CHAPTER ELEVEN: *Analyze with Parameters*

Part One introduced Waverunner Measure Tools. Now use their advanced aspects to troubleshoot and analyze your waveform.

In this chapter, see how

To customize parameters

To perform Pass/Fail tests

Parameters work

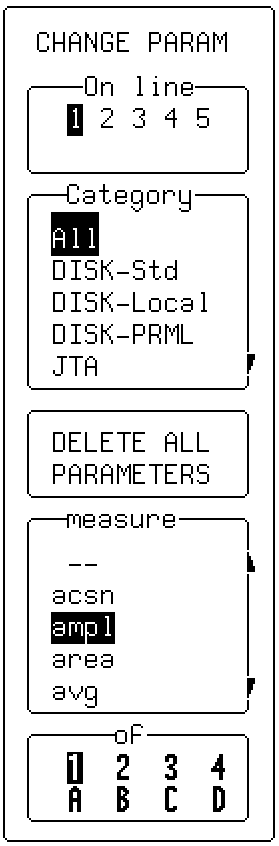
Each parameter plays a special role in measurement

Use Custom Parameters

1. Press MEASURE TOOLS to display the MEASURE menus. See Part One, Chapter 4, "Choose a Measure Tool."

2. Press the button to select **Parameters**, and the button for **Custom** in the mode menu. Use statistics if desired, and set the starting and end point for the parameter measurements using the from and to menus.

3. Then press the button to select CHANGE PARAMETERS and access the CHANGE PARAM menus.



4. Use them to change your parameters.

To select a line, and the parameter allocated to it, for modification. Five lines with five unique parameters can be displayed and modified.

To select the parameter category.

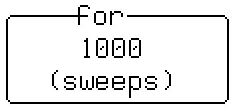
To delete all five assigned parameters from the lines.

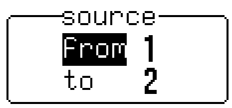
To place a new parameter for measurement on the line selected above. When "**--**" is selected, that line is not used.

To select the channel or trace on which the parameter will be measured.

CUSTOMIZE A PARAMETER

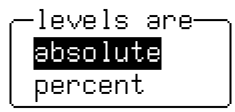
You can customize certain parameters to meet special needs:

1. Take, for example, Δ time at level, a parameter that computes the transition between different levels of a waveform, or between different sources.
2. Press the button to select the **All** category, and the button to choose **Δt@ lv** from the measure menu.
3. Turn the upper knob to set the number of sweeps: 

4. Press the button to select channel or memory 

Turn the knob for **from** and **to**.
5. Then press the button to select 

From the SETUP of Δt@ lv menus then displayed:



6. Press the button to set levels in either absolute or peak-to-peak percent signal values:
7. Press the button to set the hysteresis in divisions. This is a voltage band that extends equidistantly above and below the selected level. In order for the signal to be considered valid, and not as noise, the signal must exceed, or cross, the upper or lower limits of this band by half the hysteresis division setting.
8. Turn the knob to set the voltage or amplitude percent level in the “from” menu.

This determines where on the waveform Waverunner will start the timing measurement.

9. Press the button to make the measurement on a positive (rising) or negative (falling) edge. Or, with **First**, to make it on either edge.
10. Finally, turn the knob to set the voltage or amplitude percentage in the “to” menu.

This determines the level on the waveform at which the timing is to end.

11. Press the button to end the measurement on a positive (rising) or negative (falling) edge. Or, with **First**, to end it on either edge.

Test for Pass and Fail

You can also use parameters to carry out Pass/Fail tests. These require a combination of measurements within chosen limits. The Waverunner invokes an action when the test passes or fails — depending on what you specify. You can also test signals against a tolerance mask. As with custom parameters, you can use as many as five parameters at the same time. Whether the tests pass or fail, any or all of the following actions can be invoked:

Stop capturing further signals

Dump the screen image to a hardcopy unit

Store selected traces to internal memory, to an optional device in the PC Card slot, or to floppy disk

Sound the buzzer

Emit a pulse through the rear BNC connector

The display will show you the results on the current waveforms, the number of passing events, the total number of sweeps treated, and the actions for you to take.

SET UP A PASS/FAIL TEST

1. Set up for parameters in the MEASURE menu as shown in Chapter 4 and on the preceding pages.
2. Press the button to select **Pass** or **Fail** in the mode menu. Use statistics if desired, and set the starting and end points for the parameter measurements using the "from" and "to" menus.
3. Then press the button to select CHANGE TEST CONDITIONS

From the CHANGE TEST menus displayed:

4. Press the button to set one or more of the five parameter lines.
5. Press the button to select **Param** from the Test on menu for testing using that parameter; "**---**" for no test.
6. And press the button to select **Param** from the choose menu.
7. Set the other menus displayed as desired, according to the description on page 145.
8. Then if you wish to change the Pass/Fail test limit on the parameter, press the button to select **Limit** from the choose menu.
9. Press the button to select the adequate relation — smaller or greater than — from: True if < >

10. Then press the button to select from [limit: +0.00 E+00 / 3 digits] one of three possible modifications to the limit.

These are the limit's mantissa, exponent, and the number of digits to be represented in its mantissa.

11. Turn the knob to set the value for these.

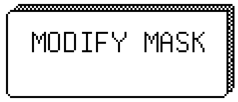
12. Finally, press the bottom button to set the limit to the latest measured value — a starting value for the final adjustment.

PASS/ FAIL TEST ON A MASK

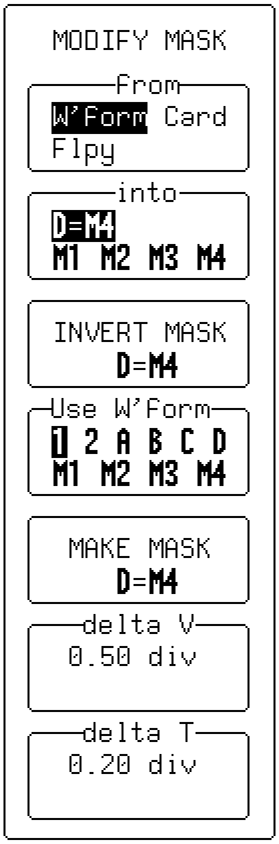
1. Follow the CHANGE TEST Steps 1 to 5 described above.
2. Press the button to select **Mask** from the "Test on" menu for testing using that parameter; "**---**" for no test.
3. Press the button to select the mask test condition from [True if: all points / some points]
4. Press the button to select the mask test condition from [are: inside / outside]
5. Press the button to select the channel or trace for testing from the of menu, and the button for the trace on which the mask is to be placed from the mask menu.

> ***NOTE: Pass/Fail testing against a mask is affected by horizontal and vertical zooming of the mask trace. The test will be made inside the area bordered by the parameter cursors. Timebases of the mask and the trace under test should be identical. For visual mask testing, use a single grid when performing a mask test on a single trace; dual-grid display for testing on two traces.***

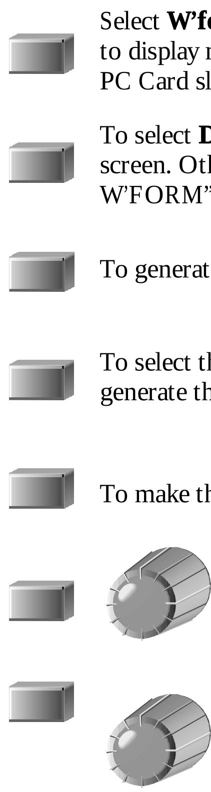
MAKE A WAVEFORM MASK

1. Press the button to select 

from the mask CHANGE TEST menus described above.



2. Use these menus to generate a mask from your waveform.



Select **W'form** to generate the mask from your displayed waveform; **Card** to display menus for recalling a mask stored to an optional device in the PC Card slot; **Floppy** to recall a stored mask from floppy disk.

To select **D=M4** if the mask is to be automatically displayed on the screen. Otherwise select **M1**, **M2**, **M3**, or **M4**. Use the "RECALL W'FORM" menus to recall and display a memory on a trace.

To generate an inverted mask.

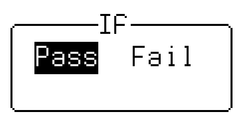
To select the waveform to be used as the reference. Waverunner will generate the mask around this.

To make the mask.

To select the tolerance in amplitude with the knob.

To select the tolerance in time with the knob.

CHANGE A TEST ACTION

1. From the CHANGE TEST menus press the button to select **Action** in the On line.
2. Press the button to determine if the action will be taken on Pass or Fail: 

3. Press the button to select the action in the "Then" menu. And press the button to activate (**Yes**) or disable (**No**) this action in the final menu, now named for the action chosen. This yes or no is in turn shown in "Then."

HOW WAVERUNNER PARAMETERS WORK

Proper determination of the top and base reference lines is fundamental for ensuring correct parameter calculations. The analysis begins with Waverunner computing a histogram of the waveform data over the time interval spanned by the left and right time cursors.

For example, the histogram of a waveform transitioning in two states will contain two peaks (Fig. 1). The analysis will attempt to identify the two clusters that contain the largest data density. Then the most probable state (centroids) associated with these two clusters will be computed to determine the top and base reference levels: the top line corresponds to the top and the base line to the bottom centroid. Once top and base are estimated, Waverunner easily calculates the rise and fall times. The oscilloscope automatically determines the 90% and 10% threshold levels, using the amplitude (ampl) parameter. (Histograms are part of the WaveAnalyzer option.)

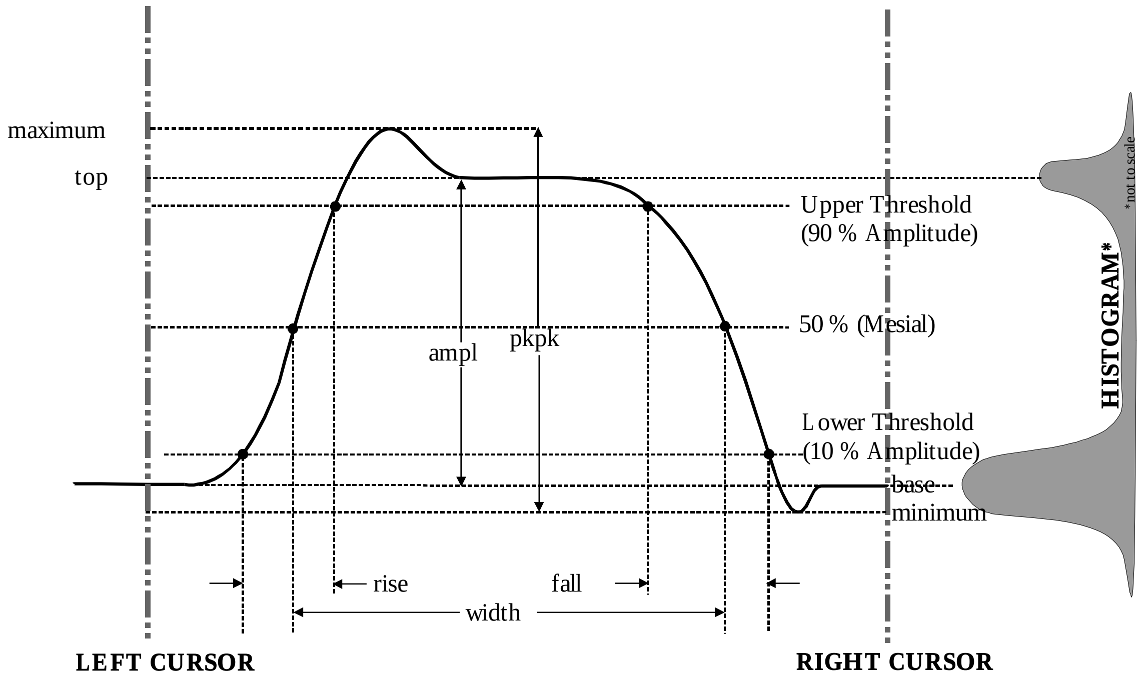


Figure 1.

Threshold levels for rise or fall time can also be selected using absolute or relative settings (r@ level, f@ level). If absolute settings are chosen, the rise or fall time is measured as the time interval separating the two crossing points on a rising or falling edge. But when relative settings are chosen, the vertical interval spanned between the base and top lines is subdivided into a percentile scale (base = 0%, top = 100%) to determine the vertical position of the crossing points.

Rising Edge Duration	$\frac{1}{Mr}\sum_{i=1}^{Mr}\left(Tr_i^{90}-Tr_i^{10}\right)$
Falling Edge Duration	$\frac{1}{Mf}\sum_{i=1}^{Mf}\left(Tf_i^{10}-Tf_i^{90}\right)$
Where Mr is the number of rising edges found, Mf the number of falling edges found, Tr_i^x the time when rising edge i crosses the x% level, and Tf_i^x the time when falling edge i crosses the x% level.	

The time interval separating the points on the rising or falling edges is then estimated to yield the rise or fall time. These results are averaged over the number of transition edges that occur within the observation window.

Time parameter measurements such as width, period and delay are carried out with respect to the mesial reference level (Fig. 2), located halfway (50%) between the top and base reference lines. Time parameter estimation depends on the number of cycles included within the observation window. If the number of cycles is not an integer, parameter measurements such as rms or mean will be biased.

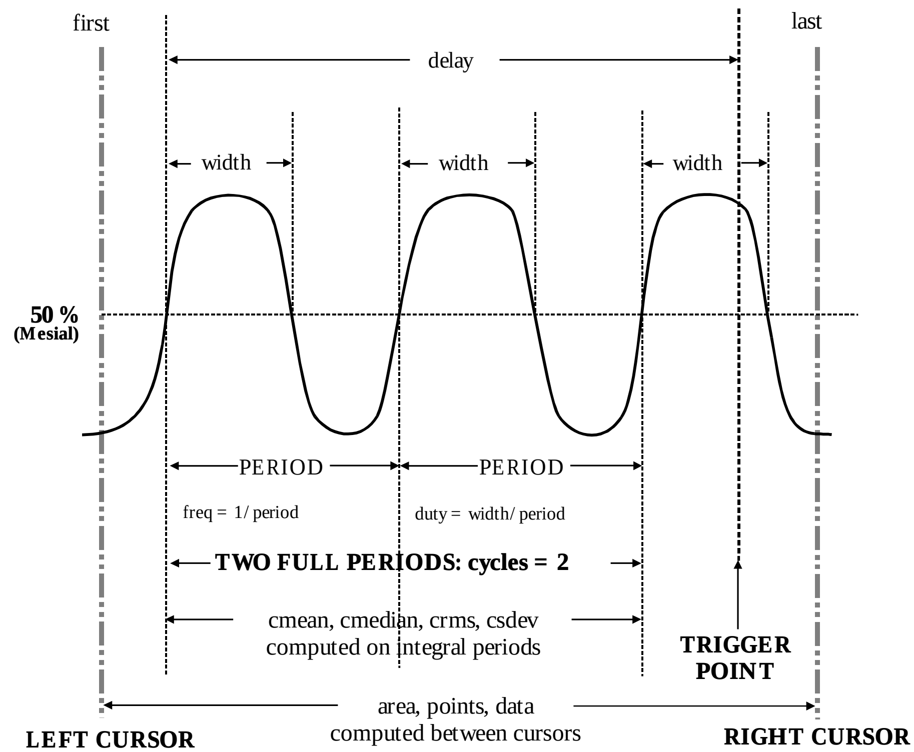


Figure 2.

To avoid these bias effects, the instrument uses cyclic parameters, including crms and cmean, that restrict the calculation to an integer number of cycles. The Waverunner enables accurate differential time measurements between two traces — for example, propagation, setup and hold delays (Fig. 3). Parameters such as Δc2d± require the transition polarity of the clock and data signals to be specified.

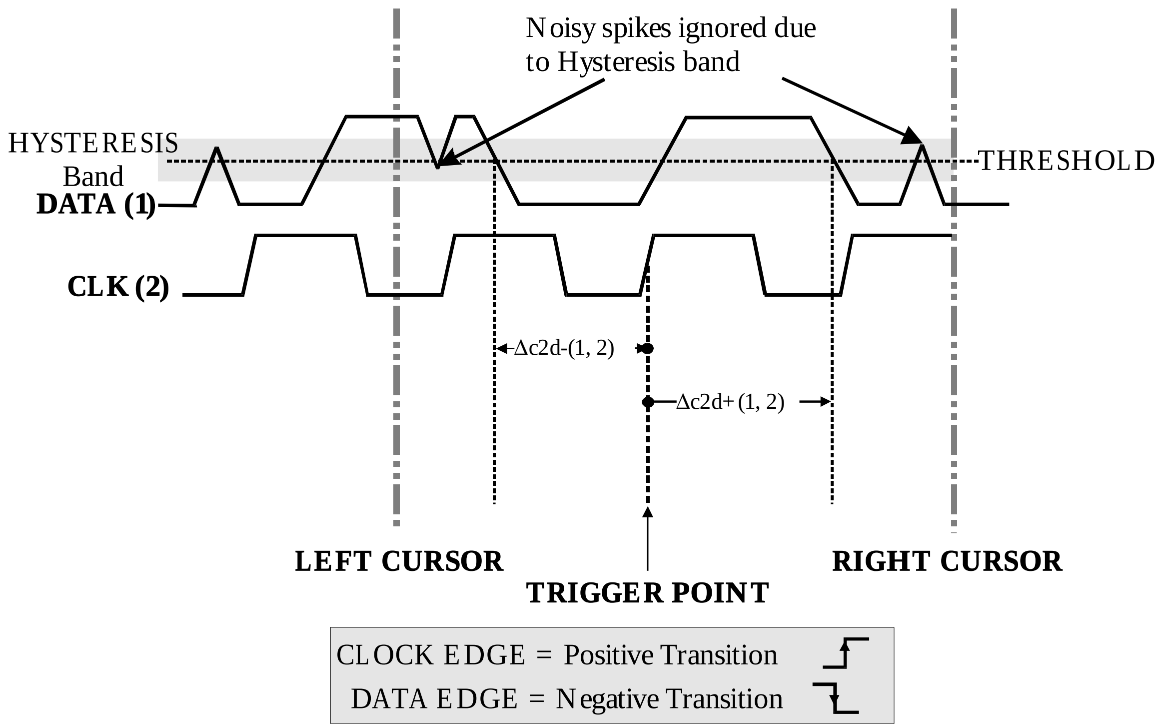


Figure 3.

Moreover, a hysteresis range may be specified to ignore any spurious transition that does not exceed the boundaries of the hysteresis interval. In Figure 3, Δc2d− (1, 2) measures the time interval separating the rising edge of the clock (trigger) from the first negative transition of the data signal. Similarly, Δc2d+ (1, 2) measures the time interval between the trigger and the next transition of the data signal.

Choose a Parameter

The following table lists, describes and defines Waverunner parameters. Those indicated by the symbol are in the Extended Math and WaveAnalyzer options (see Chapter 5, "Use a Math Tool"). All the other parameters listed here are standard on Waverunner.

PARAMETER	DESCRIPTION	DEFINITION	NOTES
ampl	Amplitude: Measures difference between upper and lower levels in two-level signals. Differs from *pkpk* in that noise, overshoot, undershoot, and ringing do NOT affect measurement.	*top − base* (See Fig. 1)	*On signals NOT having two major levels (such as triangle or saw-tooth waves), returns same value as* pkpk.
area	Integral of data: Computes area of waveform between cursors relative to zero level. Values greater than zero contribute positively to the area; values less than zero negatively.	Sum from *first* to *last* of data multiplied by horizontal time between points (See Fig. 2)	
base	Lower of two most probable states (higher is *top*). Measures lower level in two-level signals. Differs from *min* in that noise, overshoot, undershoot, and ringing do NOT affect measurement.	Value of most probable lower state (See Fig. 1)	*On signals NOT having two major levels (triangle or saw-tooth waves, for example), returns same value as* min.
cycles	Determines number of cycles of a periodic waveform lying between cursors. First cycle begins at first transition after the left cursor. Transition may be positive- or negative-going.	Number of cycles of periodic waveform (See Fig. 2)	
cmean	Cyclic mean: Computes the average of waveform data. Contrary to *mean*, computes average over an integral number of cycles, eliminating bias caused by fractional intervals.	Average of data values of an integral number of periods	
cmedian	Cyclic median: Computes average of base and top values over an integral number of cycles, contrary to *median*, eliminating bias caused by fractional intervals.	Data value for which 50 % of values are above and 50 % below	

PARAMETER	DESCRIPTION	DEFINITION	NOTES
crms	Cyclic root mean square: Computes square root of sum of squares of data values divided by number of points. Contrary to *rms*, calculation is performed over an integral number of cycles, eliminating bias caused by fractional intervals.	$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(v_i)^2}$	*Where: v_i denotes measured sample values, and N = number of data points within the periods found up to maximum of 100 periods.*
csdev	Cyclic standard deviation: Standard deviation of data values from mean value over integral number of periods. Contrary to *sdev*, calculation is performed over an integral number of cycles, eliminating bias caused by fractional intervals.	$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(v_i - mean)^2}$	*Where: v_i denotes measured sample values, and N = number of data points within the periods found up to maximum of 100 periods.*
delay	Time from trigger to transition: Measures time between trigger and first 50% crossing after left cursor. Can measure propagation delay between two signals by triggering on one and determining delay of other.	Time between trigger and first 50% crossing after left cursor (See Fig. 2)	
Δdly	Δdelay: Computes time between 50% level of two sources.	Time between midpoint transition of two sources	
Δt@ lv	Δt at level: Computes transition between selected levels or sources.	Time between transition levels of two sources, or from trigger to transition level of a single source	*Reference levels and edge-transition polarity can be selected. Hysteresis argument used to discriminate levels from noise in data.*
Δc2d±	Δclock to data ±: Computes difference in time from clock threshold crossing to either the next (Δc2d+) or previous (Δc2d–) data threshold crossing.	Time from clock threshold crossing to next or previous edge (See Fig. 3)	*Threshold levels of clock and data signals, and edge transition polarity can be selected. Hysteresis argument used to differentiate peaks from noise in data, with good hysteresis value between half expected peak-to-peak value of signal and twice expected peak-to-peak value of noise.*

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th><th>DEFINITION</th><th>NOTES</th></tr>
<tr><td>dur</td><td>For single sweep waveforms, dur is 0; for sequence waveforms: time from first to last segment's trigger; for single segments of sequence waveforms: time from previous segment's to current segment's trigger; for waveforms produced by a history function: time from first to last accumulated waveform's trigger.</td><td>Time from first to last acquisition: for average, histogram or sequence waveforms</td><td></td></tr>
<tr><td>duty</td><td>Duty cycle: Width as percentage of period.</td><td>width/ period
(See Fig. 2)</td><td></td></tr>
<tr><td>f80–20%</td><td>Fall 80–20%: Duration of pulse waveform's falling transition from 80% to 20%, averaged for all falling transitions between the cursors.</td><td>Average duration of falling 80–20% transition</td><td>On signals NOT having two major levels (triangle or saw-tooth waves, for example), top and base can default to maximum and minimum, giving, however, less predictable results.</td></tr>
<tr><td>f@ level</td><td>Fall at level: Duration of pulse waveform's falling edges between transition levels.</td><td>Duration of falling edge between transition levels</td><td>On signals NOT having two major levels (triangle or saw-tooth waves, for example), top and base can default to maximum and minimum, giving, however, less predictable results.</td></tr>
<tr><td>fall</td><td>Fall time: Measures time between two specified values on falling edges of a waveform. Fall times for each edge are averaged to produce final result.
<table>
<tr><th colspan="5">ARGUMENTS</th></tr>
<tr><th>Threshold</th><th>Remote</th><th>Lower Limit</th><th>Upper Limit</th><th>Default</th></tr>
<tr><td>Lower</td><td>Low</td><td>1%</td><td>45%</td><td>10%</td></tr>
<tr><td>Upper</td><td>High</td><td>55%</td><td>99%</td><td>90%</td></tr>
</table>
Threshold arguments specify two vertical values on each edge used to compute fall time. Formulas for upper and lower values:
$$\text{lower value} = \text{lower threshold} \times \frac{amp}{100} + base$$
$$\text{upper value} = \text{upper threshold} \times \frac{amp}{100} + base$$</td><td>Time at lower threshold minus Time at upper threshold averaged over each falling edge
(See Fig. 1)</td><td>On signals NOT having two major levels (triangle or saw-tooth waves, for example), top and base can default to maximum and minimum, giving, however, less predictable results.</td></tr>
</table>

PARAMETER	DESCRIPTION	DEFINITION	NOTES
first	Indicates value of horizontal axis at left cursor.	Horizontal axis value at left cursor (See Fig. 2)	*Indicates location of left cursor. Cursors are interchangeable: for example, the left cursor may be moved to the right of the right cursor and* first *will give the location of the cursor formerly on the right, now on left.*
freq	Frequency: Period of cyclic signal measured as time between every other pair of 50% crossings. Starting with first transition after left cursor, the period is measured for each transition pair. Values then averaged and reciprocal used to give frequency.	1/*period* (See Fig. 2)	
last	Time from trigger to last (rightmost) cursor.	Time from trigger to last cursor (See Fig. 2)	*Indicates location of right cursor. Cursors are interchangeable: for example, the right cursor may be moved to the left of the left cursor and* first *will give the location of the cursor formerly on the left, now on right.*
maximum	Measures highest point in waveform. Unlike *top*, does NOT assume waveform has two levels.	Highest value in waveform between cursors (See Fig. 1)	*Gives similar result when applied to time domain waveform or histogram of* data *of same waveform. But with histograms, result may include contributions from more than one acquisition. Computes horizontal axis location of rightmost non-zero bin of histogram — not to be confused with* maxp.
mean	Average of *data* for time domain waveform. Computed as centroid of distribution for a histogram.	Average of *data* (See Fig. 2)	*Gives similar result when applied to time domain waveform or histogram of* data *of same waveform. But with histograms, result may include contributions from more than one acquisition.*
median	The average of base and top values.	Average of *base* and *top* (See Fig. 2)	

PARAMETER	DESCRIPTION	DEFINITION	NOTES
minimum	Measures the lowest point in a waveform. Unlike *base*, does NOT assume waveform has two levels.	Lowest value in waveform between cursors (See Fig. 1)	*Gives similar result when applied to time domain waveform or histogram of data of same waveform. But with histograms, result may include contributions from more than one acquisition.*
over–	Overshoot negative: Amount of overshoot following a falling edge, as percentage of amplitude.	$\frac{(base - minimum)}{ampl} \times 100$ (See Fig. 2)	*Waveform must contain at least one falling edge. On signals NOT having two major levels (triangle or saw-tooth waves, for example), may NOT give predictable results.*
over+	Overshoot positive: Amount of overshoot following a rising edge specified as percentage of amplitude.	$\frac{(maximum - top)}{ampl} \times 100$ (See Fig. 1)	*Waveform must contain at least one rising edge. On signals NOT having two major levels (triangle or saw-tooth waves, for example), may NOT give predictable results.*
period	Period of a cyclic signal measured as time between every other pair of 50% crossings. Starting with first transition after left cursor, period is measured for each transition pair, with values averaged to give final result.	$\frac{1}{Mr}\sum_{i=1}^{Mr}\left(Tr_i^{50} - Tr_i^{50}\right)$ (See Fig. 2)	*Where: Mr is the number of leading edges found, Mf the number of trailing edges found,* Tr_i^x *the time when rising edge i crosses the x% level, and* Tf_i^x *the time when falling edge i crosses the x% level.*
pkpk	Peak-to-peak: Difference between highest and lowest points in waveform. Unlike ampl, does not assume the waveform has two levels.	*maximum minus minimum* (See Fig. 1)	*Gives a similar result when applied to time domain waveform or histogram of data of the same waveform. But with histograms, result may include contributions from more than one acquisition.*
phase	Phase difference between signal analyzed and signal used as reference.	Phase difference between signal and reference	
points	Number of points in the waveform between the cursors.	Number of points between cursors (See Fig. 2)	

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th><th>DEFINITION</th><th>NOTES</th></tr>
<tr><td>r20–80%</td><td>Rise 20% to 80%: Duration of pulse waveform's rising transition from 20% to 80%, averaged for all rising transitions between the cursors.</td><td>Average duration of rising 20–80% transition</td><td>On signals NOT having two major levels (triangle or saw-tooth waves, for example), top and base can default to maximum and minimum, giving, however, less predictable results.</td></tr>
<tr><td>r@ level</td><td>Rise at level: Duration of pulse waveform's rising edges between transition levels.</td><td>Duration of rising edges between transition levels</td><td>On signals NOT having two major levels (triangle or saw-tooth waves, for example), top and base can default to maximum and minimum, giving, however, less predictable results.</td></tr>
<tr><td>rise</td><td>Rise time: Measures time between two specified values on waveform's rising edge (10–90%). Rise times for each edge averaged to give final result.
<table>
<tr><th colspan="5">ARGUMENTS</th></tr>
<tr><td>Threshold</td><td>Remote</td><td>Lower Limit</td><td>Upper Limit</td><td>Default</td></tr>
<tr><td>Lower</td><td>Low</td><td>1%</td><td>45%</td><td>10%</td></tr>
<tr><td>Upper</td><td>High</td><td>55%</td><td>99%</td><td>90%</td></tr>
</table>
Threshold arguments specify two vertical values on each edge used to compute rise time.
Formulas for upper and lower values:
$\text{lower value} = \text{lower threshold} \times \frac{amp}{100} + base$
$\text{upper value} = \text{upper threshold} \times \frac{amp}{100} + base$</td><td>Time at upper threshold minus Time at lower threshold averaged over each rising edge
(See Fig. 1)</td><td>On signals NOT having two major levels (triangle or saw-tooth waves, for example), top and base can default to maximum and minimum, giving, however, less predictable results.</td></tr>
</table>

PARAMETER	DESCRIPTION	DEFINITION	NOTES
rms	Root Mean Square of data between the cursors — about same as *sdev* for a zero-mean waveform.	$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(v_i)^2}$ (See Fig. 2)	*Gives similar result when applied to time domain waveform or histogram of data of same waveform. But with histograms, result may include contributions from more than one acquisition. Where: v_i denotes measured sample values, and N = number of data points within the periods found up to maximum of 100 periods.*
sdev	Standard deviation of the data between the cursors — about the same as *rms* for a zero-mean waveform.	$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(v_i - mean)^2}$ (See Fig. 2)	*Gives similar result when applied to time domain waveform or histogram of data of same waveform. But with histograms, result may include contributions from more than one acquisition. Where: v_i denotes measured sample values, and N = number of data points within the periods found up to maximum of 100 periods.*
t@ level	Time at level: Time from trigger (t=0) to crossing at a specified level.	Time from trigger to crossing level	
top	Higher of two most probable states, the lower being *base*; it is characteristic of rectangular waveforms and represents the higher most probable state determined from the statistical distribution of *data* point values in the waveform.	Value of most probable higher state (See Fig. 1)	*Gives similar result when applied to time domain waveform or histogram of* data *of same waveform. But with histograms, result may include contributions from more than one acquisition.*
width	Width of cyclic signal determined by examining 50% crossings in data input. If first transmission after left cursor is a rising edge, waveform is considered to consist of positive pulses and *width* the time between adjacent rising and falling edges. Conversely, if falling edge, pulses are considered negative and *width* the time between adjacent falling and rising edges. For both cases, widths of all waveform pulses averaged for final result.	Width of first positive or negative pulse averaged for all similar pulses (See Figs. 1, 2)	*Similar to* fwhm, *though, unlike* width, *that parameter applies only to histograms.*