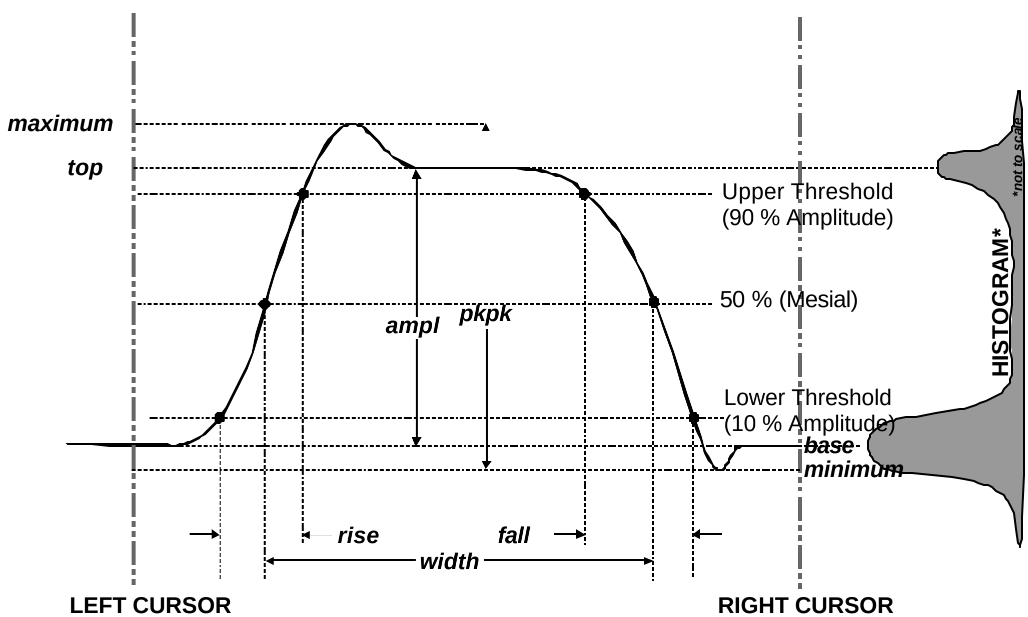
Parameters and How They Work

In this Appendix, a general explanation of how the instrument's standard parameters are computed (*see below*) is followed by a table listing, defining and describing those parameters (*page C–1*).

Determining Top and Base Lines

Proper determination of the *top* and *base* reference lines is fundamental for ensuring correct parameter calculations. The analysis begins by 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. C–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.

Figure C–1

Determining Rise and Fall Times

Once *top* and *base* are estimated, calculation of the *rise* and *fall* times is easily done (*Fig.1*). The 90 % and 10 % threshold levels are automatically determined by the LSA1000, using the amplitude (*ampl*) parameter.

Threshold levels for *rise* or *fall* time can also be selected using absolute or relative settings (*r@level, fall@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.

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.

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 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.	

Determining Time Parameters

Time parameter measurements such as *width*, *period* and *delay* are carried out with respect to the mesial reference level (*Fig. C–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.

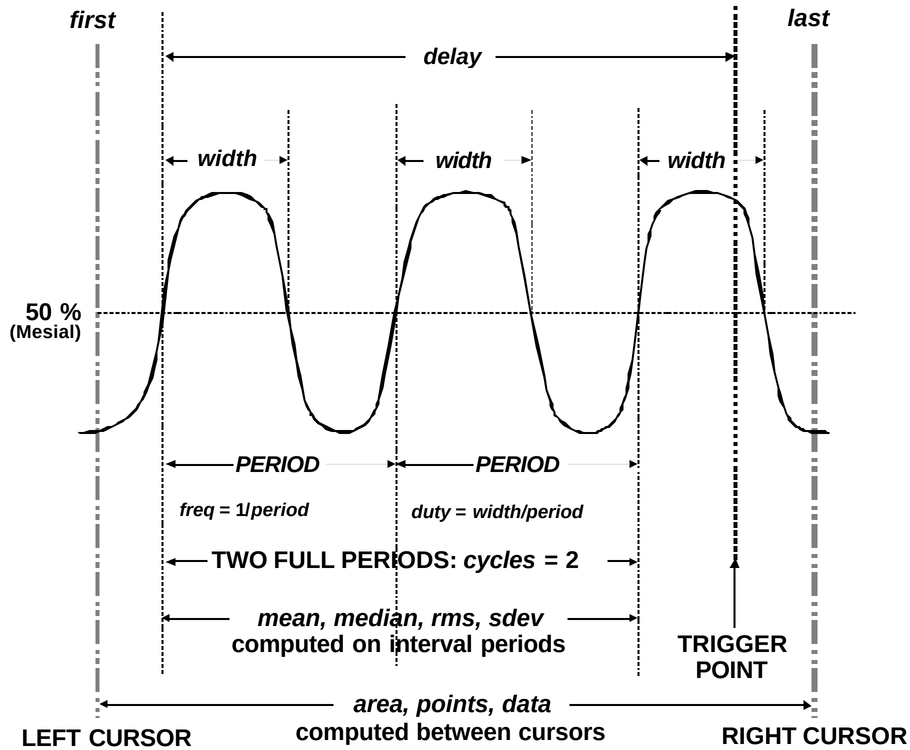


Figure C–2

To avoid these bias effects, the instrument uses cyclic parameters, including *crms* and *cmean*, that restrict the calculation to an integer number of cycles.

Determining Differential Time Measurements

The LSA1000 enables accurate differential time measurements between two traces — for example, propagation, setup and hold delays (*Fig. C–3*).

Parameters such as *Dc2d±* require the transition polarity of the clock and data signals to be specified.

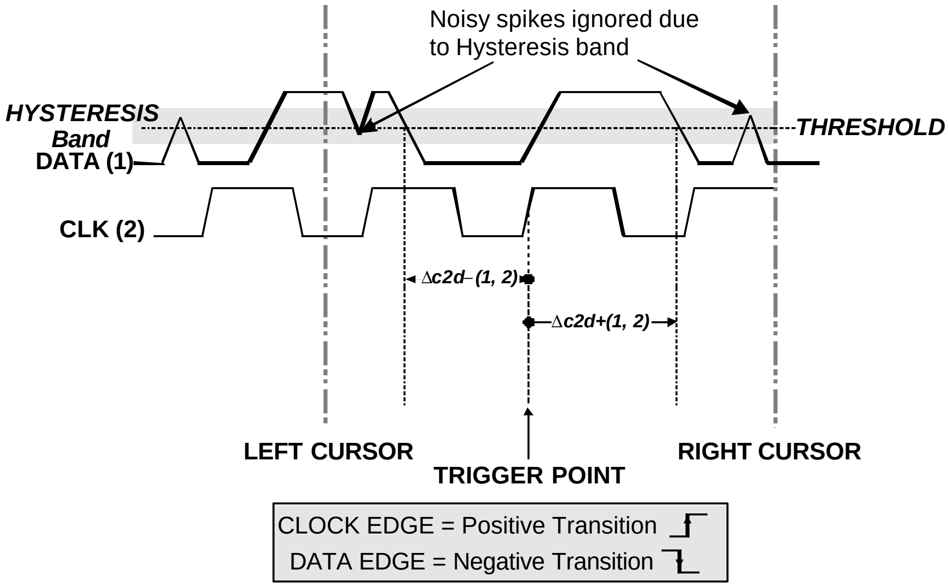


Figure C–3

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, *Dc2d-* (1, 2) measures the time interval separating the rising edge of the clock (trigger) from the first negative transition of the data signal. Similarly, *Dc2d+* (1, 2) measures the time interval between the trigger and the next transition of the data signal.

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. C–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. C–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. C–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. C–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	
crms	Cyclic root mean square: Computes square root of sum of squares of data values divided by number of points. Contrary to *rms*, calculation performed over 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.

Parameter — Description		Definition	Notes
csdev	Cyclic standard deviation: Standard deviation of data values from mean value over integral number of periods. Contrary to *sdev*, calculation performed over 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.*
data	Returns average of all data points.	All data values in analyzed region *(See Fig. C–2)*	*Multi-value parameter especially valuable for histograms and trends.*
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. C–2)*	
Ddly	Δdelay: Computes time between 50 % level of two sources.	Time between midpoint transition of two sources	
Dt@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.*
Dc2d±	Δclock to data ±: Computes difference in time from clock threshold crossing to either the next (*Dc2d+*) or previous (*Dc2d-*) data threshold crossing.	Time from clock threshold crossing to next or previous edge *(See Fig. C–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.*

Parameter	— Description	Definition	Notes
dur	Duration of acquisition: 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.	Time from first acquisition — for average, histogram or sequence waveforms	
duty	Duty cycle: Width as percentage of period.	*width/period (See Fig. C–2)*	
f80–20%	Fall 80–20 %: Duration of pulse waveform's falling transition from 80% to 20%, averaged for all falling transitions between the cursors.	Average duration of falling 80–20 % transition	*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.*
f@level	Fall at level: Duration of pulse waveform's falling edges between transition levels.	Duration of falling edge between transition levels	*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.*
fall	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. (Arguments: see below)	Time at lower threshold - Time at upper threshold averaged over each falling edge *(See Fig. C–1)*	*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.*

Arguments

Threshold	Remote	Lower Limit	Upper Limit	Default
Lower	low	1 %	45 %	10 %
Upper	high	55 %	99 %	90 %

Parameter — Description		Definition	Notes
	Threshold arguments specify two vertical values on each edge used to compute fall time. Formulas for upper and lower values: $\text{lower value} = \text{lower threshold} \times \frac{amp}{100} + base$ $\text{upper value} = \text{upper threshold} \times \frac{amp}{100} + base$		
first	Indicates value of horizontal axis at left cursor.	Horizontal axis value at left cursor *(See Fig. C–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. C–2)*	
last	Time from trigger to last (rightmost) cursor.	Time from trigger to last cursor *(See Fig. C–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.*

Parameter — Description		Definition	Notes
maximum	Measures highest point in waveform. Unlike *top*, does NOT assume waveform has two levels.	Highest value in waveform between cursors *(See Fig. C–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. But when input is periodic time domain waveform, computed on an integral number of periods.	Average of *data* *(See Fig. C–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. C–2)*	
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. C–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. C–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. C–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.*

Parameter	— Description	Definition	Notes
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. C–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 - minimum* *(See Fig. C–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. C–2)*	
r20–80%	Rise 20 % to 80 %: Duration of pulse waveform's rising transition from 20% to 80%, averaged for all rising transitions between the cursors.	Average duration of rising 20–80 % transition	*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.*
r@level	Rise at level: Duration of pulse waveform's rising edges between transition levels.	Duration of rising edges between transition levels	*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.*

<table>
<tr><th>Parameter — Description</th><th></th><th>Definition</th><th>Notes</th></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><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 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 - Time at lower threshold averaged over each rising edge

(See Fig. C–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>
<tr><td>rms</td><td>Root Mean Square of data between the cursors — about same as sdev for a zero-mean waveform.</td><td>$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(v_i)^2}$

(See Fig. C–2)</td><td>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.</td></tr>
</table>

Parameter — Description		Definition	Notes
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. C–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*. This 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. C–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, *which, however, applies only to histograms.*

C Appendix C: Parameter Measurement