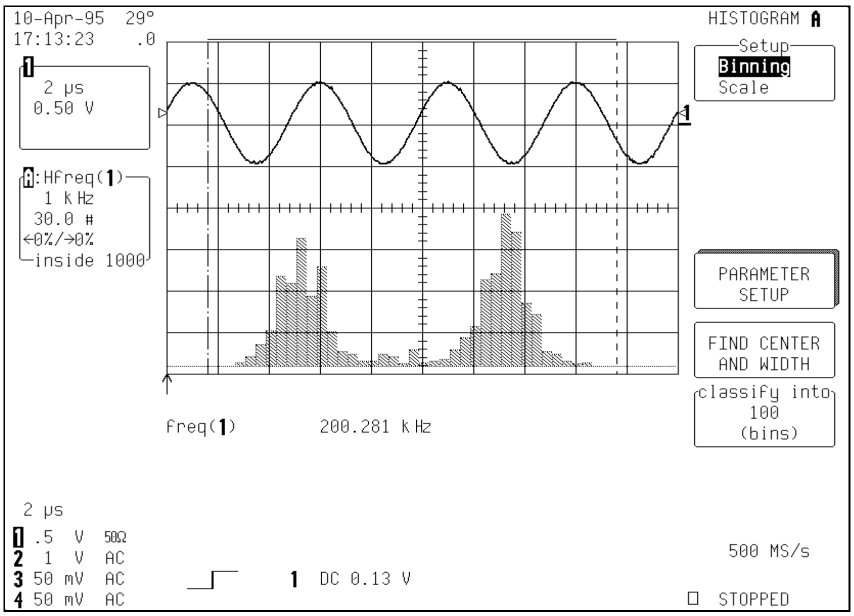


Figure 2.11

Setting Binning & Histogram Scale

The “**Setup**” menu allows modifcation of either the “**Binning**” or the histogram “**Scale**” settings. If “**Binning**” is selected, the “**classify into**” menu appears, as shown in the figure above.

The number of bins used can be set from a range of 20–2000 in a 1–2–5 sequence, by pressing the corresponding menu button or turning the associated knob.

If “**Scale**” is selected from the “**Setup**” menu, a screen similar that of *Figure 2.12* will be displayed.

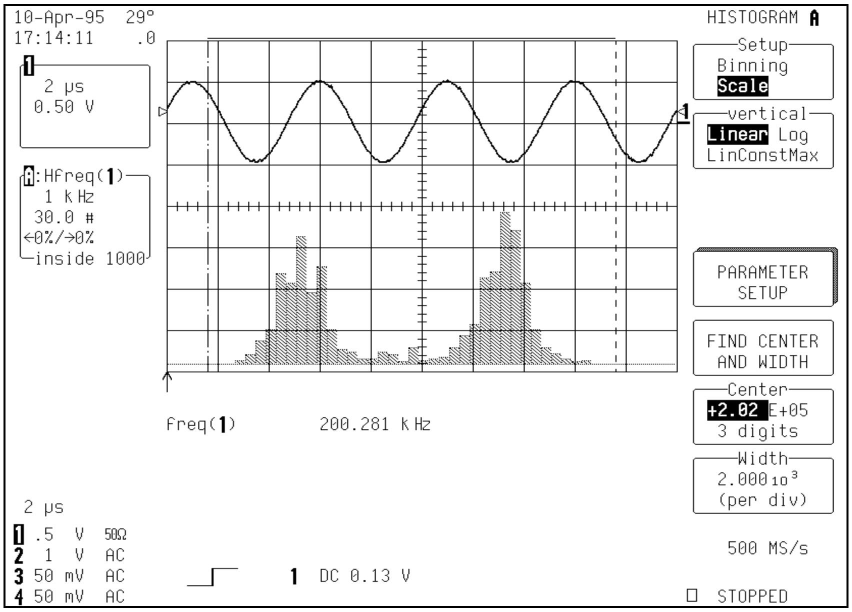


Figure 2.12

Three options are offered by the “**vertical**” menu for setting the vertical scale:

1. “**Linear**” sets the vertical scale as linear (*see previous figure*). The baseline of the histogram designates a bin value of 0. As the bin counts increase beyond that which can be displayed on screen using the current vertical scale, this scale is automatically increased in a 1–2–5 sequence.
2. “**Log**” sets the vertical scale as logarithmic (*Fig. 2.13*). Because a value of ‘0’ cannot be specified logarithmically, no baseline is provided.

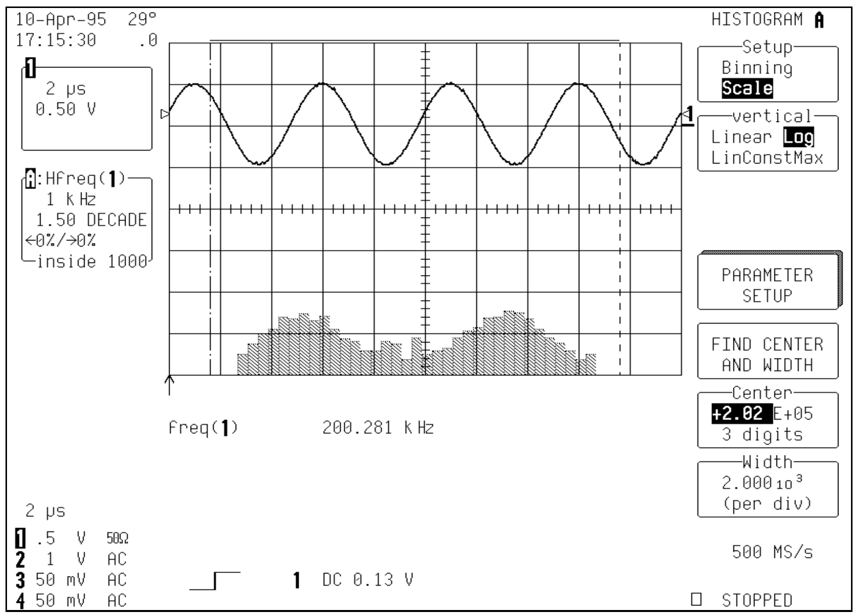


Figure 2.13

3. “**LinConstMax**” sets the vertical scaling to a linear value that uses close to the full vertical display capability of the scope (*Fig. 2.14*). The height of the histogram will remain almost constant.

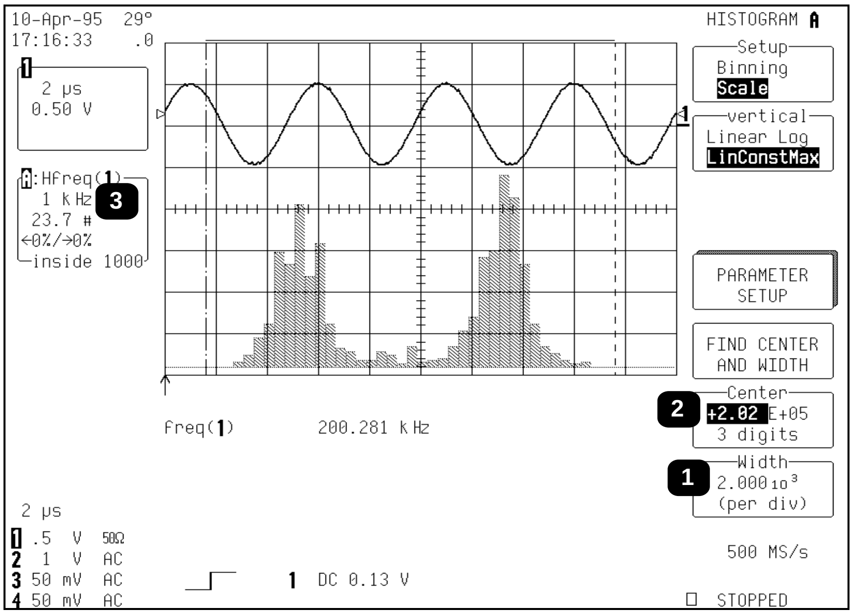


Figure 2.14

For any of these options, the scope automatically increases the vertical scale setting as required, ensuring the highest histogram bin does not exceed the vertical screen display limit.

The “**Center**” and “**Width**” menus allow specification of the histogram center value and width per division. The width per division times the number of horizontal display divisions (10) determines the range of parameter values centered on the number in the “**Center**” menu, used to create the histogram.

In the previous figure, the width per division is 2.000 $\times$ 10^3 (*Annotation* ❶). As the histogram is of a frequency parameter, the measurement parameter is hertz.

The range of parameter values contained in the histogram is therefore:

(2 k Hz/division) x (10 divisions) = 20 k Hz

with a center of 2.02 E+05 Hz (❷).

In this example, all freq parameter values within 202 k Hz ± 10 k Hz — from 192 k Hz to 212 k Hz — are used in creating the histogram. The range is subdivided by the number of bins set by the user. Here, the range is 20 k Hz, as calculated above, and the number of bins 100. Therefore, the range of each bin is:

20 k Hz / 100 bins, or

.2 k Hz per bin.

The "**Center**" menu allows the user to modify the center value's mantissa (here, 2.02), exponent (E+05) or the number of digits used in specifying the mantissa (three). The display scale of 1 k Hz/division, shown in the Trace Display Field, is indicated by *Annotation* ❸. This scale has been set using the horizontal zoom control and can be used to expand the scale for visual examination of the histogram trace.

The use of zoom in this way does *not* modify the range of data acquisition for the histogram, only the display scale. The range of measurement acquisition for the histogram remains based on the center and width scale, resulting in a range of 202 k Hz ± 10 k Hz for data acquisition.

Any of these can be changed using the associated knob. And the width/division can be incremented in a 1–2–5 sequence by selecting "**Width**", using button or knob.

Histogram Parameters

Once the histogram settings are defined, selecting additional parameter values is often useful for measuring particular attributes of the histogram.

Selecting "**PARAMETER SETUP**", as shown in the previous figure, accesses the "**CHANGE PARAM**" menus, shown in *Figure 2.15.*

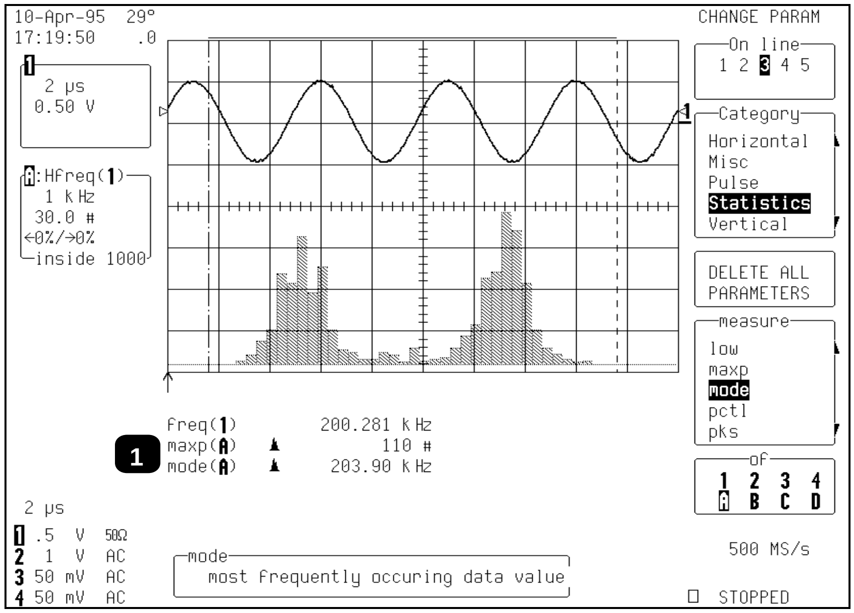


Figure 2.15

New parameters can now be selected or previous ones modified. In this figure, the histogram parameters **maxp** and **mode** (*Annotation* ❶) have been selected. These determine the count for the bin with the highest peak, and the corresponding horizontal axis value of that bin's center.

Note that both "**maxp**" and "**mode**" are followed by "**(A)**" on the display. This designates the measurements as being made on the signal on Trace A, in this case the histogram. Note:

- The value of "**maxp(A)**" is "110 #", indicating the highest bin has a count of 110 events.
- The value of **mode(A)** is "203.90 k Hz", indicating that this bin is at 203.90 k Hz.

➢ The ▲ icon to the left of "**mode**" and "**maxp**" parameters indicates that the parameter is being made on a trace defined as a histogram.

However, if these parameters were inadvertently set for a trace with no histogram they would show '---'.

Using Measurement Cursors The parameter cursors can be used to select a section of a histogram for which a histogram parameter is to be calculated.

Figure 2.16 shows the average, "**avg(A)**" (*Annotation* ❶) of the distribution between the parameter cursors for a histogram of the frequency ("**freq**") parameter of a waveform. The parameter cursors (❷) are set "**from**" 4.70 divisions (❸) "**to**" 9.20 divisions (❹) of the display.

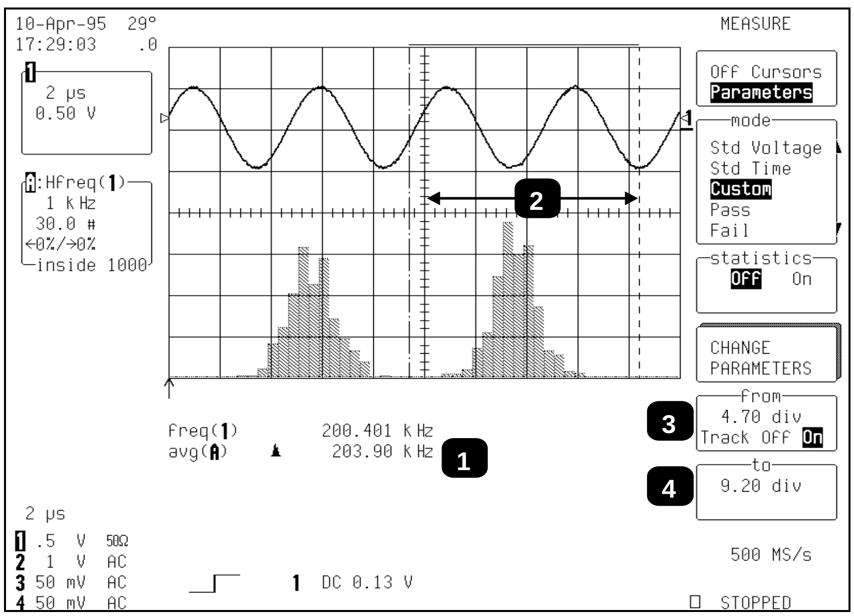


Figure 2.16

It is recommended that this capability be used only after the input waveform acquisition has been completed. Otherwise, the parameter cursors will also select the portion of the input waveform used to calculate the parameter during acquisition. This will create a histogram with only the local parameter values for the selected waveform portion.

Zoom Traces and Segmented Waveforms

Histograms can also be displayed for traces that are zooms of segmented waveforms. When a segment from a zoomed trace is selected, the histogram for that segment will appear. Only the portion of the segment displayed and between the parameter cursors will be used in creating the histogram. The corresponding Displayed Trace Field will show the number of events captured for the segment.

Figure 2.17 shows "**Selected**" a histogram of the frequency ("**freq**") parameter for "**Segment 1**" (*Annotation* ❶) of Trace "**A**", which is a zoom of a 10-segment waveform on Channel 1.

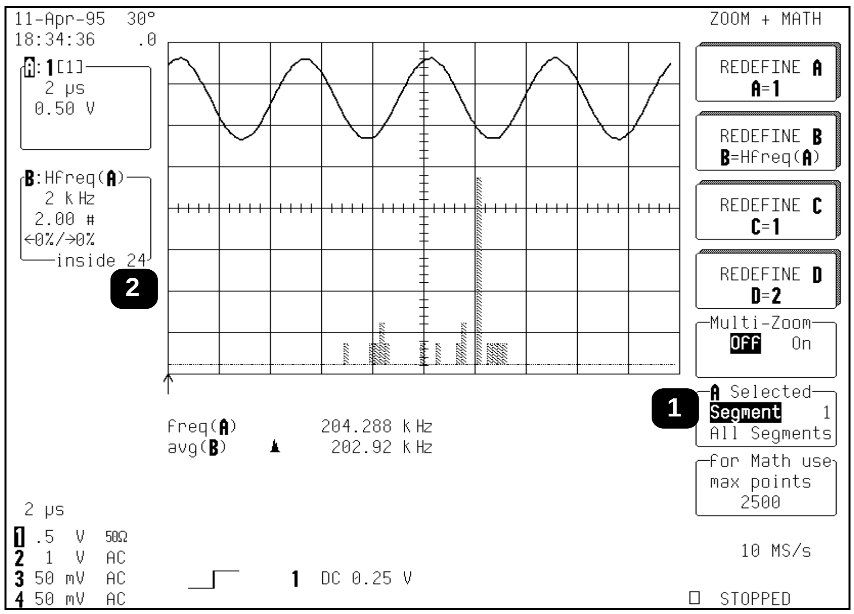


Figure 2.17

The Displayed Trace Field shows that 24 parameter events (*Annotation* ❷) have been captured into the histogram. The average value for the freq parameter is displayed as the histogram parameter, "**avg(B)**".

Figure 2.18 shows the result of selecting "**All Segments**".

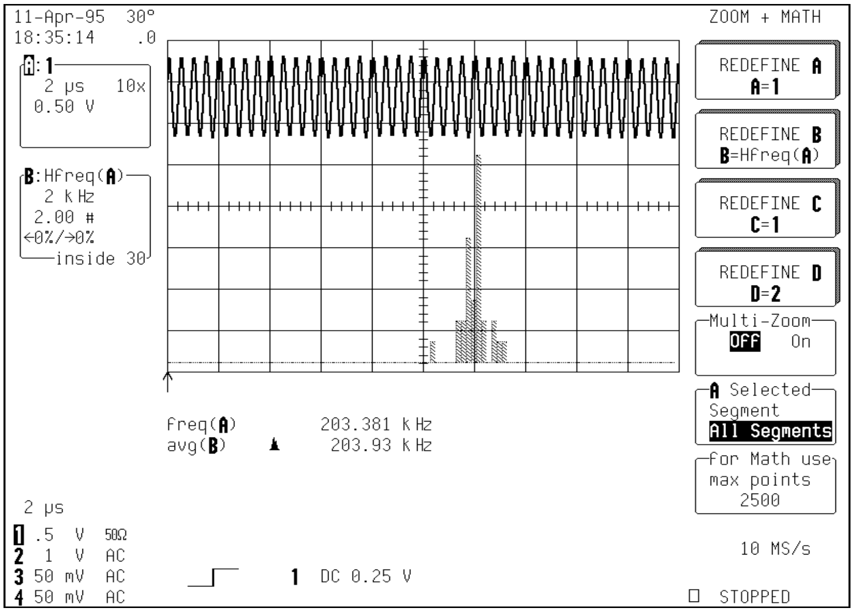


Figure 2.18

Note that the Displayed Trace Field indicates 30 events in the histogram for all segments, and the change in "**avg(B)"**.

Histogram events can be cleared at any time by pushing the **CLEAR SWEEPS** button. All events in the 20-k parameter buffer are cleared at the same time. The vertical and horizontal **POSITION** and **ZOOM** control knobs can be used to expand and position the histogram for zooming-in on a particular feature of it. The resulting vertical and horizontal scale settings are shown in the Displayed Trace Field. However, the values in the "**Center**" and "**Width**" menus do *not* change, since they determine the range of the histogram and *cannot* be used to determine the parameter value range of a particular bin. If the histogram is repositioned using the horizontal **POSITION** knob the histogram's center will be moved from the center of the screen. Horizontal measurements will then require the use of **CURSORS/MEASURE**.

The scope's measurement cursors are useful for determining the value and population of selected bins. *Figure 2.19* shows the "**Time**" cursor (❶) positioned on a selected histogram bin. The value of the bin (❷) and the population of the bin (❸) are also shown.

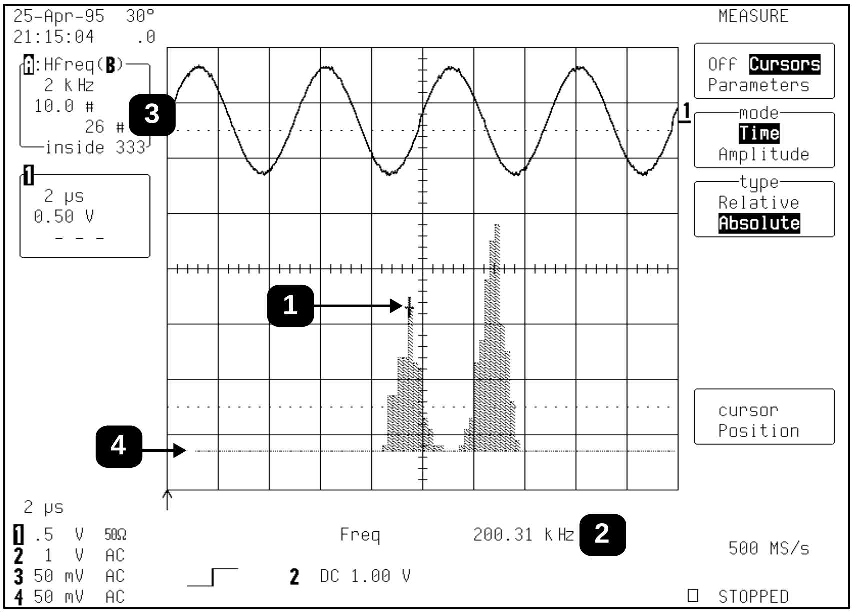


Figure 2.19

A histogram's range is represented by the horizontal width of the histogram baseline. As the histogram is repositioned vertically the left and right sides of the baseline can be seen. In this final figure of the chapter, the left edge of the range is visible (❹).

avg — Average

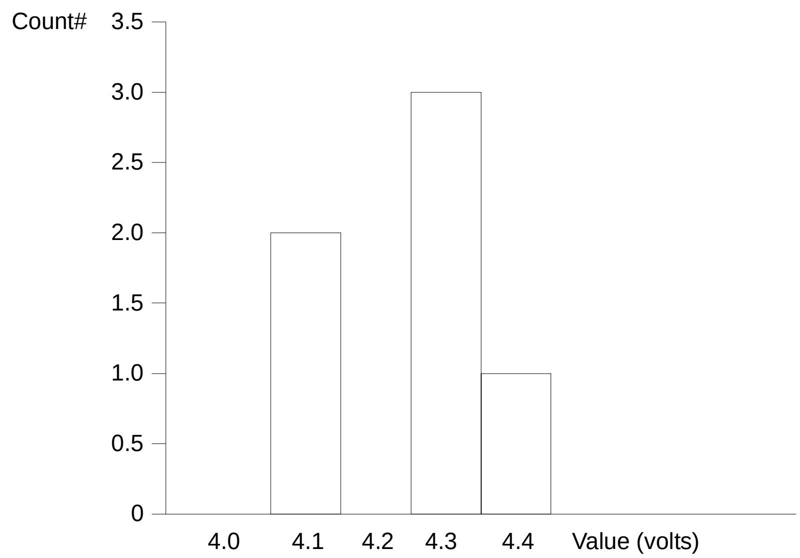
Definition Average or mean value of data in a histogram.

Description The average is calculated by the formula:

$$\text{avg} = \sum_{i=1}^{n} (\text{bin count})_i \, (\text{bin value})_i \Big/ \sum_{i=1}^{n} (\text{bin count})_i \, ,$$

where n is the number of bins in the histogram, bin count is the count or height of a bin, and bin value is the center value of the range of parameter values a bin can represent.

Example



The average value of this histogram is:

$$(4.1 * 2 + 4.3 * 3 + 4.4 * 1) / 6 = 4.25.$$

fwhm — Full Width at Half Maximum

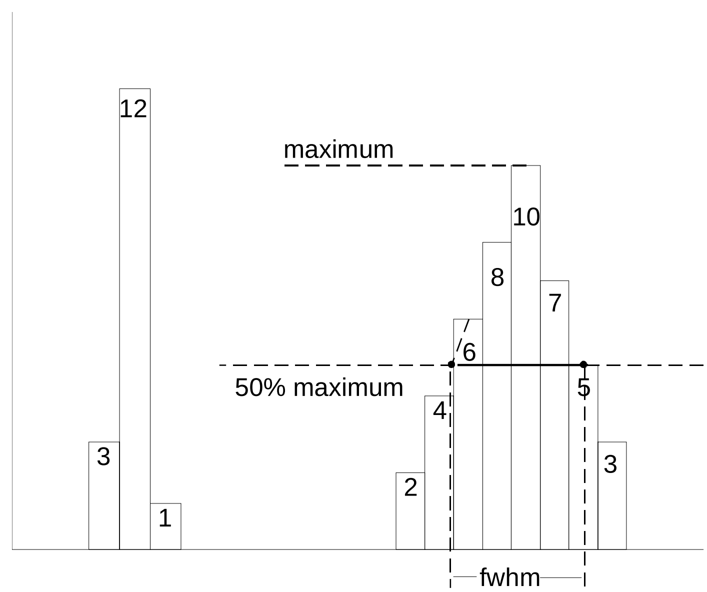
Definition

Determines the width of the largest area peak, measured between bins on either side of the highest bin in the peak that have a population of half the highest's population. If several peaks have an area equal to the maximum population, the leftmost peak is used in the computation.

Description

First, the highest population peak is identified and the height of its highest bin (population) determined (*for a discussion on how peaks are determined see the* ***pks*** *parameter description*). Next, the populations of bins to the right and left are found, until a bin on each side is found to have a population of less than 50% of that of the highest bin's. A line is calculated on each side, from the center point of the first bin below the 50% population to that of the adjacent bin, towards the highest bin. The intersection points of these lines with the 50% height value is then determined. The length of a line connecting the intersection points is the value for **fwhm**.

Example



fwxx — Full Width at xx% Maximum

Definition

Determines the width of the largest area peak, measured between bins on either side of the highest bin in the peak that have a population of xx% of the highest's population. If several peaks have an area equal to the maximum population, the leftmost peak is used in the computation.

Description

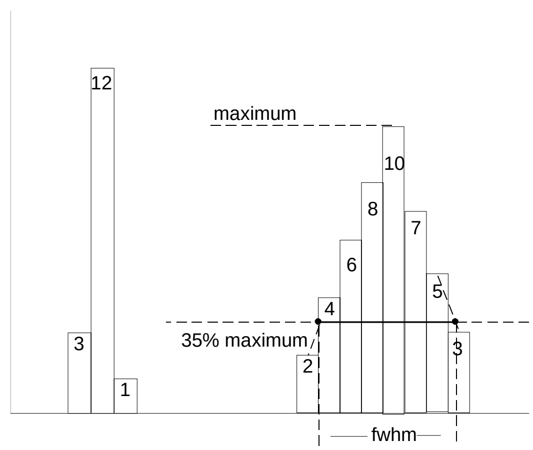
First, the highest population peak is identified and the height of its highest bin (population) determined (*see the **pks** description*). Next, the bin populations to the right and left are found until a bin on each side is found to have a population of less than xx% of that of the highest bin. A line is calculated on each side, from the center point of the first bin below the 50% population to that of the adjacent bin, towards the highest bin. The intersection points of these lines with the xx% height value is then determined. The length of a line connecting the intersection points is the value for **fwxx**.

Parameter Settings

Selection of the **fwxx** parameter in the "**CHANGE PARAM**" menu group causes the "**MORE fwxx SETUP**" menu to appear. Pressing the corresponding menu button displays a threshold setting menu that enables the user to set the 'xx' value to between 0–100% of the peak.

Example

fwxx with threshold set to 35%:



hampl — Histogram Amplitude

Definition

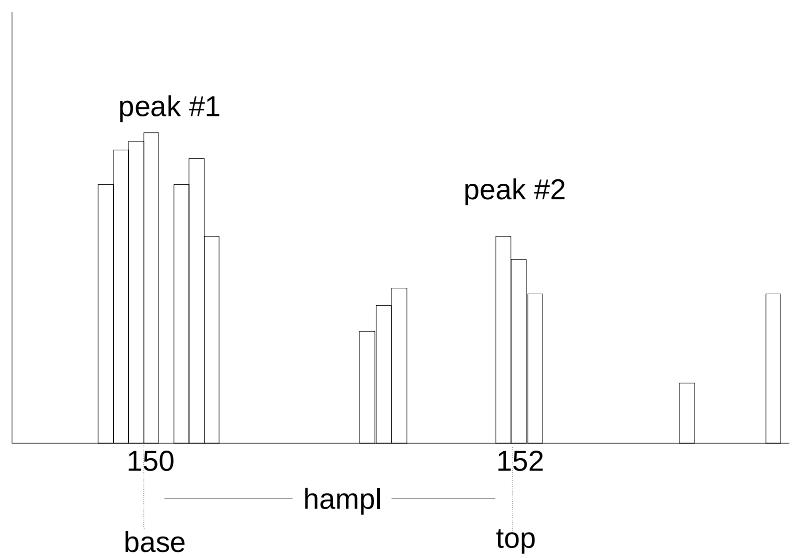
The difference in value of the two most populated peaks in a histogram. This parameter is useful for waveforms with two primary parameter values, such as TTL voltages, where **hampl** would indicate the difference between the binary ‘1’ and ‘0’ voltage values.

Description

The values at the center (line dividing the population of peak in half) of the two highest peaks are determined (*see **pks** parameter description*). The value of the leftmost of the two peaks is the histogram base (*see* **hbase**). While that of the rightmost is the histogram top (*see* **htop**). The parameter is then calculated as:

hampl = htop – hbase

Example



In this histogram, **hampl** is 152 mV – 150 mV = 2 mV.

hbase — Histogram Base

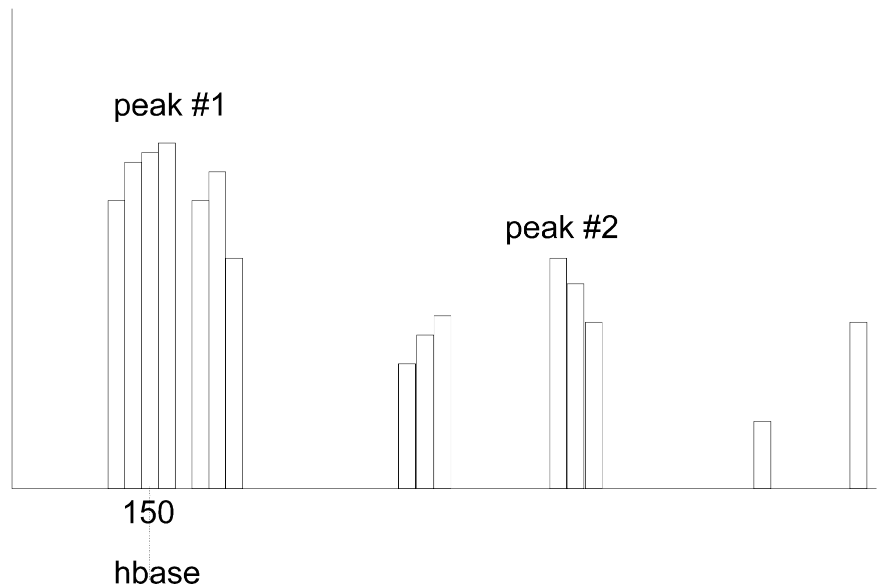
Definition

The value of the leftmost of the two most populated peaks in a histogram. This parameter is primarily useful for waveforms with two primary parameter values such as TTL voltages where **hbase** would indicate the binary ‘0’ voltage value.

Description

The two highest histogram peaks are determined. If several peaks are of equal height the leftmost peak among these is used (*see* ***pks***). Then the leftmost of the two identified peaks is selected. This peak’s center value (line that divides population of peak in half) is the **hbase**.

Example

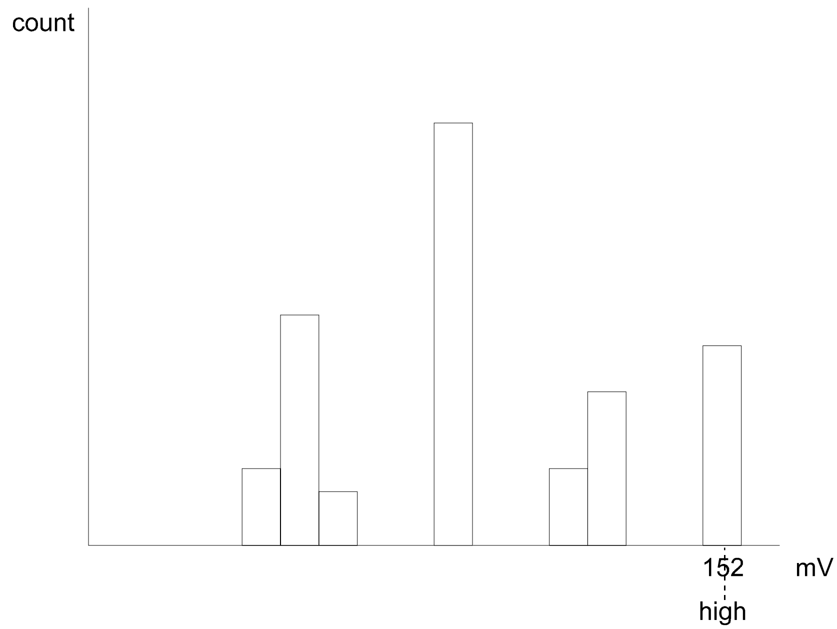


high — High

Definition The value of the rightmost populated bin in a histogram.

Description The rightmost of all populated histogram bins is determined: **high** is its center value, the highest parameter value shown in the histogram.

Example



In this histogram **high** is 152 mV.

hmedian — Histogram Median

Definition

The value of the ‘x’ axis of a histogram, dividing the histogram population into two equal halves.

Description

The total population of the histogram is determined. Scanning from left to right, the population of each bin is summed until a bin that causes the sum to equal or exceed half the population value is encountered. The proportion of the population of the bin needed for a sum of half the total population is then determined. Using this proportion, the horizontal value of the bin at the same proportion of its range is found, and returned as **hmedian**.

Example

The total population of a histogram is 100 and the histogram range is divided into 20 bins. The population sum, from left to right, is 48 at the eighth bin. The population of the ninth bin is 8 and its sub-range is from 6.1–6.5 V. The ratio of counts needed for half- to total-bin population is:

2 counts needed / 8 counts = .25

The value for **hmedian** is:

6.1 volts + .25 * (6.5 – 6.1) volts = 6.2 volts

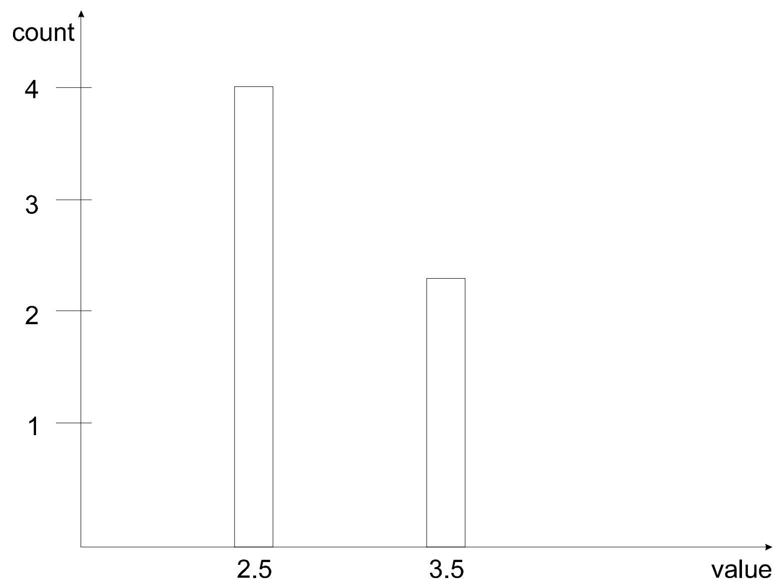
hrms — Histogram Root Mean Square

Definition The rms value of the values in a histogram.

Description The center value of each populated bin is squared and multiplied by the population (height) of the bin. All results are summed and the total is divided by the population of all the bins. The square root of the result is returned as **hrms**.

Example Using the histogram shown here, the value for **hrms** is:

$$\text{hrms} = \sqrt{(3.5^2 * 2 + 2.5^2 * 4)/6} = 2.87$$



htop — Histogram Top

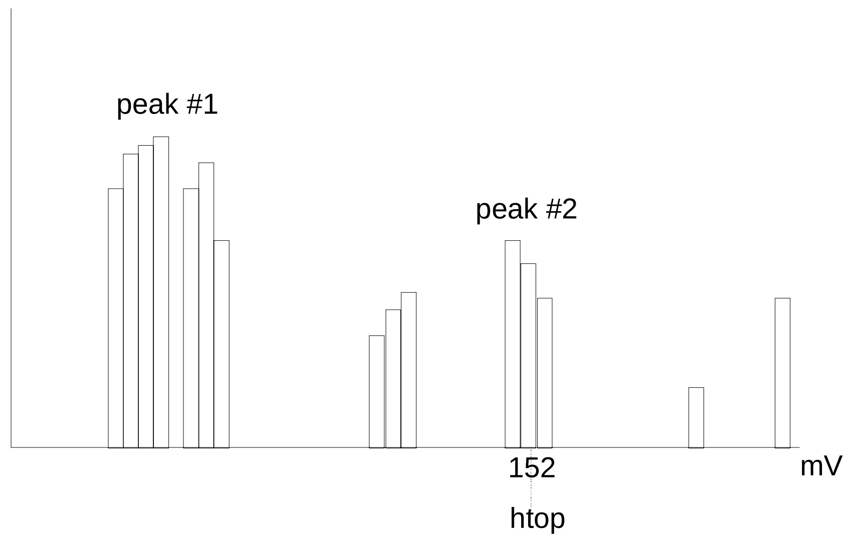
Definition

The value of the rightmost of the two most populated peaks in a histogram. This parameter is useful for waveforms with two primary parameter values, such as TTL voltages, where **htop** would indicate the binary ‘1’ voltage value.

Description

The two highest histogram peaks are determined. The rightmost of the two identified peaks is then selected. The center of that peak is **htop** (center is the horizontal point where the population to the left is equal to the area to the right).

Example

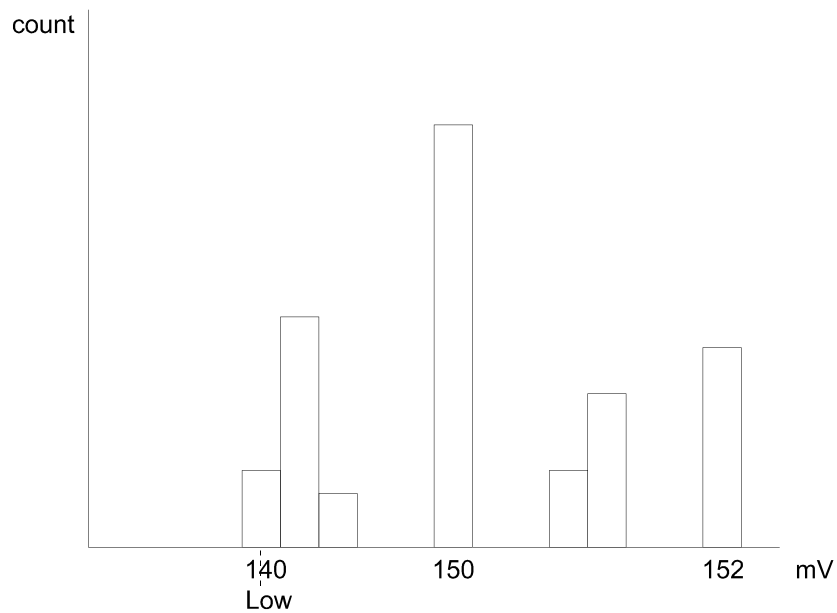


low — Low

Definition The value of the leftmost populated bin in a histogram population. It indicates the lowest parameter value in a histogram's population.

Description The leftmost of all populated histogram bins is determined. The center value of that bin is **low**.

Example



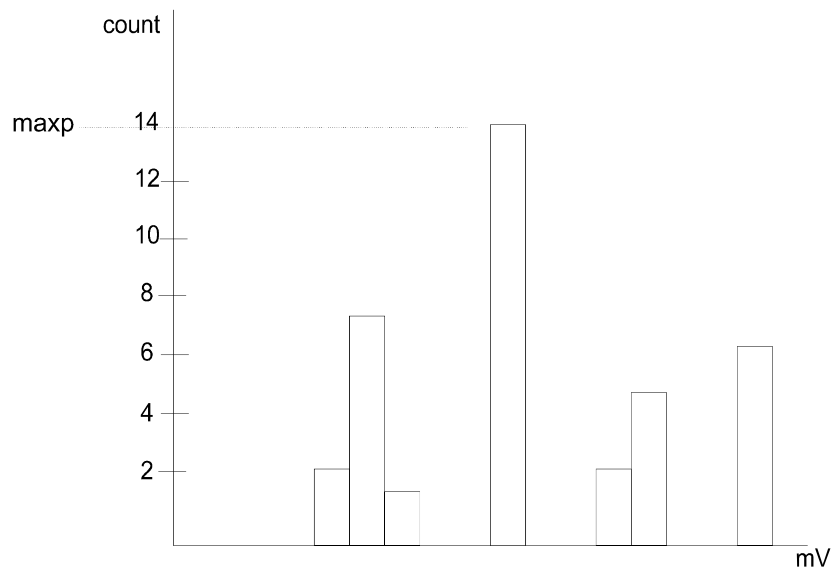
In this histogram **low** is 140 mV.

maxp Maximum Population

Definition The count (vertical value) of the highest population bin in a histogram.

Description Each bin between the parameter cursors is examined for its count. The highest count is returned as **maxp**.

Example



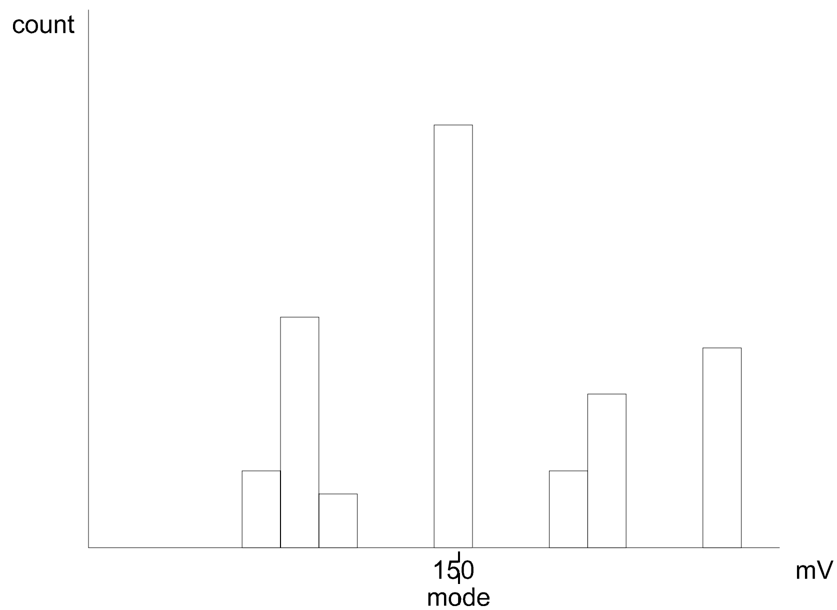
In this example, **maxp** is 14.

mode **Mode**

Definition The value of the highest population bin in a histogram.

Description Each bin between the parameter cursors is examined for its population count. The leftmost bin with the highest count found is selected. Its center value is returned as **mode**.

Example



In this example **mode** is 150 mV.

pctl Percentile

Definition

Computes the horizontal data value that separates the data in a histogram, so that the population on the left is a specified percentage 'xx' of the total population. When the threshold is set to 50%, **pctl** is the same as **hmedian**.

Description

The total population of the histogram is determined. Scanning from left to right, the population of each bin is summed until a bin that causes the sum to equal or exceed 'xx'% of the population value is encountered. A ratio of the number of counts needed for 'xx'% population/total bin population is then determined for the bin. The horizontal value of the bin at that ratio point of its range is found, and returned as **pctl**.

Example

The total population of a histogram is 100. The histogram range is divided into 20 bins and 'xx' is set to 25%. The population sum at the sixth bin from the left is 22. The population of the seventh is 9 and its sub-range is 6.1–6.4 V. The ratio of counts needed for 25% population to total bin population is:

3 counts needed / 9 counts = 1/3.

The value for **pctl** is:

6.1 volts + .33 * (6.4 – 6.1) volts = 6.2 volts.

Parameter Settings

Selection of the **pctl** parameter in the "**CHANGE PARAM**" menu group causes the "**MORE pctl SETUP**" menu to appear. Pressing the correponding menu button displays a threshold setting menu. And with the associated knob the user can set the percentage value to between 1% and 100% of the total population.

pks **Peaks**

Definition The number of peaks in a histogram.

Description The scope analyzes histogram data to identify peaks from background noise and histogram binning artifacts such as small gaps.

Peak identification is a three-step process:

1) The mean height of the histogram is calculated for all populated bins. A threshold (T1) is calculated from this mean where:

   T1= mean + 2 sqrt(mean).

2) A second threshold is determined based on all populated bins under T1 in height, where:

   T2 = mean + 2 * sigma,

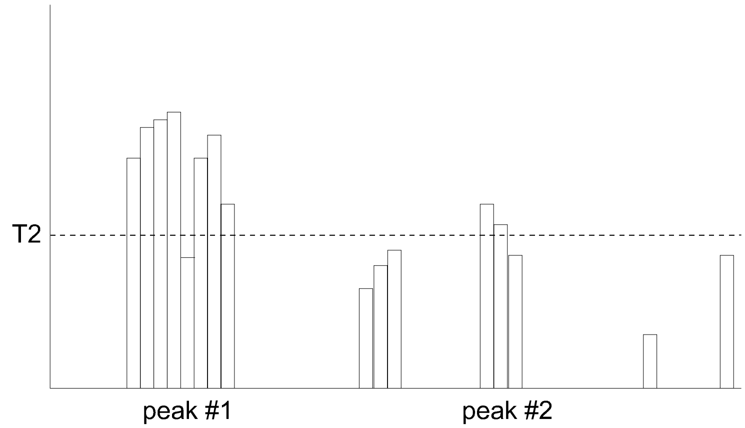
   and where sigma is the standard deviation of all populated bins under T1.

3) Once T2 is defined, the histogram distribution is scanned from left to right. Any bin that crosses above T2 signifies the existence of a peak. Scanning continues to the right until one bin or more crosses below T2. However, if the bin(s) cross below T2 for less than a hundreth of the histogram range, they are ignored, and scanning continues in search of a peak(s) that crosses under T2 for more than a hundreth of the histogram range. Scanning goes on over the remainder of the range to identify additional peaks. Additional peaks within a fiftieth of the range of the populated part of a range from a previous peak are ignored.

Note: If the number of bins is set too high a histogram may have many small gaps. This increases sigma and thereby T2, and in extreme cases can prevent determination of a peak, even if one appears to be present to the eye.

Example

The example below shows that two peaks have been identified. The peak with the highest population is peak #1.

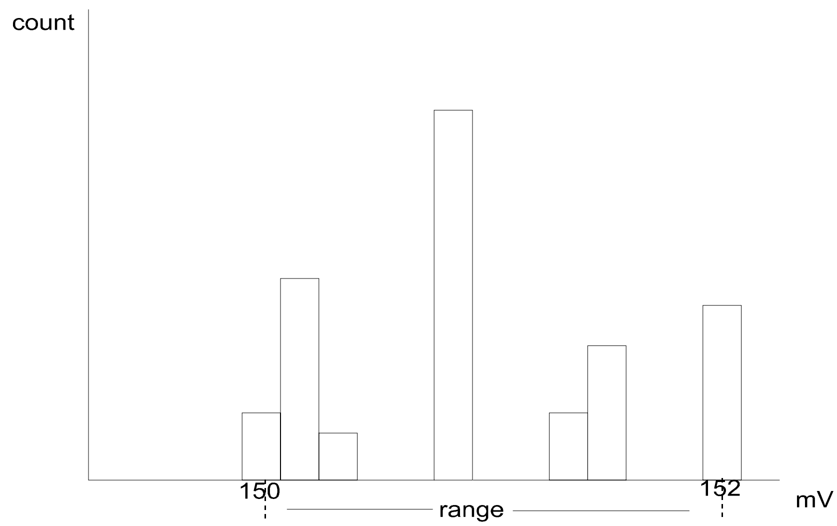


range Range

Definition Computes the difference between the value of the rightmost and that of the leftmost populated bin.

Description The rightmost and leftmost populated bins are identified. The difference in value between the two is returned as the **range**.

Example



In this example **range** is 2 mV.

sigma — Sigma

Definition The standard deviation of the data in a histogram.

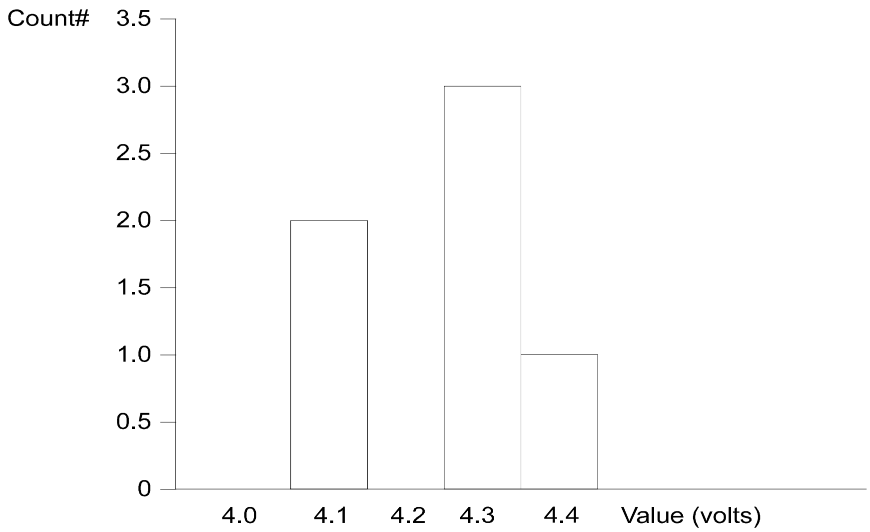
Description **sigma** is calculated by the formulas:

$$\text{mean} = \sum_{i=1}^{n}[\text{bin count}_i * \text{bin value}_i] / \left(\sum_{i=1}^{n}\text{bin count}_i\right);$$

$$\text{sigma} = \sqrt{\sum_{i=1}^{n}[\text{bin count}_i * (\text{bin value}_i - \text{mean})^2] / \left(\sum_{i=1}^{n}[\text{bin count}_i] - 1\right)},$$

where n is the number of bins in the histogram, bin count is the count or height of a bin and bin value is the center value of the range of parameter values a bin can represent.

Example For the histogram:



$$\text{mean} = (2 * 4.1 + 3 * 4.3 + 1 * 4.4) / 6 = 4.25$$

$$\text{sigma} = \sqrt{(2*(4.1 - 4.25)^2 + 3*(4.3 - 4.25)^2 + 1*(4.4 - 4.25)^2) / (6-1)} = .1225$$

totp **Total Population**

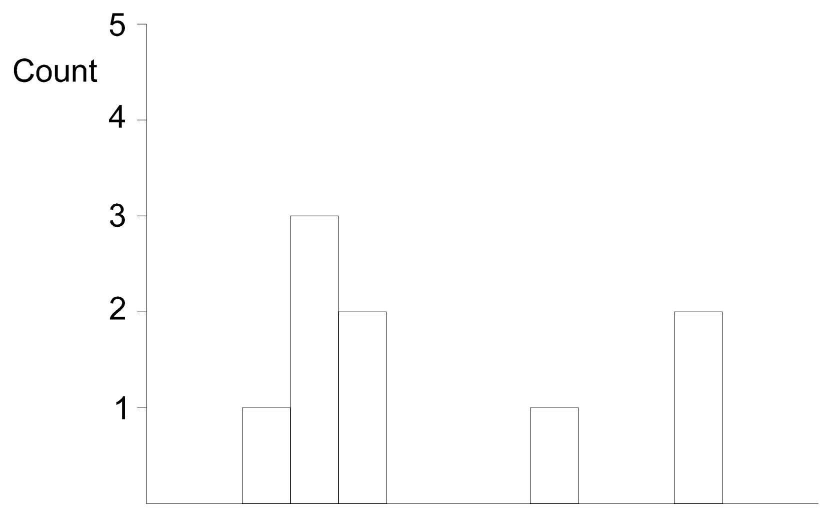
Definition

Calculates the total population of a histogram between the parameter cursors.

Description

The count for all populated bins between the parameter cursors is summed.

Example

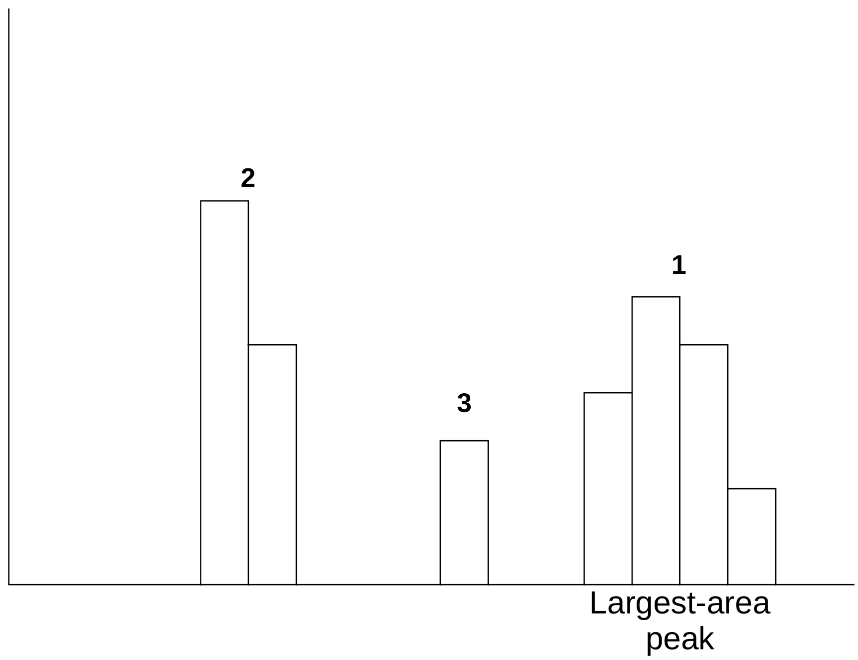


The total population of this histogram is 9.

xapk — X Coordinate of xx'th Peak

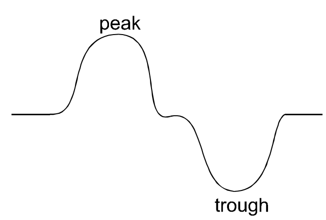
Definition Returns the value of the xx'th largest area peak in a histogram.

Description First the peaks in a histogram are determined and ranked in order of total area (for a discussion on how peaks are identified see the description for the **pks** parameter). The center of the n'th ranked peak (the point where the area to the left is equal to the area to the right), where n is selected by the user, is then returned as **xapk**.

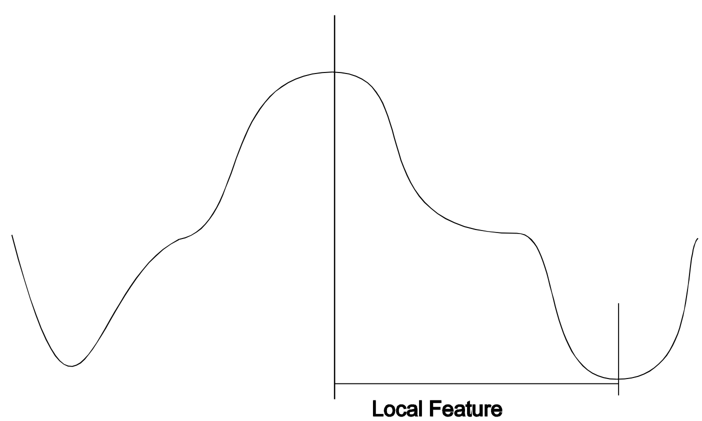


Local Features

The term *local feature computation* indicates that a parameter computed on a waveform is determined only by information in the immediate vicinity of a specified feature of that waveform. The DDM option defines a local feature as *a waveform peak followed by a trough*, like this:

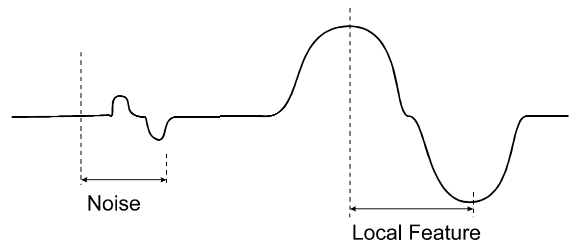


However, it is *not* the opposite — a trough followed by a peak. The diagram below shows a single local feature: the first peak and the trough that follows it.



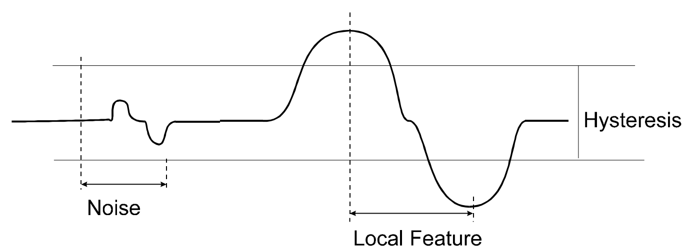
Peak–Trough Identification

The key to identifying peak–trough pairs is the ability to discriminate between real pairs and false ones. For example, noise in a signal can be mistaken for a local feature, as here:



Similarly, 'bumps' in a waveform may also be mistaken for peak–trough pairs.

In order to avoid such misidentification, a **hysteresis argument** is provided for many local feature parameters. This essentially enables the user to set a voltage band, which a peak–trough pair must exceed in order not be considered noise or a "bump":



The hysteresis setting is also essential to the way peaks and troughs are identified by the oscilloscope.

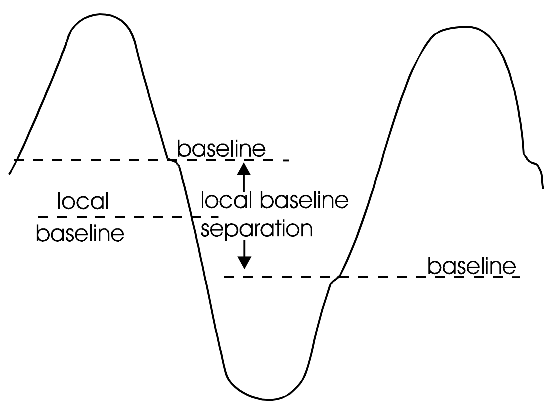
The search for local features extends from the left to the right parameter cursor. But first a peak must be found. And a waveform must rise to at least the value of the hysteresis setting in order to be positively identified as a peak.

This peak search starts with the first waveform sample, whose voltage value is used as an initial reference value for locating the peak. If a following waveform sample is found to be higher than the first by an amount greater than the hysteresis setting, a peak is said to exist. Any sample lower than the reference value, made prior to determination of a peak's existence, is used as a new reference point.

When a waveform rises by an amount that is more than the hysteresis, compared to the lowest prior waveform sample, the criterion for the existence of a peak is met. Then the search for its exact location and voltage value is initiated. Successive samples are compared to find the highest sample. Next, two points are found, one on either side of this highest sample and down from it by at least 25 % of the distance to the previous trough amplitude. A quadratic interpolation is then performed on these three samples to find the new peak location and amplitude. The same approach, using a sample lower than the highest sample by more than the hysteresis setting, is used to locate the trough.

Local Baselines

Many parameter measurements require that the **baseline** of a local feature be identified. In order to account for asymmetries due to MR heads, baselines are identified between the peak and trough, and between the trough and the following peak .



The baselines are found by locating a point at which the waveform 'rests' between the peak and trough and peak. These resting points are identified by statistically measuring the area of least change in voltage value between the peak and trough or trough and peak, with internal tolerance levels set to ensure against false baseline identification.

Another condition for identification is that the resting points must fall within a band, centered around the midpoint of the peak and trough extremes, whose height is the hysteresis setting.

If one of the baselines cannot be identified, the local baseline is set to the found value. If neither baseline can be identified, then the local baseline is set halfway between the extremes of the local feature's peak and trough.

Otherwise, the local-feature baseline is an average of the two baselines.

If the local feature is the last to be identified before arriving at the right parameter cursor, it will not be possible to identify the *trough–to–peak* baseline of the following local feature. But when the *peak–to–trough* baseline is identified, then these two baselines are assumed to be separated by the same distance as the baselines for the previous local feature. And if this baseline cannot be identified, then the local baseline becomes the midpoint of the local peak and trough.

The separation between the baselines (**local baseline separation**) can also be of interest in determining the validity of certain measurements.

The following table summarizes the determination of the local baseline and its separation when the local feature *is* and is *not* the last identified before the right parameter cursor:

Local baseline and local baseline separation if last local feature		
Baseline identified peak–to–trough (PTBase)	**Local Baseline**	**Baseline Separation**
yes	(PTBase + (PTBase + previous separation))/2	previous local feature's baseline separation
no	midpoint of local peak and trough	0

Local baseline and local baseline separation if not last local feature			
Baseline identified peak–to–trough (PTBase)	**Baseline identified trough–to–peak (TPBase)**	**Local Baseline**	**Baseline Separation**
yes	yes	average of PTBase + TPBase	PTBase – TPBase
yes	no	PTBase	0
no	yes	PTBase	0
no	no	midpoint of local peak and trough	0

Setting Hysteresis

Hysteresis must be set for all local parameters. The determining factors for a hysteresis value are:

1. The maximum peak–to–peak noise in the waveform
2. The minimum local feature amplitude
3. The maximum of the voltage difference between the mid-point of any local feature and the peak–to–trough baseline or trough–to–next peak baseline.

The value should be somewhere between the first and second factors, above, in order to ensure that noise is not mistaken for a local feature and that all local features are recognized. And for parameters that require a local baseline to be found, the value must also be twice as large as factor “3.”.

Local Parameters

The local parameters group offers measurements of common disk drive waveform parameters. They are available by selecting “**DISK–Local**” from the “**Category**” menu (*for a full description of each parameter, see Chapter 5*):

lbase	baseline of local feature
lbsep	separation between peak–to–trough and trough–to–peak baselines
lmax	maximum value of local feature
lmin	minimum value of local feature
lnum	number of local features displayed
lpp	local feature peak–to–trough amplitude
ltbe	time between peak–to–trough or rough–to–peak
ltbp	local feature’s time between peaks
ltbt	local feature’s time between troughs
ltmn	time of local feature’s minimum value
ltmx	time of local feature’s maximum value
ltot	local feature’s time over a % threshold
ltpt	time between local feature peak–to–trough
lttp	time between trough–to–following peak
ltut	local feature’s time under a % threshold

All make their measurements on identified local feature peaks and troughs.

Note: The scope’s variable hysteresis setting is essential to identifying peak–trough pairs and setting tolerances on the baseline calculation.

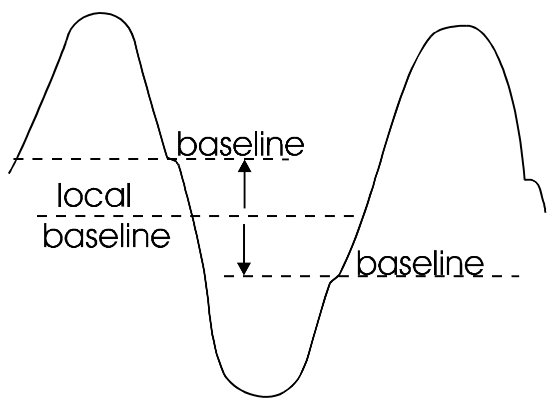
lbase Local Base

Definition The value of the baseline for a local feature.

Description The average value of the local baselines for all local features between the parameter cursors is displayed as **lbase**. For histograms, each individual baseline value for all local features between the parameter cursors is provided. *The previous chapter describes how to identify local baselines.*

Parameter Settings Selection of the **lbase** parameter in the "**CHANGE PARAM**" menus causes a "**MORE lbase SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



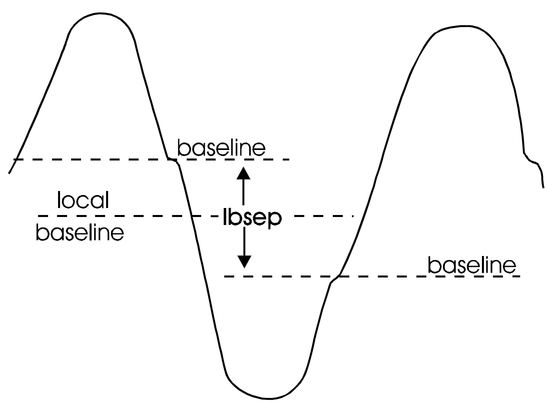
lbsep — Local Baseline Separation

Definition The value of the baseline separation for a local feature.

Description The average value of the separation of the two baselines used to calculate a local baseline is displayed for all local features between the parameter cursors. For histograms, each individual baseline separation value for all local features between the parameter cursors is provided. *The previous chapter describes how to identify local baselines.*

Parameter Settings Selection of the **lbsep** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE lbsep SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



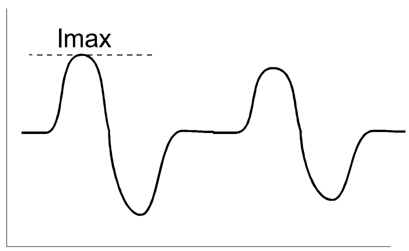
Imax — Local Maximum

Definition The maximum value of a local feature.

Description The maximum value of all local features between the parameter cursors is determined and the average value is displayed as **Imax**. For histograms, the maximum value of each local feature between the parameter cursors is provided.

Parameter Settings Selection of the **Imax** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE Imax SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



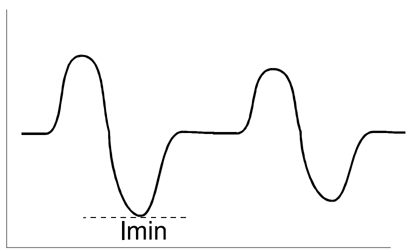
lmin Local Minimum

Definition The minimum value of a local feature.

Description The minimum value of all the local features between the parameter cursors is determined and the average value is displayed as **lmin**. For histograms, the minimum value of each local feature between the parameter cursors is provided.

Parameter Settings Selection of the **lmin** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE lmin SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



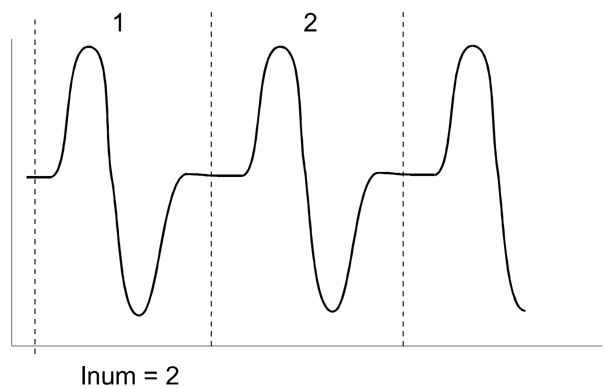
Inum Local Number

Definition The number of local features in the input waveform.

Description The number of local features between the parameter cursors is determined and displayed as **Inum**. One value of **Inum** each sweep is provided for histograms.

Parameter Settings Selection of the **Inum** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE Inum SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



lpp   Local Peak–to–Peak

Definition

The vertical difference between the peak and trough for a local feature.

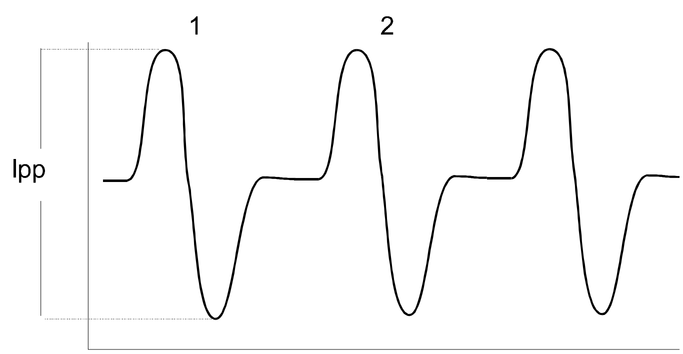
Description

The peak–to–trough voltage difference is determined for all local features in a waveform and the average is displayed as **lpp**. Provided for histograms is the peak–to–peak value of each local feature between the parameter cursors.

Parameter Settings

Selection of the **lpp** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE lpp SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



ltbe Local Time Between Events

Definition

The time between a local feature peak and trough or a local feature trough and the next local feature peak.

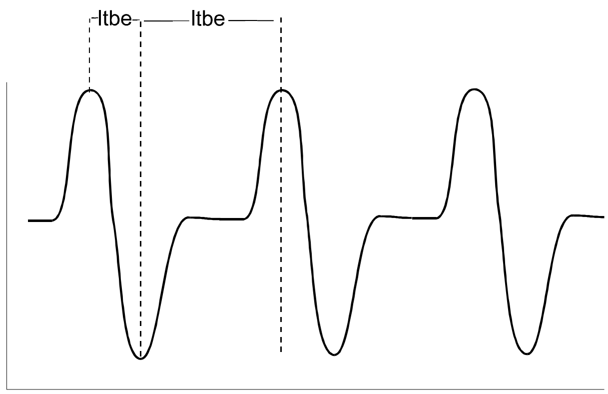
Description

Events are defined as either peaks or troughs. The average time between successive events in a waveform is displayed as **ltbe**. Provided for histograms is the time between each successive event between the parameter cursors.

Parameter Settings

Selection of the **ltbe** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE ltbe SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



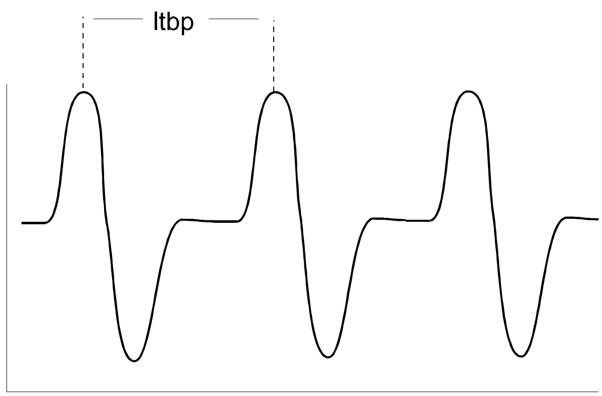
ltbp Local Time Between Peaks

Definition The time between a local feature peak and the next local feature peak.

Description The average of the time between successive local feature peaks is determined and its value displayed as **ltbp**. Provided for histograms are the times between successive peaks for all peaks between the parameter cursors.

Parameter Settings Selection of the **ltbp** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE ltbp SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



ltbt — Local Time Between Troughs

Definition

The time between a local trough and the next local trough.

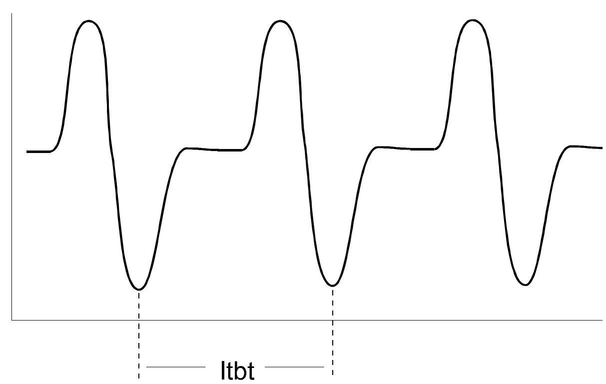
Description

The average of the time between successive troughs is determined and its value displayed as **ltbt**. Provided for histograms are the times between successive troughs for all troughs between the parameter cursors.

Parameter Settings

Selection of the **ltbt** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE ltbt SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



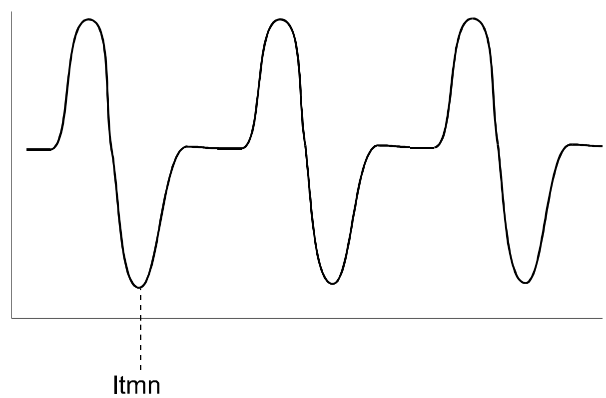
ltmn — Local Time at Minimum

Definition The time of the minimum value of a local feature.

Description The time of the minimum value of the first local feature in a waveform after the left parameter cursor is determined. The time is returned as **ltmn**. Provided for histograms are all times for local feature minimums between the parameter cursors.

Parameter Settings Selection of the **ltmn** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE ltmn SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



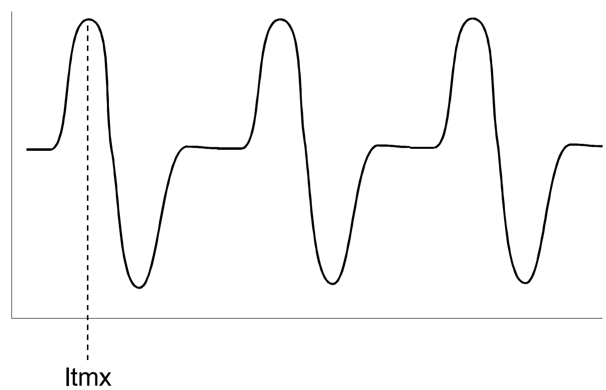
ltmx — Local Time at Maximum

Definition The time of the maximum value of a local feature.

Description The time of the maximum value of the first local feature in a waveform, after the left parameter cursor, is determined and returned as **ltmx**. Provided for histograms are all times for local feature maximums between the cursors.

Parameter Settings Selection of the **ltmx** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE ltmx SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



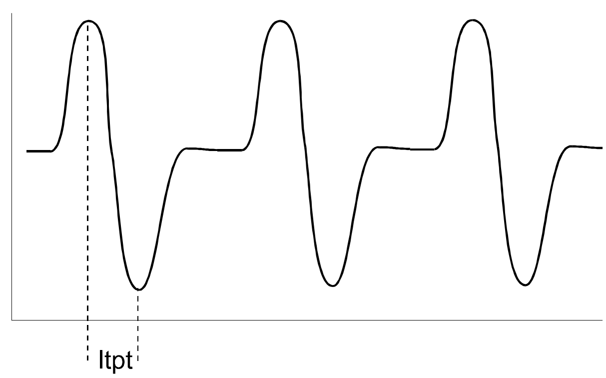
ltpt Local Time Peak–to–Trough

Definition The time between a local feature peak and trough.

Description The average of the time between all local feature peaks and troughs is displayed as **ltpt**. Provided for histograms are the times between peak–trough pairs for all local features between the parameter cursors.

Parameter Settings Selection of the **ltpt** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE ltpt SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



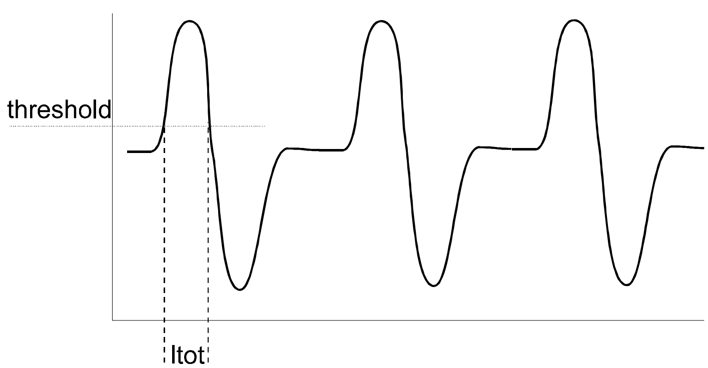
Itot — Local Time Over Threshold

Definition The time a local feature spends over a user-pecified percentage of its peak–to–trough amplitude.

Description The peak–to–trough height of a local feature is measured. The time the local feature spends over a user specified percent of the peak-to-trough height is then determined. The average for all local features in a waveform is displayed as **Itot**. Provided for histograms is the time spent over the threshold by each local feature between the parameter cursors.

Parameter Settings Selection of the **Itot** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE Itot SETUP**" menu to appear. Pressing the corresponding menu button displays hysteresis and threshold menus, whose menu buttons or associated knobs allow the setting, respectively, of the values in those menus to a specified number of vertical divisions, or a percentage of the peak–to–peak height of the local feature. *The previous chapter describes hysteresis.*

Example



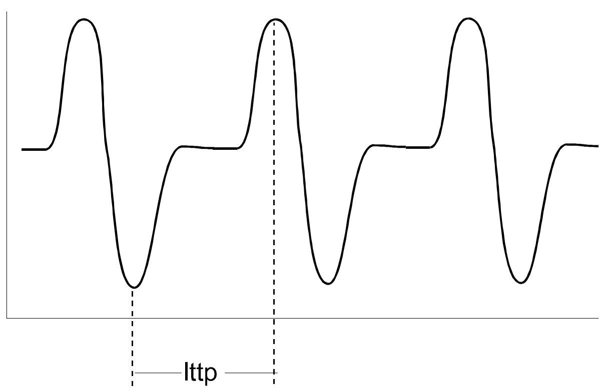
lttp Local Time Trough–to–Peak

Definition The time between a local-feature trough and the next local-feature peak.

Description The average of the time between all local feature troughs and the following local feature peak is displayed as **lttp**. Provided for histograms are the times between trough and following peak for all local features between the parameter cursors.

Parameter Settings Selection of the **lttp** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE lttp SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *The previous chapter describes hysteresis.*

Example



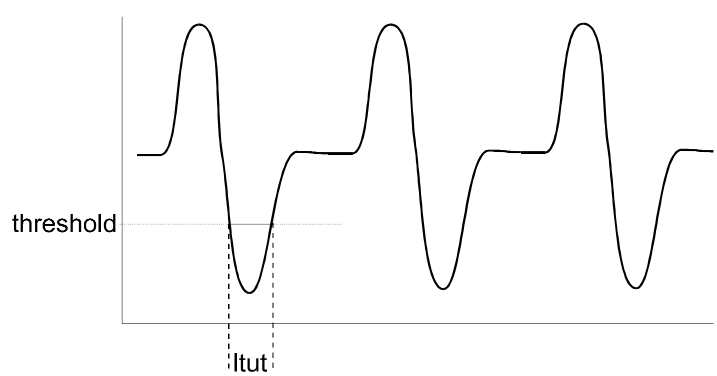
ltut Local Time Under Threshold

Definition The time a local feature spends under a user-specified percentage of its peak–to–trough amplitude.

Description The peak–to–trough height of a local feature is measured. The time the local feature spends under a user-specified percentage of this height is determined, and the average for all the waveform's local features is displayed as **ltut**. Provided for histograms is the time spent under the threshold by each local feature between the parameter cursors.

Parameter Settings Selection of the **ltut** parameter in the "**CHANGE PARAM**" menu group causes a "**MORE ltut SETUP**" menu to appear. Pressing the corresponding menu button displays hysteresis and threshold menus, whose menu buttons or associated knobs allow the setting, respectively, of the values in those menus to a specified number of vertical divisions, or a percentage of the peak-to-peak height of the local feature. *The previous chapter describes hysteresis.*

Example



Standard Disk Drive Parameters (Disk–Std)

The Disk Drive parameters enable standard disk drive waveform parameter measurements. The parameters, accessed by selecting "DISK–Std" from the "Category" menu, are:

nbph	narrow band phase of waveform DFT
nbpw	narrow band power of waveform DFT
owrt	overwrite
pw50	pulse width of peaks at 50% amplitude from baseline
pw50+	pulse width of positive peaks at 50% amplitude from baseline
pw50–	pulse width of negative peaks at 50% amplitude from baseline
res	resolution
taa	track average amplitude
taa+	track average amplitude of positive peaks from baseline
taa–	track average amplitude of negative peaks from baseline

All except **nbph**, **nbpw** and **owrt** make their measurements on waveform peak–trough pairs. In addition, several of the parameters determine the baseline of peak–trough pairs in order to perform their calculations.

Note: The scope's variable hysteresis setting is essential for identifying peak–trough pairs and setting tolerances on the baseline calculation (**see **Chapter 4).

nbph Narrow Band Phase

Definition

Provides a measurement of the phase at a specific frequency for a waveform.

Description

nbph is the *phase* of the Discrete Fourier Transform (DFT) computed on a waveform at a specific frequency. The result is the phase of the corresponding frequency sine wave component of the waveform at the first data point between the parameter cursors. The **nbph** paramter calculates one bin of a DFT centered at the frequency provided. The bin width is 1.05% of the frequency selected if the waveform trace displayed by the oscilloscope is 96 * (1/frequency) or more in length (i.e. the trace is equal to or longer than 96 cycles of a waveform at the selected frequency). Otherwise, the bin width is:

100 / integer[(oscilloscope trace length)/(1/frequency)] %,

where integer [ ] designates discarding any fractional portions in the result. Thus, if the waveform trace is 48.5 times longer than 1/frequency, the bin width will be:

100/48 = 2.1% of the selected frequency.

nbph is very sensitive to frequency and it is important that the frequency value provided be as accurate as possible if accurate results are to be obtained.

Parameter Settings

Selection of the **nbph** parameter in the "**CHANGE PARAM**" menus causes the "**MORE nbph SETUP**" menu to appear. Pressing the corresponding menu button accesses a frequency setting menu. The user can adjust the mantissa, exponent or number of mantissa digits by pressing this menu's corresponding button. And the associated 'menu' knob can be used to adjust these. However, if a large number of digits is used, selection of the exact frequency may be difficult. In this case, a number with fewer digits and less precision should be chosen for the approximate frequency, then the precision increased as desired and the exact value chosen.

nbpw — Narrow Band Power

Definition

Provides a measurement of the power at a specific frequency for a waveform.

Description

nbpw is the *magnitude* of the Discrete Fourier Transform (DFT) computed on a waveform at a specific frequency. **nbpw** calculates one bin of a DFT centered at the frequency provided. The bin width is 1.05% of the frequency selected if the waveform trace on the scope is 96*(1/frequency) or more in length (i.e. the trace is equal to or longer than 96 cycles of a waveform at the selected frequency). Otherwise, the bin width is:

100 / integer[trace length/(1/frequency)] %,

where integer [ ] designates discarding any fractional portions in the result. Thus, if the waveform trace is 48.5 times longer than 1/frequency then the bin width will be:

100/48 = 2.1% of the selected frequency.

A Blackman–Harris window is applied to the input data to minimize leakage effects. The net result is that **nbpw** will provide excellent results even if frequency changes occur due to spindle speed variations. If the actual frequency differs from the specified frequency, and the bin width is +/– 1.05%, the resulting power will be reduced from the actual as in this table:

Frequency Difference	dB Reduction
.3%	.3 dB
.6%	1.1 dB
1%	3 dB

If the bin width is greater than 1.05%, the frequency difference for which a specified dB reduction will occur will scale proportionally to the bin width/1.05.

nbpw results are presented in dB. All averaging, including statistics and trend average, is performed on linear units. Average results are converted to dB.

Parameter Settings Selection of the **nbpw** parameter in the "**CHANGE PARAM**" menus causes the "**MORE nbpw SETUP**" menu to appear. Pressing the corresponding menu button accesses a frequency setting menu. The user can adjust the mantissa, exponent or number of mantissa digits by pressing this menu's corresponding button. And the associated 'menu' knob can be used to adjust these. However, if a large number of digits is used, selection of the exact frequency may be difficult. In this case, a number with fewer digits and less precision should be chosen for the approximate frequency, then the precision increased as desired and the exact value chosen.

owrt Overwrite

Definition

The ratio of residual to original power of a low-frequency disk waveform overwritten by a higher frequency waveform.

Description

owrt measures the residual power of a low-frequency LF waveform after it has been overwritten by a high-frequency HF waveform. The LF waveform should be stored to memory (M1–M4) and the memory assigned to a trace (A, B, C or D). The HF waveform can then be input to the scope, and overwrite calculated where:

owrt = 20 log (Vr/Vo),

where Vr is the residual Vrms of the sine wave component of the HF waveform at the LF base frequency after the HF waveform write, and Vo is the Vrms of the sine wave component of the LF waveform at the LF base frequency. The calculation is performed by the scope making a narrow-band power measurement (*see nbpw parameter description*) at LF, for both the HF and LF waveforms, and subtracting the second result from the first. A menu (*see example*) enables the choice of which waveform, HF or LF, is assigned to which scope channel or trace (1, 2, 3, 4, A, B, C or D). The menu button is used to set the input for HF or LF, while the input for the selected waveform is set with the associated knob. The **owrt** results are presented in dB. All averaging, including statistics and trend average, is performed on linear units. Average results are converted to dB.

Note: In typical use it is preferable to use **nbpw** to measure the LF waveform, and then the residual LF in the HF separately, instead of the **owrt** parameter. Overwrite is the difference between the **nbpw** readings in dB. There are two reasons why this is preferable: 1) **nbpw**, with statistics on, provides average power readings. With **owrt** the low frequency signal is typically a stored single-shot acquisition due to the difficulty finding a suitable trigger for time domain averaging of a head signal. 2) **owrt** computes both nbpw results each time. If the LF is stored this is not necessary. So **nbpw** will take twice as many acquisitions as owrt and achieve a more stable average result in the same amount of time.

Parameter Settings

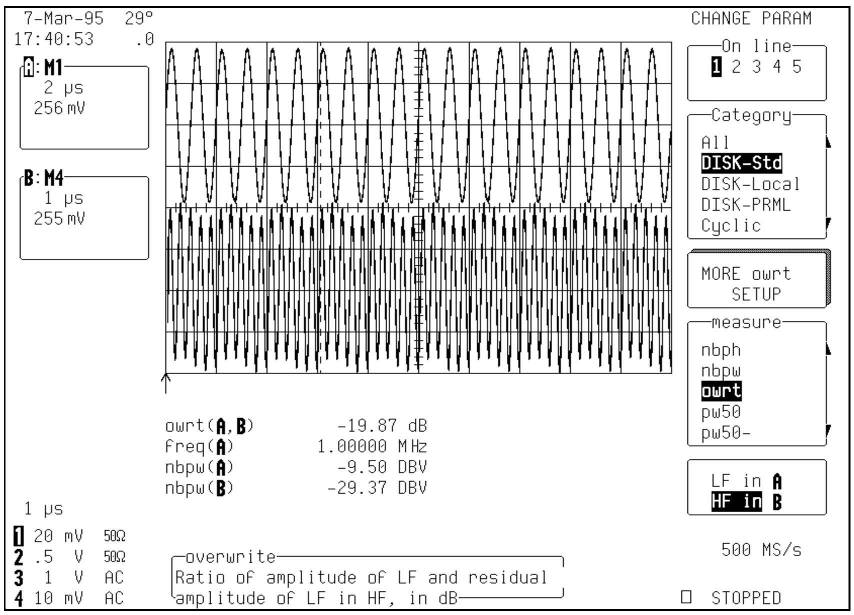
Selection of the **owrt** parameter in the "**CHANGE PARAM**" menus causes the "**MORE owrt SETUP**" menu to appear. Pressing the corresponding menu button accesses a frequency setting menu. This frequency is used to calculate **nbpw** for both the HF and LF waveforms. The user can adjust the mantissa, exponent or number of mantissa digits by pressing this menu's corresponding button. And the associated 'menu' knob can be used to adjust these. However, if a large number of digits is used, selection of the exact frequency may be difficult. In this case, a number with fewer digits and less precision should be chosen for the approximate frequency, then the precision increased as desired and the exact value chosen.

Example

In the screen display below, the LF waveform is assigned to Trace A and the HF waveform to Trace B. The LF waveform is a 1 V peak–to– peak 1 MHz sine wave, and the HF waveform a 1 V peak–to–peak 5 MHz sine wave. Using the freq parameter to determine the frequency of the LF waveform, the 1 MHz frequency value is confirmed (*see* “**freq(A)**” *in figure*). The HF waveform has a residual 1 MHz component. Zooming Trace B, the amplitude of the residual waveform is .1 V peak–to–peak. Therefore, the value for overwrite should be, approximately:

20 log (.1 volt/1 volt),

or –20 dB. The scope’s parameter display shows that **owrt** is in fact –19.87dB. Comparing this number to the difference of the **nbpw** parameter measurements at 1 MHz, shown for both the HF and LF waveforms, we arrive at the same result.



pw50 Pulse Width 50

Definition

The average pulse width at the 50% point between a local baseline and the local-feature peak, and between the local baseline and the local feature-trough.

Description

All local features (*see Chapter 4*) between the parameter cursors for an input waveform are identified. The local baseline is identified for each feature, and the height between the local baseline and the peak is determined. The pulse width is measured at 50% of the peak. The same measurement is then performed for the trough. The average of all width measurements is displayed as **pw50**. Provided for histograms is the average **pw50** value for each local feature between the parameter cursors.

Parameter Settings

Selection of the **pw50** parameter in the "**CHANGE PARAM**" menus causes a "**MORE pw50 SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis-setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *Chapter 4 describes hysteresis.*

pw50– Pulse Width 50–

Definition

The average pulse width measured at the 50% point between the local feature baseline and the local feature trough.

Description

All local features (*see Chapter 4*) between the parameter cursors for an input waveform are identified. The local baseline is identified for each feature, and the height between the local baseline and trough is determined. The pulse width is measured at 50% of the trough amplitude. The average of all width measurements is displayed as **pw50–**. Provided for histograms is the average **pw50–** value for each local feature between the parameter cursors.

Parameter Settings

Selection of the **pw50–** parameter in the "**CHANGE PARAM**" menus causes a "**MORE pw50– SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis-setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *Chapter 4 describes hysteresis.*

Pw50+ — Pulse Width 50+

Definition

The average pulse width at the 50% point between the local feature baseline and the local feature peak.

Description

All local features (*see Chapter 4*) between the parameter cursors for an input waveform are identified. The local baseline is identified for each feature, and the height between the local baseline and peak is determined. The pulse width is measured at 50% of the peak amplitude. The average of all width measurements is displayed as **pw50+**. Provided for histograms is the average **pw50+** value for each local feature between the parameter cursors.

Parameter Settings

Selection of the **pw50+** parameter in the "**CHANGE PARAM**" menus causes a "**MORE pw50+ SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis-setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *Chapter 4 describes hysteresis.*

res Resolution

Definition

The ratio of the track average amplitude for a high and low frequency waveform.

Description

res returns, as a percentage, the ratio of track average amplitude (*see* **taa** *parameter description*) for a low frequency LF and high frequency HF waveform:

res = (taa(LF) / taa(HF)) * 100%.

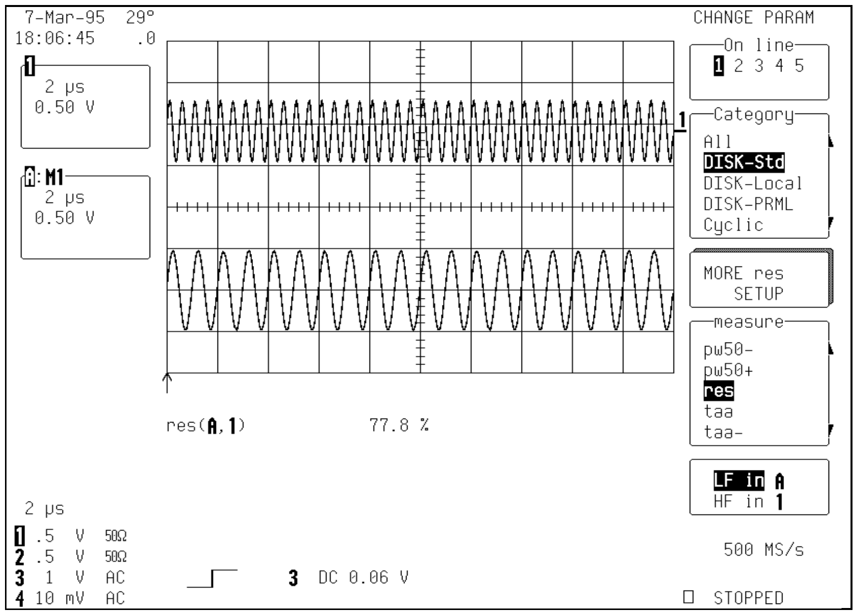
A menu (*see example*) is used to select the waveform — HF or LF — and the scope channel or trace to which it will be assigned. The first waveform read should be stored to a memory (M1–M4), and the memory to a trace (A, B, C, or D). The user selects whether to set the input for HF or LF by pushing the corresponding menu button. The source of the selected waveform — 1, 2, 3, 4, A, B ,C or D — is then set using the associated knob.

Parameter Settings

Selection of the **res** parameter in the "**CHANGE PARAM**" menus causes a "**MORE res SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis-setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *Chapter 4 describes hysteresis.*

Example

In the figure below the LF waveform is assigned to Trace A and the HF waveform to input Channel 1. The LF waveform is at 1 MHz and the HF at 2 MHz. Resolution is calculated as 77.8 %.



taa Track Average Amplitude

Definition The average peak–to–trough amplitude for all local features.

Description All local features (*see Chapter 4*) between the parameter cursors for an input waveform are identified. The peak–to–trough amplitude is determined for each feature and the average is returned as **taa**. Provided for histograms is the peak–to–trough amplitude for each local feature between the parameter cursors.

Parameter Settings Selection of the **taa** parameter in the "**CHANGE PARAM**" menus causes a "**MORE taa SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis-setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *Chapter 4 describes hysteresis.*

taa– Track Average Amplitude–

Definition The average local baseline–to–trough amplitude for all local features.

Description All local features (*see Chapter 4*) between the parameter cursors for an input waveform are identified. The local baseline–to–trough amplitude is determined for each feature and the average is returned as **taa–**. Provided for histograms is the local baseline–to–trough amplitude for each local feature between the parameter cursors.

Parameter Settings Selection of the **taa–** parameter in the "**CHANGE PARAM**" menus causes a "**MORE taa– SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis-setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *Chapter 4 describes hysteresis.*

taa+ Track Average Amplitude+

Definition

The average local baseline–to–peak amplitude for all local features.

Description

All local features (*see Chapter 4*) between the parameter cursors for an input waveform are identified. The local baseline–to–peak amplitude is determined for each feature and the average is returned as **taa+**. Provided for histograms is the local baseline–to–peak amplitude for each local feature between the parameter cursors.

Parameter Settings

Selection of the **taa+** parameter in the "**CHANGE PARAM**" menus causes a "**MORE taa+ SETUP**" menu to appear. Pressing the corresponding menu button displays a hysteresis-setting menu, whose menu button or associated knob allows setting of the hysteresis value to a specified number of vertical divisions. *Chapter 4 describes hysteresis.*

The PRML Option

The PRML option enables parameter measurements of auto-correlation signal–to–noise (ACSN) and non-linear transition shift (NLTS). The calculation of both these parameters is based on a correlation math function, which is also included in the option.

The **acsn** parameter (*see Chapter 9*) can be applied to any periodic waveform. Since these waveforms are by definition identical in every period, any deviation is due to uncorrelated noise sources. By performing an auto-correlation calculation of the waveform over successive periods, the level of less-than-perfect correlation can be measured. And with this measurement, the noise level can be derived by ACSN.

The **nlts** parameter (*Chapter 9*) offers the ability to measure all echoes in the auto-correlation calculation of a disk waveform. This includes the NLTS (adjacent location), second adjacent location, and overwrite (initial magnetization) echoes. The parameter performs NLTS averaging, pattern-length searching, and limit checking to reduce the effects of noise and ensure accurate measurements.

Correlation: Theory of Operation

The oscilloscope's correlation function measures the correlation between one section of a waveform and other sections of the same waveform having the same length, or between a section and sections of equal length belonging to another waveform.

When the correlation is performed on the same waveform it is called an **auto-correlation**. If the shape of two waveform sections are identical, the correlation value will be maximized.

The oscilloscope normalizes correlation values to ±1, with 1 indicating that the waveform sections are identical, –1 that the sections are inverted from each other, and 0 no correlation.

Noiseless periodic waveforms will have perfect correlation (a correlation value of 1) when performing auto-correlation, and when the start of the second section is an integer number of periods later than the start of the first section.

Correlation values can be calculated as a function of various amounts of time shift between two waveform sections used in calculating a correlation. This calculation, as a function of the starting point of the second section being the i'th waveform sample, is determined as:

$$\text{mean}() = \sum_{x=a}^{b} \text{wave}_x \Big/ (b-a),$$

$$\text{variance}(\text{wave}_a^b) = \frac{\sum_{x=a}^{b} (\text{wave}_x)^2}{b - a} - \text{mean}(\text{wave}_a^b)^2,$$

$\text{Corr}_i =$

$$\frac{\left(\sum_{j=0}^{N} \text{wave1}_j * \text{wave2}_{i+j} \Big/ (N+1)\right) - \text{mean}(\text{wave1}_0^N) * \text{mean}(\text{wave2}_i^{N+i})}{\sqrt{\text{variance}(\text{wave1}_0^N) * \text{variance}(\text{wave1}_i^{N+i})}},$$

where $Corr_i$ is the i'th sample point (starting from 0) of the correlation waveform, $wave1_j$ is the j'th sample of the first waveform, wave2 is the second input waveform (wave1 in an auto-correlation), and $wave_a^b$ is a section of a waveform from sample 'a' to sample 'b'. The upper bound 'N' in the summations determines the length (length is N+1 sample points, since the first sample is point 0) of the waveform sections on which the correlation calculation is performed. The divisor in the correlation function:

$$\sqrt{\text{variance}(\text{wave1}_0^N) * \text{variance}(\text{wave1}_0^N)}$$

normalizes the correlation calculation to +/– 1, while the

$$\text{mean}(\text{wave1}_0^N) * \text{mean}(\text{wave2}_i^{N+i})$$

term in the dividend removes any effect due to DC offset of the input waveforms in the correlation function.

Essentially, the correlation waveform function takes a section of the first waveform and calculates how it correlates with an equal-length section of a second waveform using different starting points in the second waveform. This can be visualized as taking a section of waveform 1, sliding it over waveform 2, and calculating the correlation value for the area that overlaps. The bounds of the starting point are from the beginning of the second waveform to its length, minus the section length. At the upper bound, the end of the first waveform section lies at the last sample point of the second waveform. Owing to the length of waveforms in the oscilloscope being limited to 10 divisions, the upper bound of the correlation function is 10 divisions minus the section length in divisions.

Operating the Scope for Correlation

This section describes the scope's operational features for defining and using the correlation math function.

In order to specify a correlation waveform, a waveform trace must first be defined as a correlation math function. This is initiated by pressing the **MATH SETUP** button, displaying the menus shown in *Figure 8.1*.

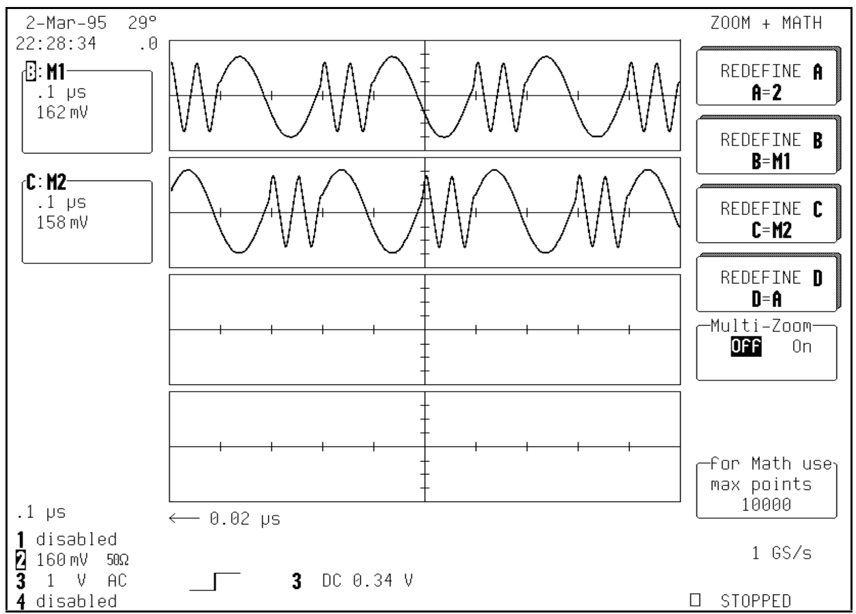


Figure 8.1

Assuming the user wishes to place the correlation waveform on Trace A, he or she will press the menu button corresponding to the "**REDEFINE A**" menu. The "**SETUP OF A**" menus will appear, as shown in *Figure 8.2.*

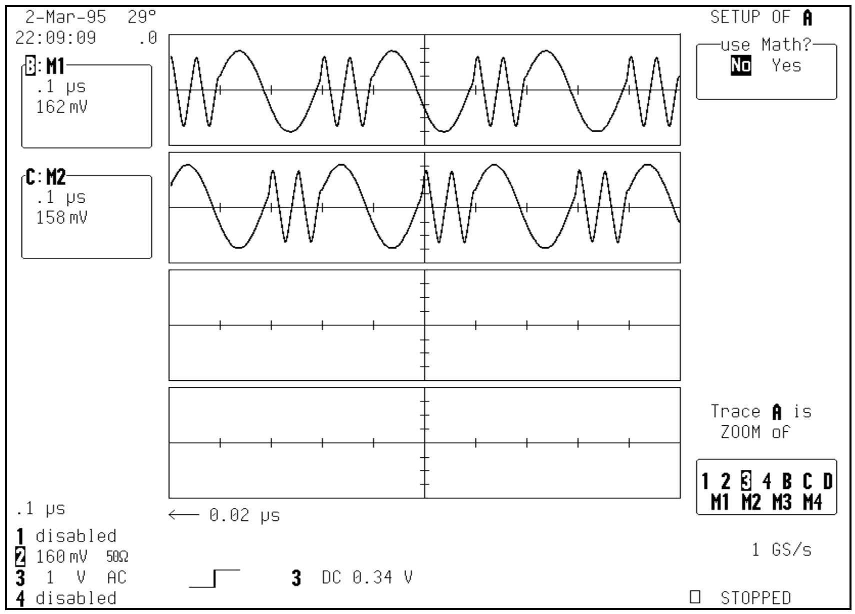


Figure 8.2

As the correlation function is a math function, “**Yes**” is selected from the “**use Math?**” menu, and the menus shown in *Figure 8.3* are accessed.

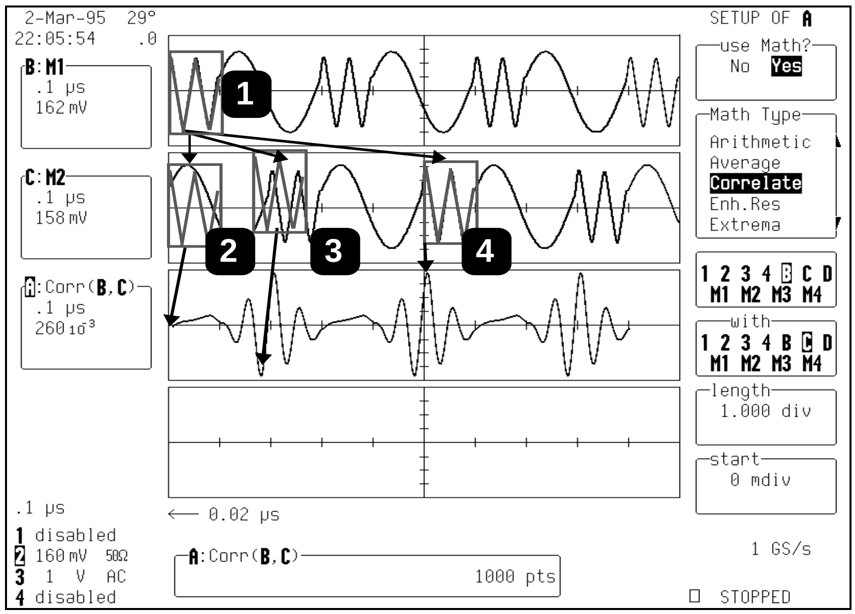


Figure 8.3

Selecting “**Correlate**” from the “**Math Type**” menu makes Trace A the correlation waveform. From the menu below it, the waveform from which the section for correlation will be taken — here, “**B**”— is selected. The “**with**” menu then enables selection of the waveform with which the section is to be correlated — here, “**C**”. While the “**length**” menu is used for setting the section’s length — one division in this example.

The annotated boxes in the above figure show the sections.

Annotation ❶ indicates the section of Trace B selected for correlation by the setting of "**length**". This section is correlated with equal-length sections of the Trace C waveform. The correlation waveform is shown in Trace A.

Annotations ❷, ❸ and ❹ indicate the selected waveform section overlaid on different sections of the waveform in Trace C.

With the waveform section delayed by zero (❷), it is clear that there is little correlation with the corresponding section of Trace C. The arrow from the box to the correlation waveform indicates the proximity of the waveform to zero at this point.

With the selected waveform section delayed by 1.8 divisions (❸), the corresponding section of Trace C appears almost an inversion of the selected waveform section. The correlation waveform is nearly –1 at this point, indicating inverse correlation.

Finally, at a delay of five divisions (❹), the sections are identical and the correlation waveform is at 1. With a waveform section length of one division, the last point at which the correlation waveform can be calculated is a nine-division delay. For any longer delay, a portion of the selected waveform section would extend further than the last sample point in Trace C — which is why the correlation waveform display stops at nine divisions.

Figure 8.4 on the following page shows the result of setting the "**start**" menu to one division. This menu is used for determining at what point in the "**with**"-selected waveform the selected section will begin the correlation. In this figure the selected waveform section from Trace B is initially correlated with the waveform in Trace C, starting at one division. The resulting correlation waveform is identical to the correlation waveform in the preceding figure *8.3*, from one division on. Since the correlation starts one division from the start of the waveform in Trace C, it is reduced in length by one, to eight divisions.

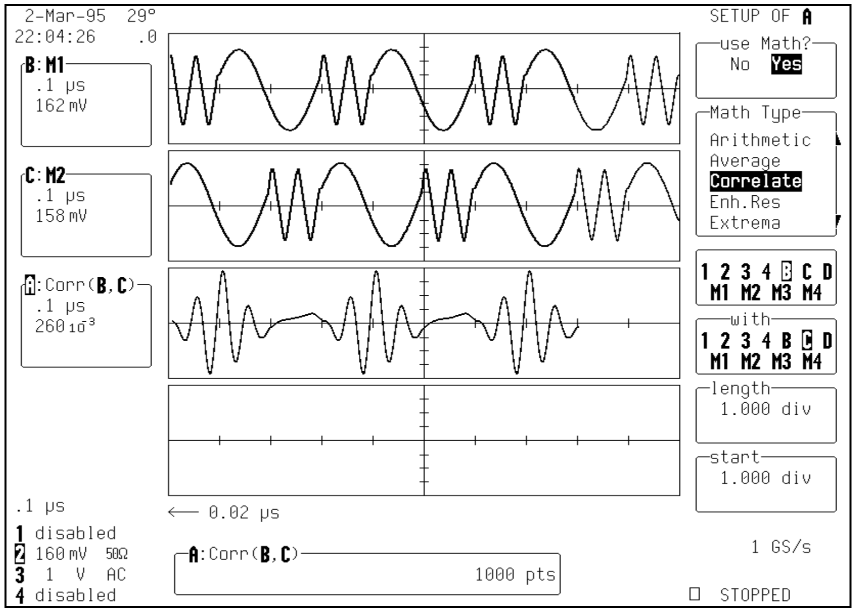


Figure 8.4

Figure 8.5, below, shows the resulting correlation waveform: the waveform section is selected from Trace C, "**with**" Trace B. A correlation waveform very different from that of the preceding figures appears. Again, the annotated boxes show the selected Trace C waveform section (❶) overlaid on different sections of the Trace B waveform (❷, ❸, ❹).

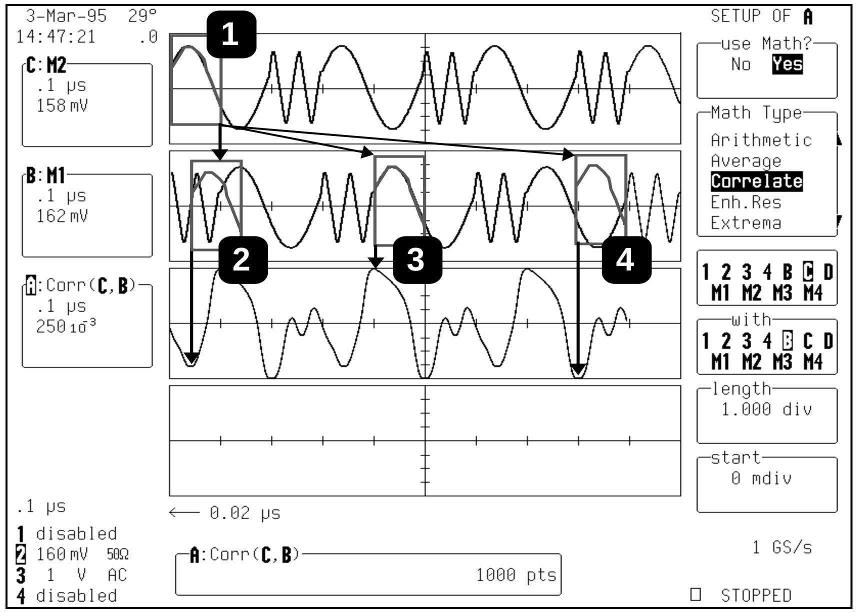


Figure 8.5

The correlation function can be very useful in determining the length of a periodic complex disk waveform. As such waveforms have a correlation value of close to 1 (although normally not precisely 1, due to noise), with every cycle, the period can be determined by measuring the relative times when the correlation waveform is this value.

Figure 8.6 shows an example of determining the period for a PRML waveform using the measurement cursors (Annotation ❶). The period is 980 ns (❷).

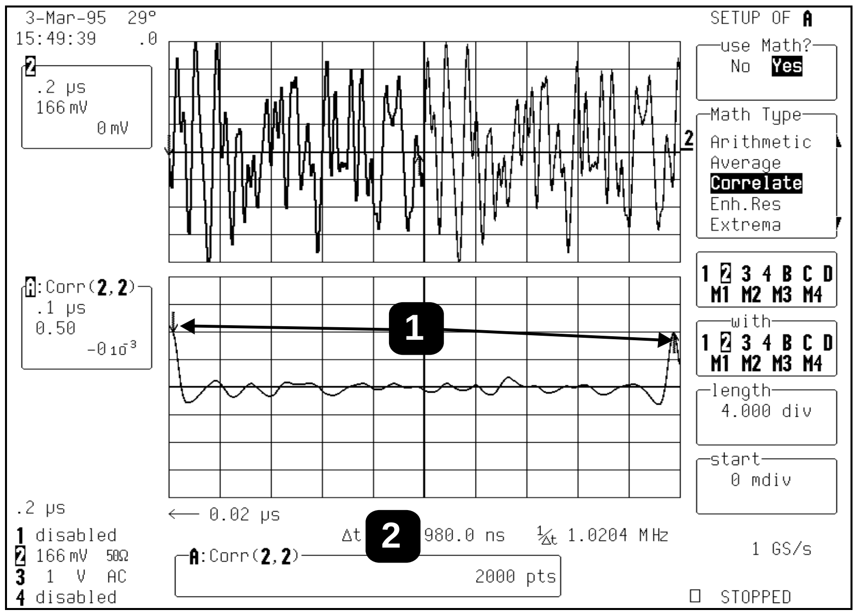


Figure 8.6

acsn Auto-Correlation Signal–to–Noise

Definition

Provides a signal–to–noise ratio for periodic waveforms.

Description

Using the oscilloscope’s correlation function, **acsn** provides a measurement of the auto-correlation signal–to–noise for a repetitive waveform. At least two waveform repetitions need to be acquired in order to calculate **acsn**. In addition, the period of the waveform must be specified.

The parameter then verifies, and may adjust, the period based on the value provided. This is crucial, because variations in disk rotation speed make the exact length of time for a disk waveform difficult to determine.

Using the period as a starting point, the scope performs an auto-correlation and looks for an auto-correlation peak at the period. At the top of the peak, the pattern repeats. The scope locates the top and notes the corresponding time so that it can determine the period. Then it recalculates the auto-correlation using this period. The value of the auto-correlation at the period peak, R, is used to calculate the ACSN as:

$$S/N = R/(1-R),$$

$$ACSN = 10 * \log10\ S/N.$$

For greater accuracy, the instrument averages several ACSN measurements when calculating **acsn.** If the number of periods in the input waveform is 26 or more, an ACSN measurement is performed for each pattern and the result averaged. Otherwise, the scope performs 25 ACSN measurements by incrementing by 25 times the starting point, approximately 1/25th of the input waveform’s length minus the period of the input waveform used to perform the correlation calculation, and then averages the result.

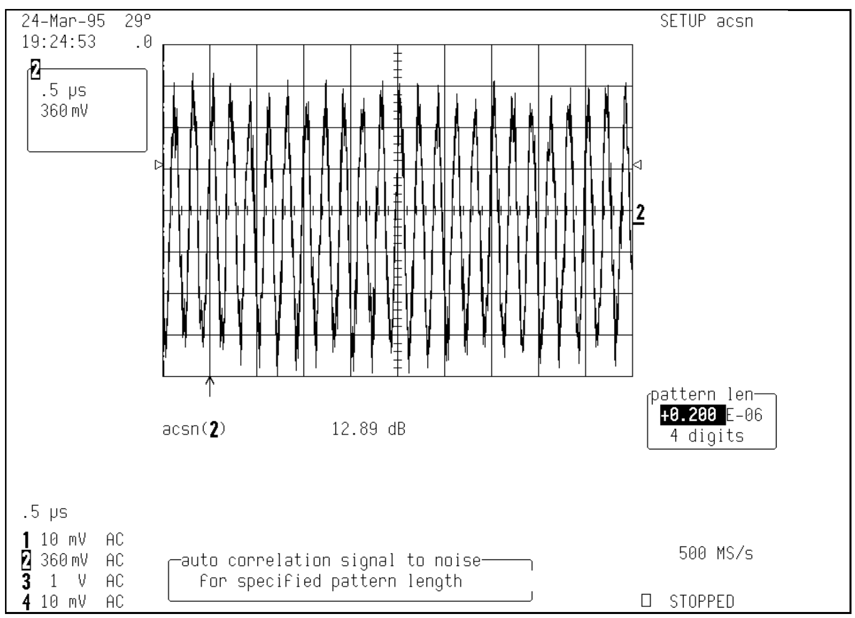
All individual ACSN measurements can be observed by histogramming the **acsn** parameter. ACSN is limited to measuring signal–to–noise ratios of 9.6 dB or greater.

ACSN results are presented in dB. All averaging, including statistics and trend average, is performed on linear units. Average results are converted to dB.

Parameter Settings Selection of **acsn** in the "**CHANGE PARAM**" menus causes the "**MORE acsn SETUP**" menu to appear. The user can adjust the mantissa, exponent or number of mantissa digits by pressing this menu's corresponding button. And the associated 'menu' knob can be used to adjust these. However, if a large number of digits is used, selection of the exact frequency may be difficult. In this case, a number with fewer digits and less precision should be chosen for the approximate frequency, then the precision increased as desired and the exact value chosen.

The pattern length should be set as an integral number of waveform periods. Since these periods will be correlated with the same number of following periods, the pattern length must be no more than half the number of full periods available in the sweep.

Example On the screen below, a noisy 5 MHz period waveform has been captured on Channel 2. The "**pattern len**" menu shows the pattern length set to 200 ns. The value for **acsn** is 12.89dB.



nlts Non-Linear Transition Shift

Definition

Provides a measurement of the nonlinear transition shift for a disk drive signal.

Description

Using the oscilloscope's correlation function, **nlts** measures the nonlinear transition (adjacent location) shift. At least two full cycles of the test sequence are required for the auto-correlation. In addition, the period of the waveform must be specified.

The parameter then verifies, and may adjust, the pattern length based on the value provided. This is crucial, because variations in disk rotation speed make the exact pattern length for a disk waveform difficult to determine.

Using the pattern length as a starting point, the oscilloscope looks for an auto-correlation peak at the length. At the top of the peak, the pattern repeats. The scope locates the top and notes the corresponding time so as to determine the exact pattern length. Then it recalculates the auto-correlation using this length. If the value of the auto-correlation peak at the pattern length is less than .9, the **nlts** is *not* calculated. This is because the pattern-length sections will be too uncorrelated to provide a meaningful result. Otherwise, the pattern length value is used to calculate **nlts**. Using the pattern delay value, the scope measures the auto-correlation coefficient for the first pattern-length 'chunk' of the input waveform with a second pattern-length 'chunk', starting from the beginning of the input waveform at the delay value.

In order to correctly calculate **nlts**, the disk drive waveform must be a pseudo-random sequence that will create an echo in an auto-correlation calculation, corresponding to the non-linear transition shift. Typically, this waveform is a 127-bit pattern based on a $x^7 + x^3 + 1$ polynomial, and the NLTS echo appears at a pattern delay of 20.06% of the input pattern length. Ideally, the value of NLTS is:

NLTS(%) = –200* Correlation Coefficient (at delay).

However, because noise in the input waveform can affect the correlation coefficient's value, the scope averages several NLTS measurements to reduce the effect of noise. If the number of pseudo-random patterns in the input waveform is 26 or more, an NLTS measurement is performed for each pattern and the result averaged.

Otherwise, the scope performs 25 NLTS measurements by incrementing 25 times the start point —approximately 1/25'th of the input waveform's length minus pattern length — of the input waveform used to perform the correlation calculation. And then averages the resulting 25 NLTS measurements. All the individual NLTS measurements can be observed by histogramming the **nlts** parameter.

The greater the number of pseudo-random pattern periods in the input waveform, the greater the reduction in the effect of noise on the **nlts** result. In order to further reduce the impact of noise, the NLTS calculations are adjusted by dividing their value by the correlation coefficient value at an integral number of pattern-length delays.

The following table gives the standard deviation of the **nlts** parameter for varying amounts of auto-correlation signal–to–noise, and numbers of repetitions of the pseudo-random sequence in the input waveform. The sampling rate used was four samples/bit cell, and the input waveform had 20% NLTS.

ACSN	#Pattern Repetitions	nlts Standard Deviation
26 dB	2	0.44%
	10	0.28%
	25	0.20%
23 dB	2	0.59%
	10	0.32%
	25	0.26%
20 dB	2	0.65%
	10	0.42%
	25	0.28%
17 dB	2	1.08%
	10	0.57%
	25	0.35%

Parameter Settings Selection of the "**nlts**" parameter in the "**CHANGE PARAM**" menus causes a "**MORE nlts SETUP**" menu to appear. Pressing the corresponding menu button acesses pattern length and pattern delay menus. The user can adjust the mantissa, exponent or number of mantissa digits by pressing these menus' corresponding buttons. And the associated 'menu' knob can be used to adjust these. However, if a large number of digits is used, selection of the exact frequency may be difficult. In this case, a number with fewer digits and less precision should be chosen for the approximate frequency, then the precision increased as desired and the exact value chosen. The pattern length should be set to the pattern period.

Although the scope searches for the correct pattern length, the value provided needs to be sufficiently close to the actual pattern length for **nlts** to perform the search. A 1 µsec pattern may, for example, accept a range of 1 µsec ± 40 nsec. Within this range a value for **nlts** will be provided. Otherwise "---" appears on the screen, indicating that no measurement can be made.

The pattern delay setting is a percentage of the pattern length. The scope will internally scale the delay value entered by the ratio of the pattern length calculated internally to the pattern entered by the user. Several disk drive waveform attributes can be measured by using different delay values. The following table provides delay values to enter for the commonly used 127-bit pseudo random sequence ($x^7 + x^3 + 1$ polynomial) when measuring various waveform attributes:

Waveform Attribute	Bit Cell Location	Delay (%)
Adjacent Location	25.5	20.08%
Second Adjacent Location	30.5	24.02%
Initial Magnetization	45.5	35.83%
Interaction Interference	60.5	47.64%

Operating the Scope Remotely

The final chapter of this manual lists the commands for performing remote programming of the DDM and PRML options. Refer to your *Remote Control Manual* for a complete description of remote control capabilities. These commands — DEF, PACU and PAVA by their short names — are to be used when remotely programming DDM and PRML functions.

FUNCTION

DEFINE, DEF

Command/Query

DESCRIPTION

The DEFINE command specifies the mathematical expression to be evaluated by a function. This command is used to control all functions in the standard oscilloscopes and WP0X processing packages.

COMMAND SYNTAX

<function> **: DEFine EQN,'**<equation>**'** [**,**<param_name>**,**<value>**,**...]

Note 1: Parameters are grouped in pairs. The first in the pair names the variable to be modified, <param_name>, while the second one gives the new value to be assigned. Pairs can be given in any order and restricted to the variables to be changed.

Note 2: Space (blank) characters inside equations are optional.

QUERY SYNTAX

<function> **: DEFine?**

RESPONSE FORMAT

<function> **: DEFine EQN,'**<equation>**'**[**,MAXPTS,**<max_points>] [**,SWEEPS,**<max_sweeps>][**,WEIGHT,**<weight>][**,BITS,**<bits>]

<param_name>	<value>	Description
EQN	'<equation>'	Function equation as defined below
DELAY	<delay>	Delay by time
MAXPTS	<max_points>	Max. number of points to compute
SWEEPS	<max_sweeps>	Maximum number of sweeps
Parameters To Support Additional Functions in WP01		
BITS	<bits>	Number of ERES bits
UNITS	<units>	Physical units
WEIGHT	<weight>	Continuous Average weight

Parameters To Support Additional Functions in WP02		
WINDOW	<window_type>	FFT window function
Parameters To Support Additional Functions in WP03 or DDM		
MAXBINS	<bins>	Number of bins in histogram
MAX_EVENTS	<max_values>	Max. no. of values in histogram
CENTER	<center>	Horizontal center position for histogram display.
WIDTH	<width>	Width of histogram display
VERT	<vert_scale>	Vertical scaling type
Parameters To Support Additional Functions in PRML		
LENGTH	<length>	No. points to use from first waveform
START	<start>	Starting point in second waveform

Function Equations And Names Available On All Models	
<source>	Identity
+<source>	Identity
-<source>	Negation
<source1> + <source2>	Addition
<source1> - <source2>	Subtraction
<source1><source2>	Multiplication
<source1>/<source2>	Ratio
AVGS(<source>)	Average Summed
RESAMP(<source>)	Resample (deskew)
SINX(<source>)	Sin(x)/x interpolator
ZOOMONLY (<extended_source>)	Zoom only (No Math)
Extended Functions Available On Instruments With WP01 Processing Firmware	
ABS(<source>)	Absolute Value

AVGC(<source>)	Continuous Average
DERI(<source>)	Derivative
ERES(<source>)	Enhanced Resolution
EXP(<source>)	Exponential (power of e)
EXP10(<source>)	Exponential (power of 10)
EXTR(<source>)	Extrema (Roof and Floor)
FLOOR(EXTR(<source>))	Floor (Extrema source only)
INTG(<source>[{+,📫} <addend>])	Integral
LN(<source>)	Logarithm base e
LOG10(<source>)	Logarithm base 10
RESC([{+,📫}][<multiplier>*]<source>[{+,📫}<addend>])	Rescale
ROOF(EXTR(<source>))	Roof (Extrema source only)
1/<source>	Reciprocal
SQR(<source>)	Square
SQRT(<source>)	Square Root
FFT Functions Available on Instruments with WP02 Processing Firmware *Note: The source waveform must be a time-domain signal, single segment.*	
FFT(<source>)	Fast Fourier Transform (complex result)
REAL(FFT(<source>))	Real part of complex result
IMAG(FFT(<source>))	Imaginary part of complex result
MAG(FFT(<source>))	Magnitude of complex result
PHASE(FFT(<source>))	Phase angle (degrees) of complex result
PS(FFT(<source>))	Power spectrum
PSD(FFT(<source>))	Power density
RESC([{+,📫}][<multiplier>*]<source>[{+,📫}<addend>])	Rescale
Power Average Functions Available on Instruments with WP02 Processing Firmware *Note: The source waveform must be another function defined as a Fourier transform.*	

MAG(AVGP(<function>))	PS(AVGP(<function>))	PSD(AVGP(<function>))
Function Equations and Names Available on Instruments with WP03 or DDM Firmware		
HIST(<custom_line>)	Histogram of parameter on custom line	
Function Equations and Names Available on Instruments with PRML Firmware		
CORR(<source1>,<source2>)	Cross Correlation	

Source values

Note: The numbers in CUST1, CUST2, CUST3, CUST4, and CUST5 refer to the line numbers of the selected custom parameters.

<sourceN> : = {**TA**, **TB**, **TC**, **TD**, **M1**, **M2**, **M3**, **M4**, **C1**, **C2**, **C3**☝, **C4**☝}

<function> : = {**TA**, **TB**, **TC**, **TD**}

<custom_line> : = {**CUST1, CUST2, CUST3, CUST4, CUST5**}

<extended_source> : = {**C1, C2, C3**☝,**C4**☝**, TA, TB, TC, TD, M1, M2, M3, M4**}

Values to define number of points/sweeps

<max_points> : = 50 to 10 000 000

<max sweeps> : = 1 to 1000 (For standard instruments)

<max_sweeps> : = 1 to 1 000 000 (For WP01 only)

<max_sweeps> : = 1 to 50 000 (WP02 Power Spectrum only)

Values for Resample Function

<delay> : = –2e–6 to +2e–6 seconds

Values for Rescale Function

<addend> : = 0.0 to 1e15

<multiplier> : = 0.0 to 1e15

Values for Summation Average and ERES

<weight> : = {**1**, **3**, **7**, **15**, **31**, **63**, **127**, **255**, **511**, **1023**}

<bits> : = {**0.5**, **1.0**, **1.5**, **2.0**, **2.5**, **3.0**}

Values for FFT window function

<window_type> : = {**BLHA**, **FLTP**, **HAMM**, **HANN**, **RECT**}

FFT Window Function Notation	
LHA	Blackman–Harris window
FLTP	Flat Top window
HABMM	Hamming window
HANN	von Hann window
RECT	Rectangular window

Values for WP03 histogramming

<max bins> : = {**20**, **50**, **100**, **200**, **500**, **1000**, **2000**}
<max_events> : = 20 to 2e9 (in a 1–2–5 sequence)
<center> : = –1e15 to 1e15
<width> : = 1e–30 to 1e30 (in a 1–2–5 sequence)
<vert_scale> : = {**LIN**, **LOG**, **CONSTMAX**}

Histogram Notation	
LIN	Use linear vertical scaling for histogram display
LOG	Use log vertical scaling for histogram display
CONSTMAX	Use constant maximum linear scaling for histogram display

Values for PRML correlation

<length> : = 0 to 10 divisions
<start> : = 0 to 10 divisions

AVAILABILITY

<sourceN> : = {C3, C4} only on four-channel instruments.

<extended_source> : = {C3, C4} only on four-channel instruments

SWEEPS is the maximum number of sweeps (Average and Extrema only).

Note: The pair SWEEPS,<max_sweeps> applies only to the summed averaging (AVGS).

EXAMPLE (GPIB)

The following instruction defines Trace A to compute the summed average of Channel 1 using 5000 points over 200 sweeps:

```
CMD$="TA:DEF EQN,'AVGS(C1)',MAXPTS,5000,SWEEPS,200":
CALL IBWRT(SCOPE%,CMD$)
```

WP01 EXAMPLE

The following instruction defines Trace A to compute the product of Channel 1 and Channel 2, using a maximum of 10 000 input points:

```
CMD$="TA:DEF EQN,'C1*C2',MAXPTS,10000":
CALL IBWRT(SCOPE%,CMD$)
```

WP02 FFT EXAMPLE (GPIB) The following instruction defines Trace A to compute the Power Spectrum of the FFT of Channel 1. A maximum of 1000 points will be used for the input. The window function is Rectangular.

```
CMD$="TA:DEF EQN,'PS(FFT(C1))',MAXPTS,1000,WINDOW,
RECT": CALL IBWRT(SCOPE%,CMD$)
```

WP02 PS EXAMPLE (GPIB) The following instruction defines Trace B to compute the Power Spectrum of the Power Average of the FFT being computed by Trace A, over a maximum of 244 sweeps.

```
CMD$="TB:DEF EQN,'PS(AVGP(TA))',SWEEPS,244":
CALL IBWRT(SCOPE%,CMD$)
```

WP03 EXAMPLE The following command defines Trace C to construct the histogram of the all rise time measurements made on source Channel 1. The rise time measurement is defined on custom line 2. The histogram has a linear vertical scaling and the rise time parameter values are binned into 100 bins.

```
CMD$="PACU 2,RISE,C1":CALL IBWRT(SCOPE%,CMD$)
CMD$="TC:DEF EQN,'HIST(CUST2)',VERT,LIN,MAXBINS,100":
CALL IBWRT(SCOPE%,CMD$)
```

RELATED COMMANDS FIND_CTR_RANGE, FUNCTION_RESET, INR?, PARAMETER_CUSTOM, PARAMETER_VALUE?, PASS_FAIL_CONDITION

CURSOR

PARAMETER_CUSTOM, PACU

Command/Query

DESCRIPTION

The PARAMETER_CUSTOM command controls the parameters that have customizable qualifiers, (for example, *Dt@lev* or *r@level*) and may also be used to assign any parameter for histogramming.

Note: The measured value of a parameter setup with PACU may be read using PAVA?

COMMAND SYNTAX

`PArameter_Custom` <line>**,**<parameter>**,**<qualifier>[**,**<qualifier>**,**...]

<line> : = 1 to 5

<parameter> : = {a parameter from the table below or any parameter listed in the PAVA? command}

<qualifier> : = Measurement qualifier(s) specific to each <param>. *See below.*

<param>	**definition**	**<qualifier> list**
	Parameters available on all models	
DC2DPOS	delta clock to data positive	<source1>,<clockedge>,<level1>,<source2>, <slope2>, <level2>,<hysteresis>
DC2DNEG	delta clock to data negative	<source1>,<clockedge>,<level1>,<source2>, <slope2>, <level2>,<hysteresis>
DDLY	delta delay	<source1>,<source2>
DTLEV	delta time at level	<source1>,<slope1>,<level1>,<source2>,<slope2>,<level2>,<hysteresis>
FLEV	fall at level	<source>,<high>,<low>
PHASE	phase difference	<source1>,<edge1>,<level1>,<source2>,<edge2>,<level2>,<hysteresis>,<angular unit>
RLEV	rise at level	<source>,<low>,<high>
TLEV	time at level	<source>,<slope>,<level>,<hysteresis>
	Parameters available on instruments equipped with WP03 or DDM processing firmware	
FWXX	full width at xx% of max	<source>,<threshold>
PCTL	percentile	<source>,<threshold>

<param>	definition	<qualifier> list
XAPK	x position at peak	<source>,<rank>
Parameters available on instruments equipped with DDM processing firmware		
LBASE	local base	<source>,<hysteresis>
LBSEP	local baseline separation	<source>,<hysteresis>
LMAX	local maximum	<source>,<hysteresis>
LMIN	local minimum	<source>,<hysteresis>
LNUM	number of local events	<source>,<hysteresis>
LPP	local peak to peak	<source>,<hysteresis>
LTBE	local time between events	<source>,<hysteresis>
LTBP	local time between peaks	<source>,<hysteresis>
LTBT	local time between troughs	<source>,<hysteresis>
LTMN	local time at minima	<source>,<hysteresis>
LTMX	local time at maxima	<source>,<hysteresis>
LTOT	local time over threshold	<source>,<hysteresis>,<threshold>
LTPT	local time peak to trough	<source>,<hysteresis>
LTTP	local time trough to peak	<source>,<hysteresis>
LTUT	local time under threshold	<source>,<hysteresis>,<threshold>
NBPH	narrow band phase	<source>,<freq>
NBPW	narrow band power	<source>,<freq>
OWRITE	overwrite	<source 1>,<source 2>,<freq>
PW50	pulse width 50	<source>,<hysteresis>
PW50NEG	pulse width 50 for troughs	<source>,<hysteresis>
PW50POS	pulse width 50 for peaks	<source>,<hysteresis>
RES	resolution	<source 1>,<source 2>,<hysteresis>
TAA	track average amplitude	<source>,<hysteresis>

<param>	definition	<qualifier> list
TAANEG	track average amplitude for troughs	<source>,<hysteresis>
TAAPOS	track average amplitude for peaks	<source>,<hysteresis>
Parameters available on instruments equipped with PRML processing firmware		
ACSN	auto correlation signal to noise	<source>,<length>
NLTS	non-linear transition shift	<source>,<length>,<delay>

Where:

<sourceN> : = {**C1**, **C2**, **C3**,**C4**,**TA**, **TB**, **TC**, **TD**}
<slopeN> : = {**POS**, **NEG**, **FIRST**}
<edgeN> : = {**POS**, **NEG**}
<clock edge> : = {**POS**, **NEG**, **ALL**}
<levelN>, <low>, <high> : = 1 to 99 if level is specified in percent (PCT), or
<levelN>, <low>, <high> : = Level in <sourceN> in the units of the waveform.
<delay> : = –100 PCT to 100 PCT
<freq> : = 10 to 1e9 Hz (Narrow Band center frequency).
<hysteresis> : = 0.01 to 8 divisions
<length> : = 1e–9 to 0.001 seconds
<rank> : = 1 to 100
<threshold> : = 0 to 100 percent
<angular unit> = {**PCT**, **DEG**, **RAD**}

QUERY SYNTAX **PArameter_CUstom?** <line>

RESPONSE FORMAT **PArameter_Custom** <line>**,**<parameter>**,**<qualifier>[**,**<qualifier>**,**...]

AVAILABILITY <sourceN> : = {C3, C4} only on four-channel instruments.

EXAMPLE 1 DTLEV

Command Example **PACU 2,DTLEV,C1,POS,345E–3,C2,NEG,–789E–3**

Query/Response Examples **PACU? 2** returns:
PACU 2,DTLEV,C1,POS,345E–3,C2,NEG,–789E–3
PAVA? CUST2 returns:
C2:PAVA CUST2,789 NS

EXAMPLE 2	DDLY
Command Example	`PACU 2,DDLY,C1,C2`

Query/Response Examples	`PACU? 2` returns:
	`PACU 2,DDLY,C1,C2`
	`PAVA? CUST2` returns:
	`C2:PAVA CUST2,123 NS`

EXAMPLE 3	RLEV
Command Example	`PACU 3,RLEV,C1,2PCT,67PCT`

Query/Response Examples	`PACU? 3` returns:
	`PACU 3,RLEV,C1,2PCT,67PCT`
	`PAVA? CUST3` returns:
	`C1:PAVA CUST3,23 MS`

EXAMPLE 4	FLEV
Command Example	`PACU 3,FLEV,C1,345E–3,122E–3`

Query/Response Examples	`PACU? 3` returns:
	`PACU 3,FLEV,C1,345E–3,122E–3`
	`PAVA? CUST3` returns:
	`C1:PAVA CUST3,23 MS`

RELATED COMMANDS	PARAMETER_DELETE, PARAMETER_VALUE, PASS_FAIL_CONDITION

CURSOR	PARAMETER_VALUE?, PAVA? Query

DESCRIPTION

The PARAMETER_VALUE query returns the current value(s) of the pulse waveform parameter(s) and mask tests for the specified trace. Traces do not need to be displayed or selected to obtain the values measured by the pulse parameters or mask tests.

Parameters Available on All Models					
ALL	all parameters	**DUTY**	duty cycle	**OVSP**	positive overshoot
AMPL	amplitude	**FALL**	falltime	**PER**	period
AREA	area	**FALL82**	fall 80 to 20%	**PKPK**	peak-to-peak
BASE	base	**FREQ**	frequency	**PNTS**	points
CMEAN	mean for cyclic waveform	**FRST**	first point	**RISE**	risetime
CMEDI	median for cyclic waveform	**LAST**	last point	**RISE28**	rise 20 to 80%
CRMS	root mean square for cyclic part of waveform	**MAX**	maximum	**RMS**	root mean square
CSDEV	standard deviation for cyclic part of waveform	**MEAN**	mean	**SDEV**	standard deviation
CYCL	cycles	**MEDI**	median value	**TOP**	top
DLY	delay	**MIN**	minimum	**WID**	width
DUR	duration of acquisition	**OVSN**	negative overshoot		

Custom Parameters Defined using PARAMETER_CUSTOM Command[1]				
CUST1	CUST2	CUST3	CUST4	CUST5

Parameters Available on Instruments with WP03 or DDM Processing Firmware					
AVG	average of distribution	**HMEDI**	median of a histogram	**PKS**	number of peaks
DATA	data values	**HRMS**	histogram rms value	**RANGE**	range of distribution
FWHM	full width at half max	**HTOP**	histogram top value	**SIGMA**	sigma of distribution
HAMPL	histogram amplitude	**LOW**	low of distribution	**TOTP**	total population

[1] *The numbers in the terms CUST1, CUST2, CUST3, CUST4 and CUST5 refer to the line numbers of the selected custom parameters.*

HBASE	histogram base	**MAXP**	maximum population		
HIGH	high of histogram	**MODE**	mode of distribution		

Parameter Computation States			
AV	averaged over several (up to 100) periods	**OF**	signal partially in overflow
GT	greater than given value	**OK**	deemed to be determined without problem
IV	invalid value (insufficient data provided)	**OU**	signal partially in overflow and underflow
LT	less than given value	**PT**	window has been period truncated
NP	no pulse waveform	**UF**	signal partially in underflow

Mask Test Names			
ALL_IN	all points of waveform inside mask (TRUE = 1, FALSE = 0)	**SOME_IN**	some points of waveform inside mask (TRUE = 1, FALSE = 0)
ALL_OUT	all points of waveform outside mask (TRUE = 1, FALSE = 0)	**SOME_OUT**	some points of waveform outside mask (TRUE = 1, FALSE = 0)

QUERY SYNTAX

<trace> : **PArameter_VAlue?** [<parameter>,...,<parameter>]

<trace> : = {**TA**, **TB**, **TC**, **TD**, **C1**, **C2**, **C3**☝,**C4**☝}

<parameter> : = *See table of parameter names on previous page*.

Alternative forms of query for mask tests:

<trace> : **PArameter_VAlue?** <old_mask_test>

<trace> : **PArameter_VAlue?** <mask_test>, <mask>

<mask_test> : = {**ALL_IN**, **SOME_IN**, **ALL_OUT**, **SOME_OUT**}

<old_mask_test> : = {**ALLI**, **ANYI**, **ALLO**, **ANYO**}

<mask> : = {**TA**, **TB**, **TC**, **TD**}

Note: Old mask test keywords ALLI, ANYI, ALLO, ANYO imply testing of <trace> against the mask waveform TD. Old mask test keywords INSIDE and OUTSIDE are equivalent to ALL_IN and SOME_OUT; they are only supported for compatibility with older-model instruments.

RESPONSE FORMAT

<trace> : **PArameter_VAlue** <parameter>**,**<value>**,**
<state> [**,**...**,**<parameter>**,**<value>**,**<state>]

<value> : = A decimal numeric value
<state> : = {**OK**, **AV**, **PT**, **IV**, **NP**, **GT**, **LT**, **OF**, **UF**, **OU**}

Note: If <parameter> is not specified, or is equal to ALL, all the standard voltage and standard time parameters followed by their values and states are returned.

AVAILABILITY

<trace> : {C3, C4} only available on four-channel instruments.

EXAMPLE (GPIB)

The following query reads the risetime of Trace B (TB):

```
CMD$="TB:PAVA? RISE": CALL IBWRT(SCOPE%,CMD$):
CALL IBRD (SCOPE%,RD$): PRINT RD$
```

Response message:

```
TB:PAVA RISE,3.6E-9S,OK
```

RELATED COMMANDS

CURSOR_MEASURE, CURSOR_SET,
PARAMETER_CUSTOM, PARAMETER_STATISTICS