

ORM & AORM

**Optical Recording
Measurements/Advanced**

**Operator's
Manual**

October 2000



LeCroy Corporation

700 Chestnut Ridge Road
Chestnut Ridge, NY 10977-6499
Tel: (845) 578 6020, Fax: (845) 578 5985

Internet: www.lecroy.com

Copyright © 2000 by LeCroy Corporation. All rights reserved. Information in this publication supersedes all earlier versions. Specifications subject to change.

LeCroy, ProBus and SMART Trigger are registered trademarks of LeCroy Corporation. Centronics is a registered trademark of Data Computer Corp. Epson is a registered trademark of Epson America Inc. I²C is a trademark of Philips. Mathcad is a registered trademark of MATHSOFT Inc. MATLAB is a registered trademark of The MathWorks, Inc. Microsoft, MS and Microsoft Access are registered trademarks, and Windows and NT are trademarks of Microsoft Corporation. PowerPC is a registered trademark of IBM Microelectronics. DeskJet, ThinkJet, QuietJet, LaserJet, PaintJet, HP 7470, and HP 7550 are registered trademarks of Hewlett-Packard Company.

ORM-OM-E

Rev E

1000





Chapter 1 – Introduction

What Can ORM Do?	1-1
Histogramming	1-1
Trending	1-1
Model of Optical Recording Processing	1-2
Parameter Measurements	1-2
Selecting Parameters	1-2
Custom Parameters	1-4
List by nT Mode	1-6
BES or EES Table	1-8

Chapter 2 – Setup and View Wizard

Screen Access	2-2
Setup Menu	2-3
View Wizard	2-6
Measurement Table	2-8

Chapter 3 – Parameters and Values

Doing Optical Data Measurements	3-1
Measurement Value Display	3-2
Parameter Configuration	3-2
Configuration Options	3-4
Configuration Menus	3-5
Setting Levels	3-7
Setting nT	3-8
Configuration Tracking	3-9
Maximizing Performance	3-9
Pit or Space Identification	3-10
nT Pit/Space Categorization	3-12
Memory Limitations	3-13



Chapter 4 – Measurement Parameters

bes	4-1
bess	4-5
ees	4-7
eess	4-11
bees	4-13
$\Delta p2c$ Delta Pit to Clock	4-16
$\Delta p2cs$ Delta Pit to Clock Sigma	4-20
edgsh Edge Shift	4-22
lper Local Period	4-26
paa Pit Average Amplitude	4-28
pasym Pit Asymmetry	4-30
pbase Pit Base	4-32
pmax Pit Maximum	4-34
pmidl Pit Middle Level	4-36
pmin Pit Minimum	4-38
pmoda Pit Modulation Amplitude	4-40
pnum Pit Number	4-43
pres Pit Resolution	4-45
ptop Pit Top	4-48
pwid Pit Width	4-50
t@pit Time At Pit	4-55
timj Timing Jitter	4-61
Signals, Coupling and Threshold Settings	4-65
Using Parameters with Trends and XY Plots	4-68
Improving Horizontal Measurement Accuracy	4-72
Base and Top Calculation Details	4-74

Chapter 5 – Trending

Displaying Trends	5-1
To Configure a Trend	5-1
The Trend Configuration Menus	5-2
Trend Calculation	5-6
Parameter Buffer	5-6
Parameter Events Capture	5-7
Reading Trends	5-8
Using Measurement Cursors	5-9

Chapter 6 – Histograms

Theory of Operation	6-1
LeCroy DSO Process	6-2
Parameter Buffer	6-3
Parameter Events Capture	6-4
Histogram Parameters	6-5
Zoom Traces and Segmented Waveforms	6-6
Histogram Peaks	6-6
Binning and Measurement Accuracy	6-7
Creating and Analyzing Histograms	6-10
Selecting the Histogram Function	6-10
Histogram Trace Setup Menu	6-12
Setting Binning and Histogram Scale	6-17
Histogram Parameters	6-20
Using Measurement Cursors	6-22
Zoom Traces and Segmented Waveforms	6-23

Chapter 7 – Histogram Parameters

Average (avg)	7-1
Full Width at Half Maximum (fwhm)	7-2
Full Width at xx% Maximum (fwxx)	7-3
Histogram Amplitude (hampl)	7-4



Histogram Base (hbase)	7-5
High (high)	7-6
Histogram median (hmedian)	7-7
Histogram Root Mean Square (hrms)	7-8
Histogram Top (htop)	7-9
Low (low)	7-10
Maximum Population (maxp)	7-11
Mode (mode)	7-12
Percentile (pctl)	7-13
Peaks (pks)	7-14
Range (range)	7-16
Sigma (sigma)	7-17
Total Population (totp)	7-18
X Coordinate of xx'th Peak (xapk)	7-19

Chapter 8 – DVD Processing Model

Filtering	8-3
Slicer	8-3
Clock Recovery	8-4
OR Data Configuration Menu	8-5
Setup of A	8-5
Optical Recording Setup	8-6

Chapter 9 – ORM Remote Control Commands

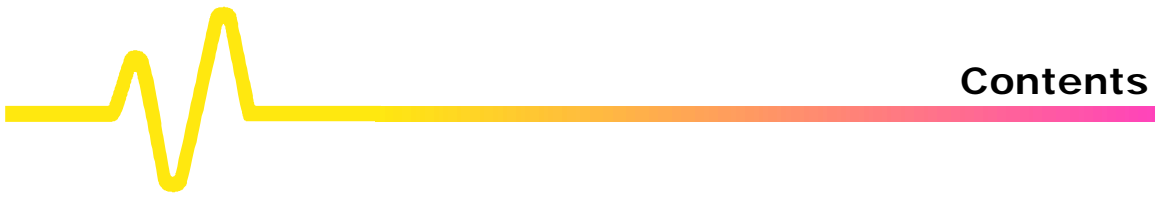
CURSOR_MEASURE, CRMS	9-1
CURSOR_SET, CRST	9-4
CURSOR_VALUE?, CRVA?	9-6
DEFINE, DEF	9-7
PARAMETER_CLR, PACL	9-14
PARAMETER_CUSTOM, PACU	9-15
PARAMETER_DELETE, PADL	9-19

PARAMETER_LIST, PALI.....	9-20
PARAMETER_LIST_VALUES?, PALV?	9-23
PARAMETER_STATISTICS?, PAST?.....	9-24
PARAMETER_VALUE?, PAVA?	9-25

Appendix A – Notes on OR Data Math Function

Operational Notes.....	A-3
How the Starting VCO Frequency and Phase are Determined	A-15

#



Contents

BLANK PAGE

What Can ORM Do?

The Optical Recording Measurement (ORM) Package for LeCroy digital oscilloscopes provides a set of waveform measurements and mathematical functions for the analysis of optical recording signals. Parameter measurements allow the categorizing and listing of measurement values in a variety of ways. The math functions (Histogramming and Trending) enable information to be revealed graphically.

In addition to all the capabilities of ORM, the Advanced Optical Recording Measurement (AORM) package provides parameter measurements for evaluating jitter due to intersymbol interface and emulation of DVD's equalizer, slicer, and PLL. This functionality helps you to perform clock and jitter measurements, independent of a specific Integrated Circuit, allowing you to concentrate on optical head or media performance only. It also provides you with a new Setup and View wizard, which simplifies the setup process and lets you see the waveforms and measurements — with a histogram, trend or XY plot of the measurements — at the press of a button. To support advanced optical recording drives that have constant angular velocity (CAV) or zone constant linear velocity (ZCLV), parameter measurements support automatic determination of the clock period.

Histogramming

Histograms can be created for any waveform parameter. They are displayed based on a set of user settings such as bin width or number of parameter events to be used. Histogram parameters are provided for measuring different histogram features such as standard deviation, number of peaks, and most populated bin. Histograms are selected by defining a trace (A, B, C, or D) as a math function, and selecting Histogram as the math function. As with other Zoom traces, histograms can be positioned and expanded by using the front panel POSITION and ZOOM knobs. See Chapters 6 and 7.

Trending

The Trend function allows you to create a graph containing successive waveform parameter measurement values. The trend function provides useful visual information on the variation of a waveform parameter within a sector, or even over multiple sectors.



The Trend functionality, coupled with other scope features, enables you to graph certain parameters against one another. See Chapter 5.

Model of Optical Recording Processing

In many applications, it is important to make timing and jitter measurements directly from the RF signal, independent of a specific DVD chip. The optical recording processing function in AORM can perform this processing and can let you view the equalized data, sliced data, threshold, and/or the recovered clock. You can control the cutoff frequency and boost of the equalizing filter, the closed loop bandwidth of the 1st order integrating slicer, and the bandwidth of the phase lock loop (PLL). See Chapter 8.

Parameter Measurements

Two measurement modes for waveform parameters are available in the Optical Recording Measurement Package. These are “Custom” and “List by nT.” For each mode, you can select the parameter measurement(s) to be displayed.

Custom mode is a standard DSO parameter selection-and-display option in which up to five parameters can be selected and displayed simultaneously on individual lines. **List by nT** is a special waveform measurement mode specifically designed for ORM. One measurement at a time is selected, and a list of values is displayed (indexed by multiples of the clock period). The parameter measurement values in the AORM package can also be viewed in a table. See Chapters 2 and 3.

Selecting Parameters

Parameters are accessed by first pressing the MEASURE TOOLS or CURSORS/MEASURE button on the scope front panel. The “Measure” menu group will appear on screen. **Parameters** must then be selected in order to display the menus shown in Figure 1.1.

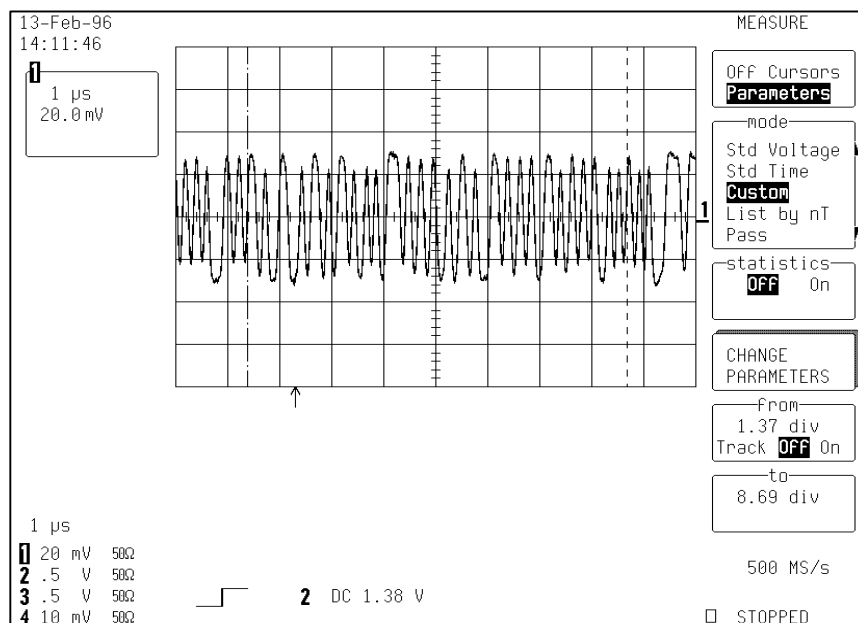


Figure 1.1

The **mode** menu enables you to select a variety of parameter measurement modes. But for ORM, the modes of interest are **Custom**, shown selected in the above figure, and **List by nT**.

Parameters allow measurements of the section of waveform lying between the parameter cursors, the broken vertical lines at left and right on the grid in Figure 1.1. The position of the parameter cursors is set by means of the **from** and **to** menus and is controlled by the associated rotary knobs on the front panel. When you set tracking **On**, you can move the parameter cursors across the waveform so that measurement results can be taken on different sections of the waveform.

Custom Parameters

With **Custom** selected, the **CHANGE PARAMETERS** submenu appears, which, when selected, produces the CHANGE PARAM menu panel shown in Figure 1.2.

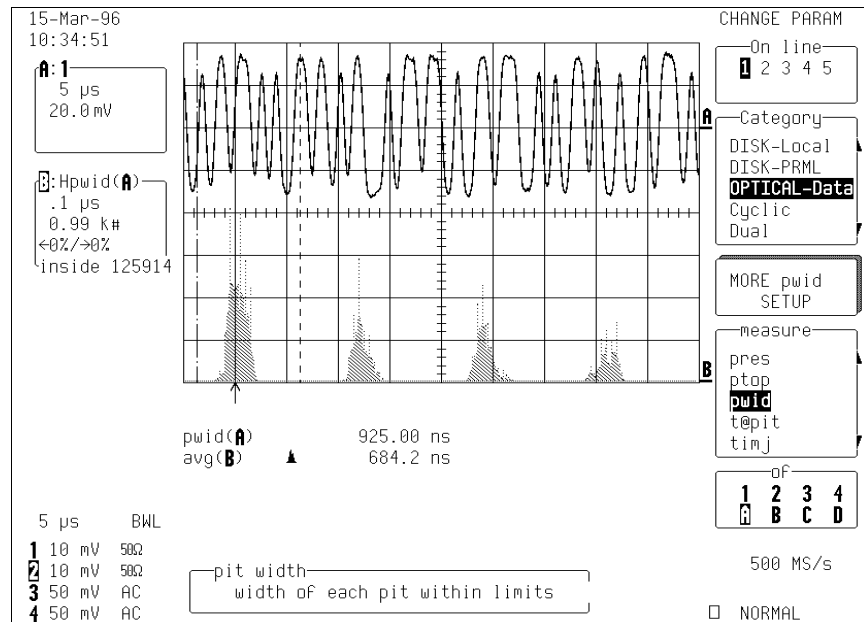


Figure 1.2

Up to five parameters can be selected, each displayed on its own line below the waveform display grid. Select a parameter display line from the "On line" menu.

Figure 1.2 has the Pit Width (pwid) parameter selected for line 1 and the Histogram Average (avg) parameter selected for line 2. The avg parameter provides the average value for the histogram between the parameter cursors. Notice that the parameter cursors are set in this example to surround the first histogram distribution. In this way the avg parameter displays the histogram average on the surrounded distribution only. No parameters are selected for lines 3 to 5.

Selecting from "Category" determines which set of parameter measurements is displayed in the "Measure" menu.

Figure 1.2 shows the **Optical-Data** category and the **pwid** parameter selected. For all custom parameter measurements in ORM, **Optical-Data** must be chosen as the category. If a parameter has settings needed for performing measurements, the "MORE xxxx SETUP" menu appears.

The same figure shows that the **pwid** parameter requires you to provide additional settings. If none is required, a "DELETE ALL PARAMETERS" menu appears. Pressing the associated menu button causes all five lines of parameters to be cleared.

Note: All parameters in the ORM package require configuration. See the scope Operator's Manual for a complete description of front panel operations, including menu selection.

After you have selected a custom parameter, use the "of" menu to determine on which input channel (1, 2, 3, or 4) or trace (A, B, C, or D) the parameter measurement will be performed. Some parameters require two sources, with these appearing in the menu.

The results displayed for a selected parameter are dependent on whether **statistics** and the **Sequence** option have been selected. Depending on the parameter and these factors, results may be provided for a single acquisition (trigger) or multiple acquisitions. In all cases, only the waveform section between the parameter cursors is used in calculating a measurement value. If the waveform source is a memory (M1, M2, M3, or M4), loading a new waveform into memory acts as a new acquisition. Similarly, if the waveform source is a ZOOM of an input channel, and Sequence is on, selection of a new segment or the **All Segments** menu option acts as a new acquisition.

Waveforms with **statistics** off display the parameter results for only the last acquisition. Those acquired with the timebase set for **Sequence** give results for the last *segment* acquired. For zoomed traces of segmented waveforms, selecting an individual segment causes the parameter value for the selected segment to be displayed; whereas, here, selection of **All Segments** provides the parameter results from the trace's last segment. For zoomed traces of segmented waveforms the statistics for the selected segment are displayed. Selecting a new segment or **All Segments** acts as a new sweep and causes the parameter calculations for the new segment(s) to contribute to the statistics.

Depending on the parameter, a single calculation or multiple calculations may be performed per acquisition. One example is the

Pit Width parameter, which performs a calculation of the width of each pit and/or space when it is calculating a parameter value for a single acquisition. In this case, there will typically be many parameter results. With **statistics** off, if multiple values result from a parameter calculation, the parameter result displayed will be the average value of these calculations for the last DSO waveform acquisition. With **statistics** on, the display will show the average, low, high, and sigma of all the values calculated for all DSO acquisitions since the last time you pressed **CLEAR SWEEPS**.

List by nT Mode

When you select **List by nT** from the “mode” menu, the “CHANGE MEASUREMENT” menu appears. Selecting this new choice causes the CHANGE MEAS menu panel to be displayed, as in Figure 1.3.

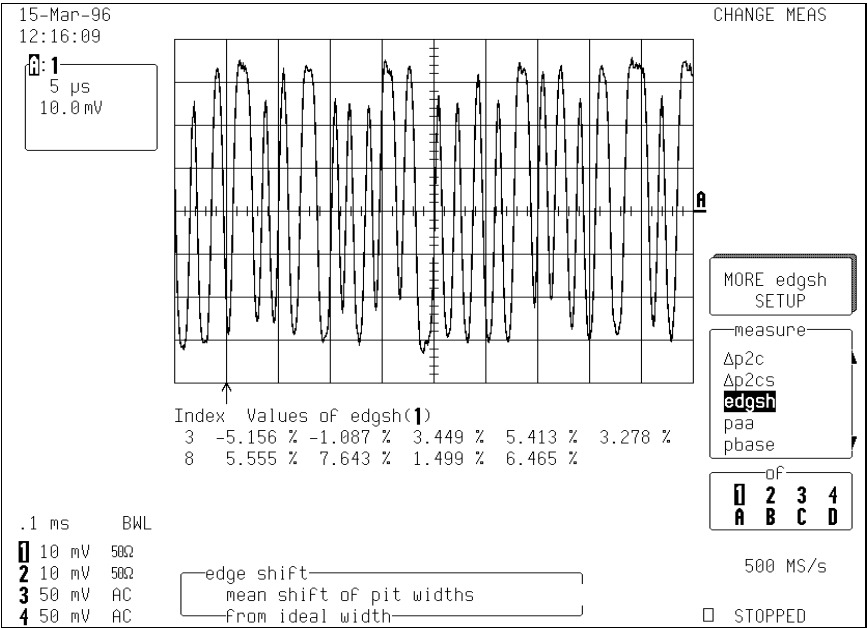


Figure 1.3

* There is one exception to this case, the **t@pit** parameter, which returns the value of the first calculation result.

One measurement type at a time is selected in this mode, its values displayed below the grid. Selection is made using the “Measure” menu. The values are displayed indexed up to 25 values. The column beneath the grid headed “Index” provides the first index value for the adjacent row of values.

Figure 1.3 shows Edge Shift (**edgsh**) selected, and the values for an index range of 3–11.

All measurements available in **List by nT** mode need to have configuration settings supplied in order to calculate values. Selecting the “MORE ‘xxxx’ SETUP” menu accesses the appropriate measurement configuration for the selected parameter.

The “of” menu determines the input channel (1, 2, 3, or 4) or trace (A, B, C, or D).



BES or EES Table

When the selected measurement is Begin Edge Shift (BES), End Edge Shift (EES), or their sigmas (BESS or EESS), the results can be shown in a table. Press the **Show Table** key to display a full-page table of the average value of BES or EES for each subject nT vs. each “preceded” or “followed” nT (see Figure 1.4). This menu has the following softkeys:

Accumulate on/off – All entries in the table may not be captured in a single acquisition. Therefore, you can accumulate data over many acquisitions by selecting accumulate on.

Print – When this button is pressed, the BES or EES table is sent as ASCII text to a currently defined hardcopy device.

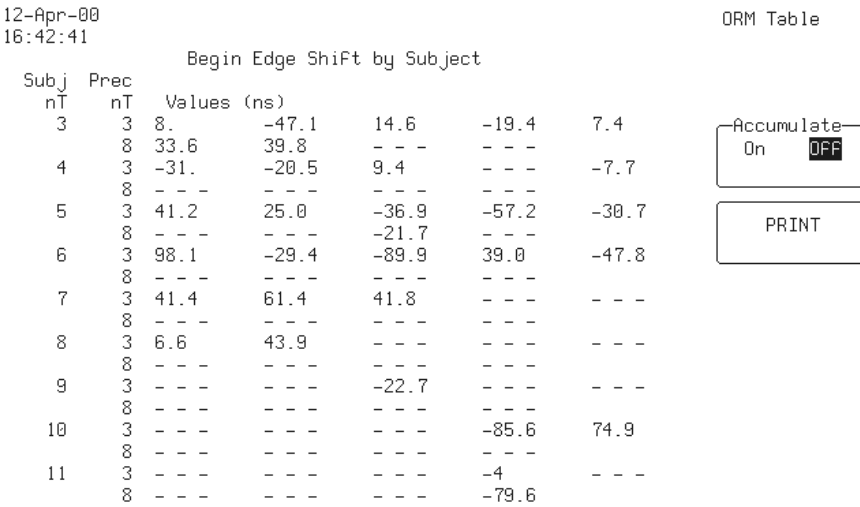


Figure 1.4

Scroll – Because the table can have 50 lines (1 to 25 T), a scroll knob is active when max *n* minus min *n* is greater than 8.

Note: For EES “Following nT” is displayed instead of “Preceding nT.” The nT is the range specified, starting from the low T. The subject T (i.e., s(n)) will also start from Low T to High T.

#

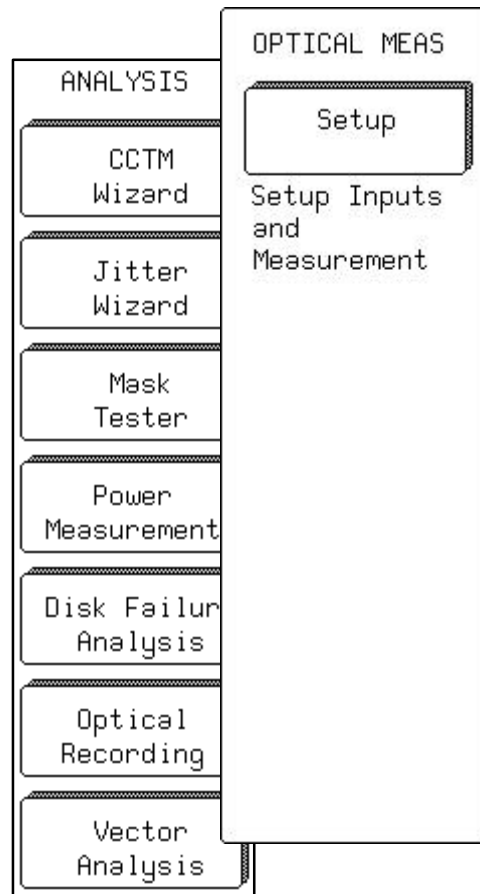
Advanced ORM Setup and View Wizard

The Advanced ORM package provides a Setup and View wizard to simplify setup of the most common AORM parameters and processing functions. The View wizard allows you to quickly switch between different views of the information. In addition, a full-page setup menu allows you to specify information about the signal and the measurements to be made. When you exit this menu, the scope will execute the setup accordingly.

The wizard redefines parameters, math traces, and the display setup of the oscilloscope. Once the wizard has done its work, you can change the setup, using the standard scope menus and controls. However, if you re-enter the wizard, it may modify those changes, depending on the changes you made vis-a-vis its own predefined settings.

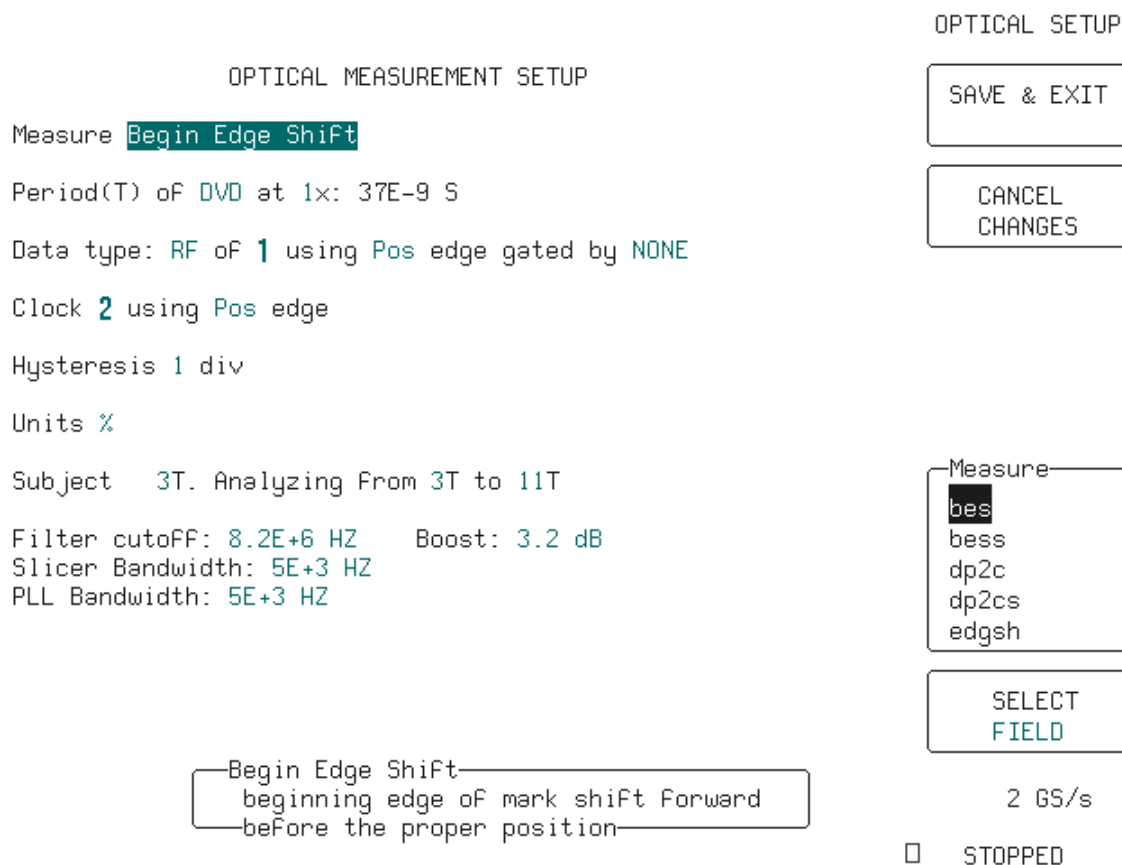
Screen Access

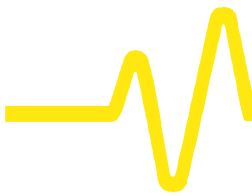
You can access the Setup and View Wizard by pressing the **ANALYSIS PACKAGES** button on the *WavePro* DSO (**CURSOR/MEASURE** or **CUSTOM** button on other scope models) and selecting **Optical Recording**. The “Optical Meas” menu panel is then displayed. If no measurement is currently defined, only the **Setup** menu appears, as shown below. Pressing the Setup button brings up a full-page menu that presents the common settings for the parameters.



Setup Menu

The current settings of the appropriate parameters and functions are displayed in the “Optical Measurement Setup” screen, as shown in the figure below. The bottom two sub-menus, and their associated knob and button, are used to navigate from one field to the next. No changes to the scope setup will be made until you exit the menu either by selecting **SAVE & EXIT** or by pressing the front panel RETURN button. At that time, the scope configuration will be modified. **CANCEL CHANGES** exits the menu without saving any changes.





AORM Setup & View Wizard

The following table explains the fields and their possible values:

Field	Description	
Measure	Selects the primary measurement to be made. The selected calculation is described at the bottom of the screen.	
Period	Indicates the period of the clock. The choices are: CD, DVD, DVD RW 2.6, DVD RW 4.7GB from Clock, from Data, Custom.	
	CD or DVD	When selected, the period is set to the value defined by the standard. You can also set a multiplier (e.g., 10x).
	From clock	Indicates that the period should be automatically measured from the clock provided. The clock must then be configured below.
	Custom	Allows you to specify the clock period
Data Type	Specifies what type of data is being acquired: RF is the raw, unfiltered data, Equalized is the data after the filter, Leveled is the data with the threshold subtracted, and Sliced is the output of the slicer. If RF data is input, the data will be equalized and leveled before the measurements are made. If the input data is already Equalized, it will just be leveled. No additional processing is performed if the input data is leveled or sliced. You must also specify the following information about the input data:	
	Source	The channel or memory that has the optical data.
	Edge	Polarity of the pits/spaces to use for the measurement, when appropriate. Positive polarity refers to pits, Negative polarity refers to spaces, All can be selected to use both pits and spaces.
	Gate	Optionally, you can specify a channel or memory that will be used to determine where to perform measurements on the input signal. If this is specified, you must also specify the active polarity of the gate (i.e., process when low or high).
Clock	The clock need only be specified if the parameter requires a clock for the calculation, or it is used as the source of the period.	
	Source	Channel or memory that has the clock, or the Extracted Clock may be selected, in which case the clock will be recovered from the data.
	Edge	Polarity of the clock edge to be used in the measurement. Near refers to the nearest clock edge to the data edge.
Hysteresis	Size of the hysteresis band (in screen divisions) with the thresholds at the center of the band. Any waveform being analyzed must pass beyond this band before the next threshold crossing is recognized.	

Field	Description
Units	The units used for the horizontal parameter results. Time refers to absolute units. Percent refers to results being calculated as a percent of the clock period
Subject	For BES, EES, BEES, BESS, and EESS, this specifies the pit of interest. The results will be computed for each space/pit (pit/space) pair using subject pit and all the spaces within the range specified.
Analyzing from ... to	Specifies the range of n indices that define the pits/spaces used in the calculation. The range of n coupled with T are used to categorize the pits/spaces based on their widths.
Filter cutoff and boost	If the input data is RF, an equalizer filter is applied prior to the measurements. You can adjust the cutoff frequency and boost of the filter.
Slicer Bandwidth	If the input data is RF or Equalized, the data passes through a slicer to level the data (removes the threshold due to low frequency effects). You can set the bandwidth of the slicer.
PLL Bandwidth	If you select Extracted as the clock source, a PLL is used to recover the clock from the data waveform. In that case, the bandwidth of the PLL can be adjusted.

View Wizard

OPTICAL MEAS

Setup

View

Parameter

List by nT

Histogram

Trend

XY Plot

SHOW TABLE

Accumulate

On OFF

from

0.00 div

Track OFF On

to

10.00 div

After the measurement setup is complete and you exit the setup page, the “View” wizard becomes available. The View Wizard allows you to determine how the results are be displayed. The choices are summarized in the following table:

View	Displays	Additional Keys	Cursors
Parameter	The source trace(s) will be displayed along with the custom parameters (see Measurement Table). If two traces are to be displayed, dual grids will be drawn.	Statistics – toggles the parameter statistics on/off. Show Table – for BES, EES, BESS, and EESS this brings up a full-page table of the measurements.	The parameter cursors are active.
List by nT	The source trace(s) will be displayed along with the list by nT parameter display. If two traces are to be displayed, dual grids will be drawn.	Accumulate – averages parameter values over multiple sweeps. Show Table – for BES, EES, BESS, and EESS this brings up a full-page table of the measurements.	The parameter cursors are active.
Histogram	The histogram of the selected parameter is shown. When Histogram is selected, it shows the source trace in a second grid.	Show Source – toggles the display of the source traces (and dual grid). Find Range – determines the best scaling for the histogram (center and width) based on up to the last 20000 samples collected.	Horizontal difference cursors are active.
Trend	The trend of the selected parameter is shown. When trend is selected, it shows the source trace in a second grid.	Show Source – toggles the display of the source traces (and dual grid). Find Range – determines the best scaling for the trend (center and height).	Horizontal difference cursors are active.

View	Displays	Additional Keys	Cursors
Plot	Plots the trend of the selected measurement v.s. either the trend t@pit or pwid as appropriate; not available for all measurements (see Measurement Table for details).	XY only – toggles the display of the XY grid only and the XY grid plus the display of the trends. Find Range – determines the best scaling for trends (center and height).	Horizontal difference cursors are active.

Measurement Table

When the parameter view is selected, up to 4 additional parameters, which are related to the selected measurement, are displayed. The following table shows these additional parameters. For parameters that can be shown in the XY display, it also shows the parameter that is used for the X axis.

Measurement	Parameters	XY
	<i>(setup for custom parameters)</i>	<i>(x axis)</i>
dp2c (s)	t@pit,pwid,numt	t@pit
edgesh	t@pit,pwid,numt	t@pit
ees (s)	pwid,ptop,pbase,pnum	n/a
bes (s)	pwid,ptop,pbase,pnum	n/a
paa	pwid,ptop,pbase,pnum	n/a
pwid	t@pit, ptop,pbase,pnum	t@pit
timj	t@pit, ptop,pbase,pnum	t@pit
pbase	pwid,ptop,pbase,pnum	pwid
ptop	pwid,ptop,pbase,pnum	pwid
pmin	pwid,ptop,pbase,pnum	pwid
pmidl	pwid,ptop,pbase,pnum	pwid
pasym	pwid,ptop,pbase,pnum	n/a
pmax	pwid,ptop,pbase,pnum	pwid
pnum	pwid,ptop,pbase	n/a

#

Doing Optical Data Measurements

The two modes available for Optical Recording Measurements, “Custom” and “List by nT,” both display measurements either as waveform parameters or as a list of values. This chapter further describes these modes. The following table indicates which measurements can be made in each mode.

Measurement	Parameter	List by nT
$\Delta p2c$	v	v
$\Delta p2cs$	v	v
bes	v	v
bees	v	v
bess	v	v
ees	v	v
eess	v	v
edgsh	v	v
lper	v	
paa	v	v
pasym	v	
pbase	v	v
pmax	v	v
pmidl	v	v
pmin	v	v
pmoda	v	
pnum	v	v
pres	v	
ptop	v	v

Measurement	Parameter	List by nT
pwid	v	v
t@pit	v	
timj	v	v

Measurement Value Display

When a measurement is configured for selecting a range of pit or space widths, the measurement values displayed in its calculation will be determined by the oscilloscope's display mode .

If **Custom** is selected, the normal DSO parameter calculation and display options are available. A single measurement value will be calculated and displayed for the range of nT values selected. Measurements performed in this mode are referred to in this manual as "parameter" measurements.

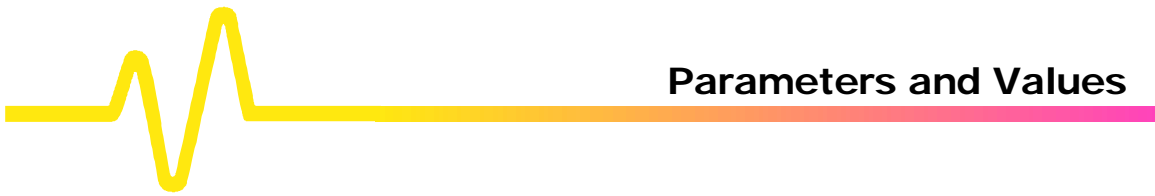
However, if the mode selected is **List by nT**, a special ORM display mode is provided. In this case, a list of values corresponding to the measurements for each individual nT in the selected range is displayed. Measurements performed in this mode are referred to as "List by nT" measurements.

Parameter Configuration

The configuration for most parameters is similar, although there are slight variations. Essentially, two categories (levels and nT) are set up. The levels setup determines how pits and spaces are to be extracted from the waveform and involves the selection of threshold, polarity, and hysteresis. On the other hand, the nT setup determines how pits or spaces are *categorized* — which n index a pit or space belongs to based on its width, and which pit's or space's n values are to be used in the calculation and display.

This table gives the superset of configurable items for the available parameters.

Data Source	The source waveform for the optical data signal.
Clock Source	The source waveform for the clock signal used for sampling the optical data signal.
Data Threshold	Voltage threshold used to identify pits and spaces. All 'qualified' threshold crossings identify the boundaries of a pit/space. Qualification of a threshold crossing is based on hysteresis.
Clock Threshold	Voltage threshold used to identify clock edges. All 'qualified' threshold crossings of the clock waveform identify clock edges. Qualification of a threshold crossing is based on hysteresis.
Hysteresis	Size of the hysteresis band (in screen divisions) with the thresholds at the middle location. Any waveform being analyzed must pass beyond the band before the next threshold crossing is recognized.
Units	The units used for horizontal parameter results. Time refers to absolute time units. Percent refers to results being calculated as a percent of the clock period.
Data Polarity	Polarity of pits/spaces used in the measurement. Positive polarity refers to pits; Negative polarity refers to spaces. All can be selected to use both pits and spaces.
Clock Edge	Polarity of clock edges to be used in the measurement. Near refers to the nearest of either clock edge.
Single or Range of n	Specifies the single n or range of n indices that define pits/spaces used in the calculation. The range of n coupled with T are used to categorize the pits/spaces based on their widths.
Period (T)	The ideal clock period. The period, coupled with n is used to categorize pits/spaces based on their widths.
For AORM:	
Period from	For automatic period determination, this specifies how the period is determined. The period can be measured from a clock provided, or entered by the user.
Subject n	This specifies the nT of interest for beginning and ending edge shift parameters. The measurements will be performed on pit/space pairs preceded (and followed) by this nT value.



Parameters and Values

Configuration Options

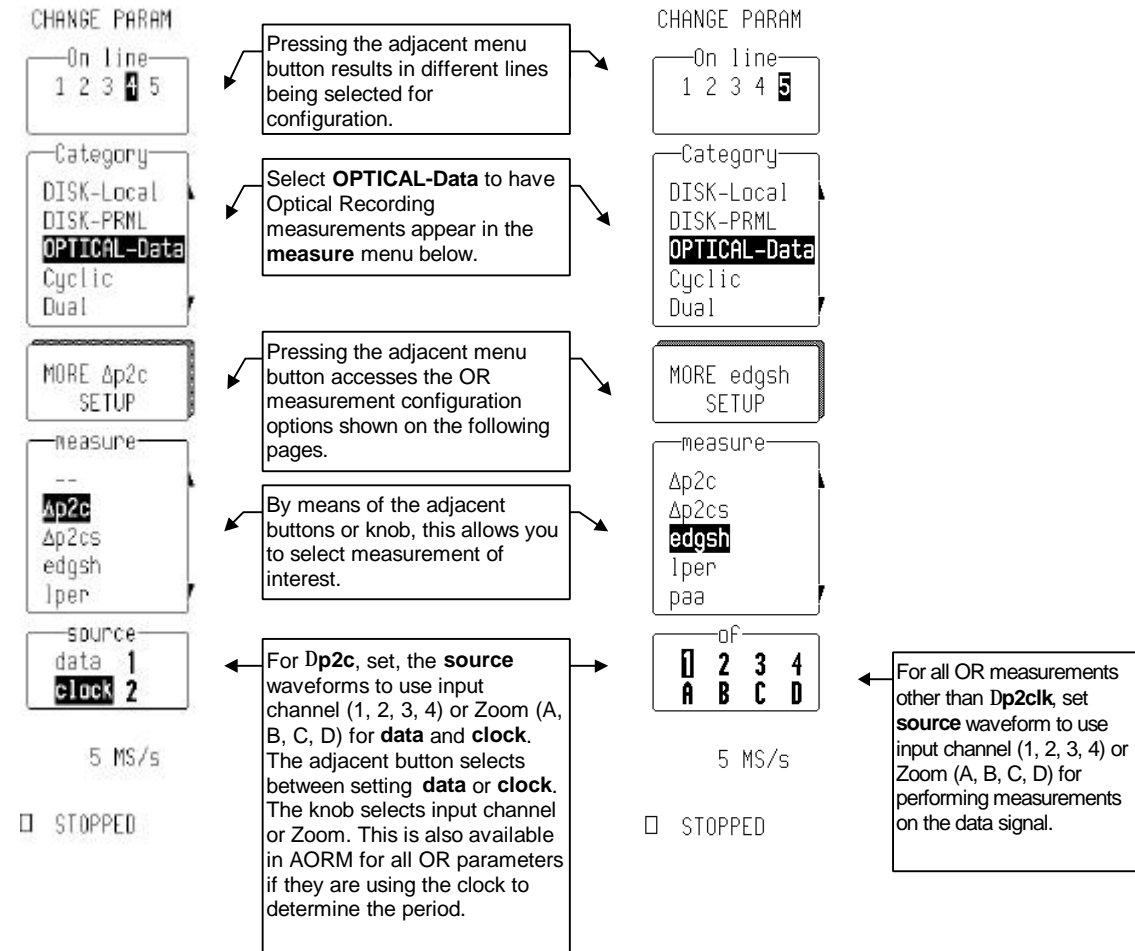
The following table is a comprehensive list of configuration options for each parameter.

Parameter	Clock Source	Clock Threshold	Clock Edge	Data Source	DataThreshold	Data Polarity	Hysteresis	Units	Single n	Range of n	Period	Subject n
Dp2c	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	
Dp2cs	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	
bes	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
ees	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
bess	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
eess	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
bees	☒	☒	☒	☒	☒	☒	☒	☒	☒		☒	☒
edgsh				☒	☒	☒	☒	☒	☒	☒	☒	
lper	☒	☒	☒				☒					
paa				☒	☒		☒		☒	☒	☒	
pasym				☒	☒		☒			☒	☒	
pbase				☒	☒		☒		☒	☒	☒	
pmax				☒	☒		☒		☒	☒	☒	
pmidl				☒	☒		☒		☒	☒	☒	
pmin				☒	☒		☒		☒	☒	☒	
pmoda				☒	☒		☒			☒	☒	
pnum				☒	☒	☒	☒		☒	☒	☒	
pres				☒	☒		☒			☒	☒	
ptop				☒	☒		☒		☒	☒	☒	

Parameter	Clock Source	Clock Threshold	Clock Edge	Data Source	DataThreshold	Data Polarity	Hysteresis	Units	Single n	Range of n	Period	Subject
pwid				☒	☒	☒	☒	☒	☒	☒	☒	
t@pit				☒	☒	☒	☒		☒	☒	☒	
timj				☒	☒	☒	☒	☒	☒	☒	☒	

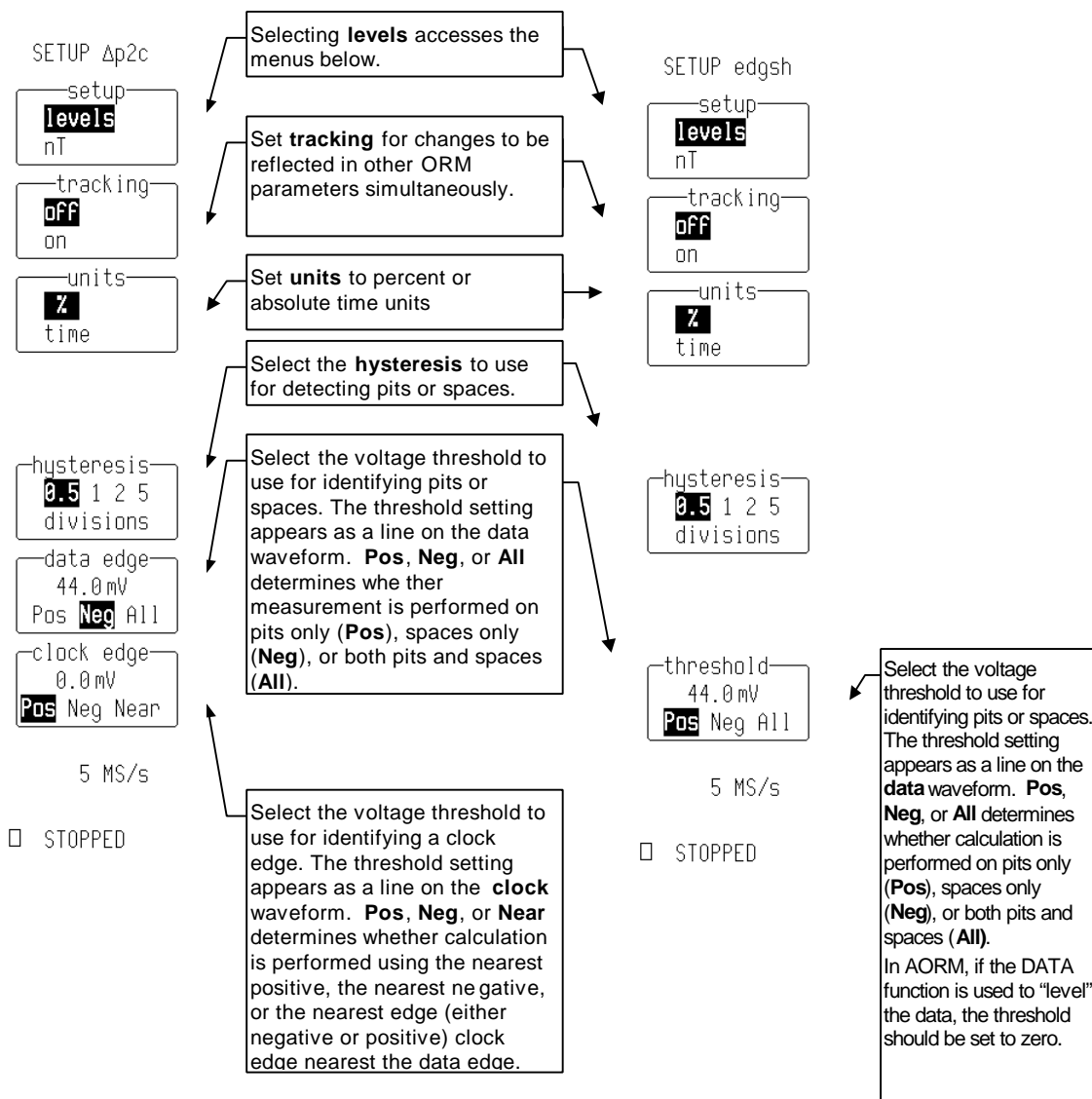
Configuration Menus

The menus illustrated and described on the following pages show how to configure any parameter, using as representative examples the parameters $\Delta p2c$ and $edgsh$.



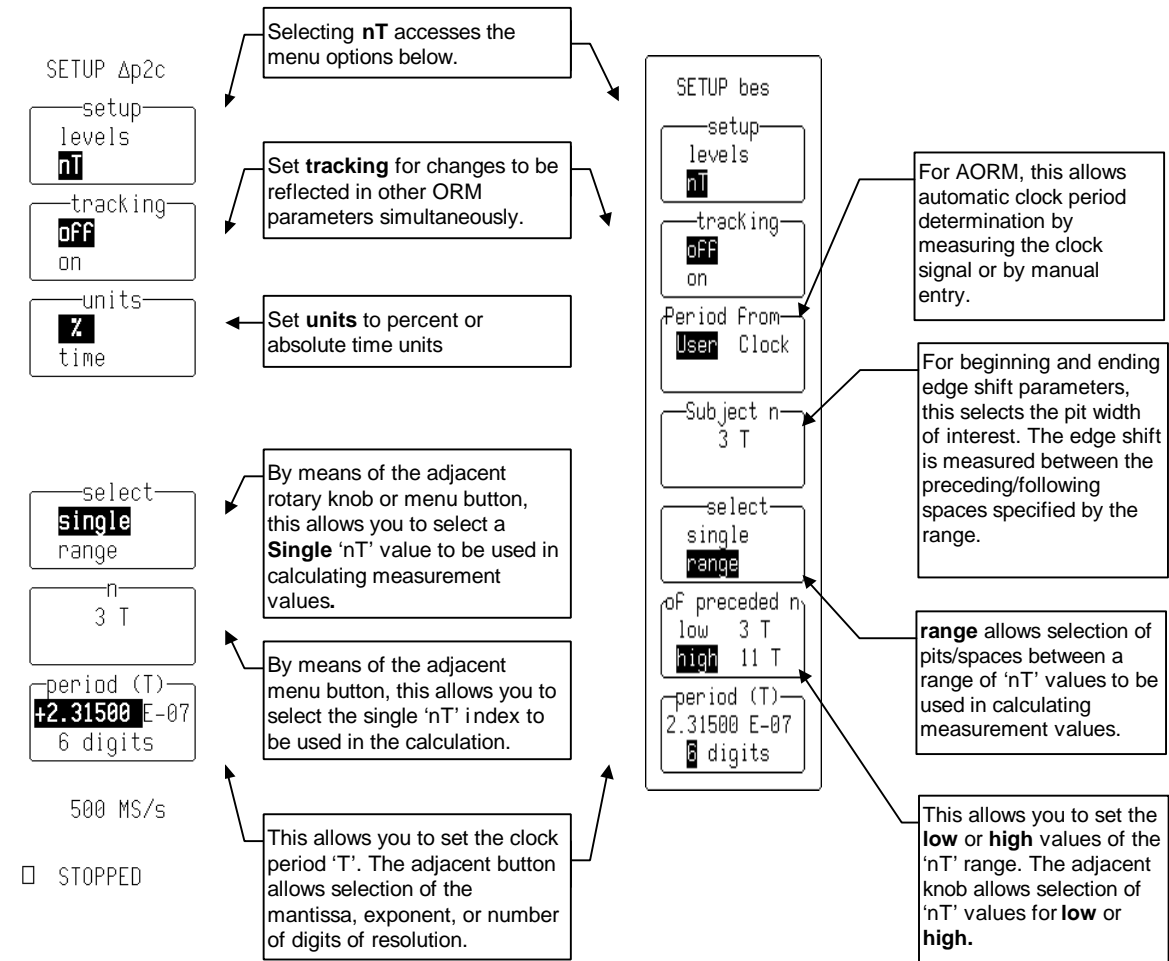
Setting Levels

To identify pits or spaces, thresholds and hysteresis are set.



Setting 'nT'

These menus allow the setting of both 'n' and 'T' (clock period) v values .



Configuration Tracking

The ORM package has many configurable items, most of which are the same from parameter to parameter. To aid you in configuring parameters, a 'tracking' mechanism has been provided. This means that when tracking is on, all other ORM parameters track (follow) the configuration changes made.

The tracking menu is always visible when you are using ORM. For optimum ease of parameter configuration, you should define all of the parameters to be displayed prior to beginning parameter configuration. Turn tracking off when the changes affect only the parameter being set up.

In general, use tracking when configuring thresholds, hysteresis , and the clock period. Turn tracking off when configuring polarity and ranges/single n values *unless you want the changes to be reflected in other parameters.*

There are two restrictions to configuration tracking:

1. Changes to thresholds do not affect other ORM parameters that are not using the same source waveform.
2. Changes to ranges/single n values on custom parameters do not affect the ranges of n values selected on 'list by nT' parameters.

Otherwise, all configuration changes track across all selected custom and list by nT parameters.

Maximizing Performance

The ORM package is designed to make intelligent use of measurement similarities. This means that when multiple custom parameters are specified, the DSO will only recalculate necessary items when calculating parameters. This results in quicker calculations when correct configuration is performed. The speed of calculation is independent of the order of calculation.

A basic guideline that you should follow to maximize the performance of calculation in multiple parameter configurations is that **precisely the same Value for the clock period 'T', Threshold level, and Hysteresis value should be used.**

Following this guideline ensures that parameters can make use of results obtained in previous parameter calculations. However, in most cases there is no need for different configurations of the above three items in different parameter setups. Tracking can help in setting these values correctly.

Pit or Space Identification

This is determined uniquely by the threshold, hysteresis, and edge polarity of threshold crossings. A positive threshold crossing indicates the start of a positive polarity pit and the end of a negative polarity space. A positive threshold crossing followed by a negative threshold crossing fully delineates a pit. A negative crossing followed by a positive crossing fully delineates a space, as illustrated in Figure 3.1.

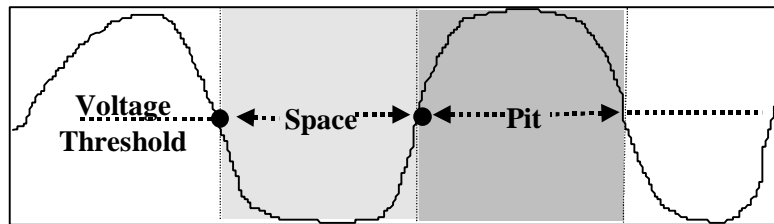


Figure 3.1

In order to prevent false pit and space identifications, hysteresis is provided. Hysteresis adds an additional condition that must be met before a threshold crossing is recognized as a pit/space edge. It requires that the waveform make an excursion of a certain distance from the threshold before the next threshold crossing is recognized.

Figure 3.2 shows a threshold crossing that would result in incorrect pit identification without hysteresis.

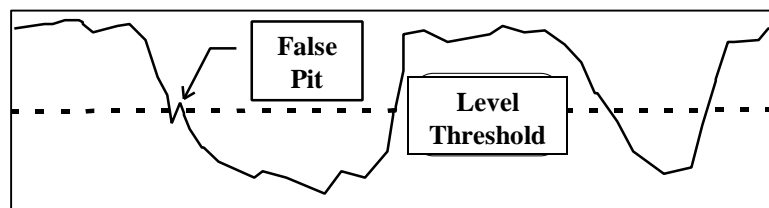


Figure 3.2

The hysteresis band shown in Figure 3.3 is centered on the user-selected voltage level threshold.

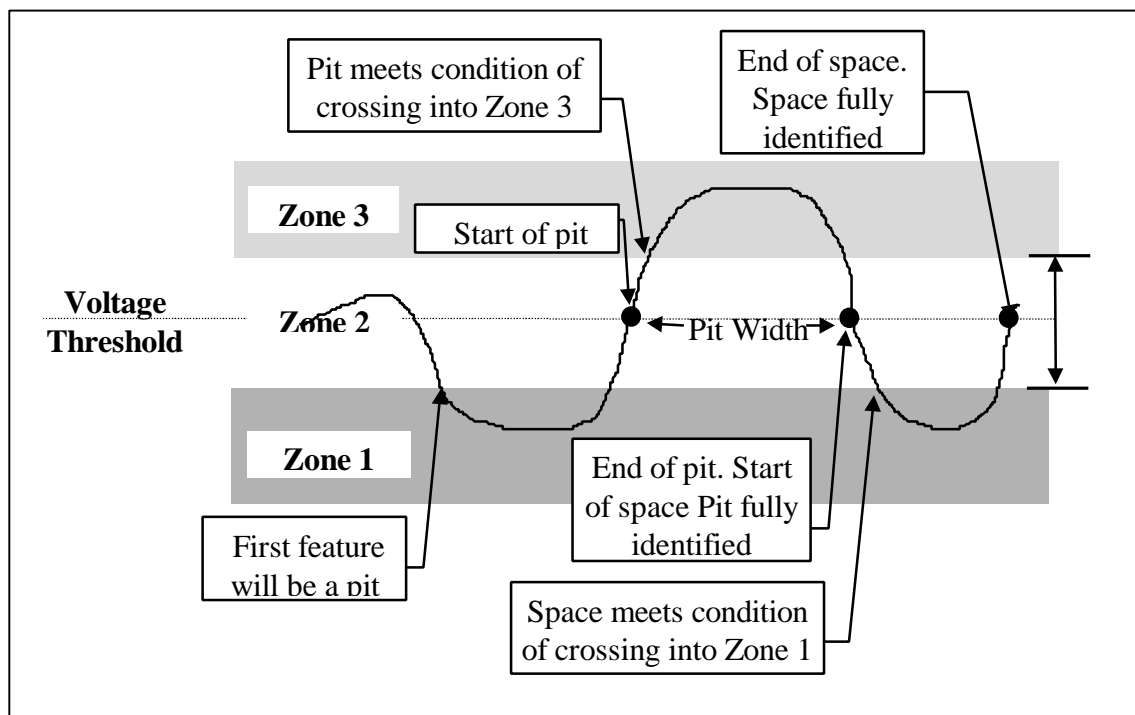
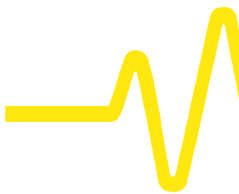


Figure 3.3

The hysteresis band divides the display into three zones. The ORM Package uses both the voltage threshold and hysteresis settings to identify pits and spaces.



Criteria for identifying a “feature” (pit or space):

- The first feature identified after the left parameter cursor can be either a pit or space. If the signal first enters Zone 1, the first feature identified (if additional constants are met) will be a pit. If the signal first enters Zone 3, it will be a space.
- After first crossing into Zone 1 or Zone 3, the next time the signal crosses the voltage threshold, it is recorded as the start time of a feature.
- If the first feature to be identified is a pit (signal entered Zone 1 first), after crossing the voltage threshold the signal must cross into Zone 3 and then pass the voltage threshold again to complete all conditions for identification as a pit. The first time that the signal crosses the voltage threshold after entering Zone 3 is recorded as the end time of the pit and the start time of the following space. The time between the start and end of the pit is recorded as the pit width. If the first feature to be identified is a space, the signal first entered Zone 3. The algorithm is used with directions reversed.
- For the entire signal, only a space can be identified after a pit, and only a pit can be identified after a space.
- All subsequent features are identified by crossing into the appropriate zone after the end of the previous feature. For a pit this is Zone 3, and for a space it is Zone 1. The end of the previous feature is the beginning of the current feature being identified. The subsequent first time the signal crosses the voltage threshold is recorded as the time of the feature being identified. At this point, the feature has been fully identified.

nT Pit/Space Categorization Because optical recording data is encoded using a pulse-width modulation mechanism, it is often useful to perform signal analysis for selected pulse widths. Exploiting the fact that optical recording data widths are ideally integral multiples of the data clock period ‘T’, the ORM Package separates optical recording signal pits and spaces into groups whose widths fall into the same integral multiple of clock periods. As a result, ORMs can be configured to provide values for only pits or spaces, or both of these for a selected ‘nT’

value ('nT' denotes an integer multiple of the clock period) or for a range of 'nT's.

The ideal clock period (T) is configured on the parameter nT setup.

Categorization of pits and spaces by nT based on width is done using the following equation:

$$(n - 0.5) \cdot T \leq w < (n + 0.5) \cdot T$$

When this condition is met, the pit or space of width w is said to belong to the n^{th} index.

Memory Limitations

To make use of previous calculations, the ORM package maintains an internal buffer containing intermediate calculation results. The size of this buffer determines the number of pits/spaces that can be used for measurements in a given waveform. The size is in turn determined by the amount of memory in the scope, and whether other options are installed. The following table shows the maximum number of features used per waveform v.s. options and memory installed.

	Memory Installed	
Software Options Installed	8 MB memory	= 16 MB memory
ORM only	5000	50 000
ORM and DDM	2500	25 000

Note: It is not the amount of memory alone that determines the buffer size, but rather the amount of free memory which changes with each new software version. These numbers are therefore subject to change. For best results, the ORM and associated packages should be used with the maximum amount of memory possible.

#



BLANK PAGE

bes

Beginning Edge Shift

Description

BES provides a measurement of the time between the beginning edge of the subject *n* in a specified space/pit pair and the nearest specified clock edge. The measurement is calculated between the points where the data and clock signals cross selected voltage thresholds. The clock period *T* can be entered by the user, or measured from a user supplied clock signal, as described below.

The value calculated depends on the clock and data edges selected, as shown in the table below. The **data edge** menu selects the polarity of the **subject *n*** pit/space. If **Pos** (positive) is selected, the measurement is performed from the beginning edges of positive polarity pits and categorized by the preceding space. If **Neg** (negative) is selected, the measurement is performed from the beginning edges of negative polarity spaces and categorized by the preceding pit. If **All** is selected, the beginning edges of both pits and spaces are used in the calculation and categorized by the preceding inverse polarity space/pit. The sizes of pits or spaces used in the measurement are also determined by the range of '*nT*' values chosen.

Clock Edge	Data Edge		
	Pos	Neg	All
Positive	time between beginning edge of positive polarity subject pit and nearest positive clock edge	time between beginning edge of negative polarity subject space and nearest positive clock edge	time between beginning edge of subject pits and spaces to nearest positive clock edge
Negative	time between beginning edge of positive polarity subject pit and nearest negative clock edge	time between beginning edge of negative polarity subject space and nearest negative clock edge	time between beginning edge of subject pits and spaces to nearest negative clock edge
Near	time between beginning edge of positive polarity subject pit and nearest clock edge	time between beginning edge of negative polarity subject space and nearest clock edge	time between beginning edge of subject pits and spaces and nearest clock edge

Figure 4.1 demonstrates the measurement of the beginning edge shift on a single subject 4T pit preceded by a 3T space. In this example, the clock is specified as the positive edge. For each space/pit combination, the beginning edge shift is calculated as the time difference between the beginning pit edge and the clock edge. Additionally, the measurements will be sorted by the space/pit pairs. For the positive polarity pit example shown in Figure 4.2, the measurements t_+ and t_- are for a single beginning edge shift measurement configured for positive edge, or negative edge. If nearest is selected, the smaller of t_- or t_+ is used.

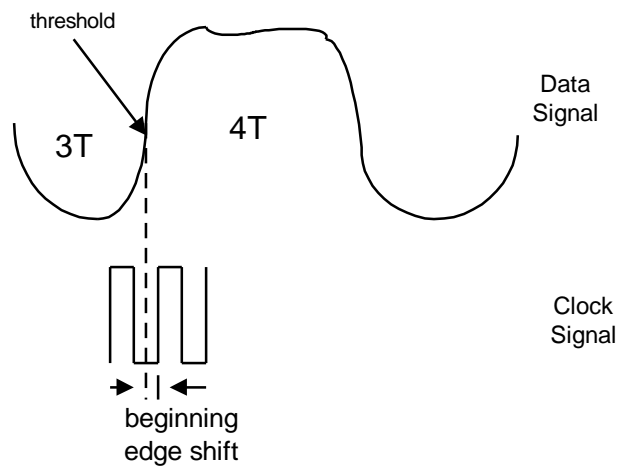


Figure 4.1: Beginning Edge Shift Measurement of subject 4Tpit

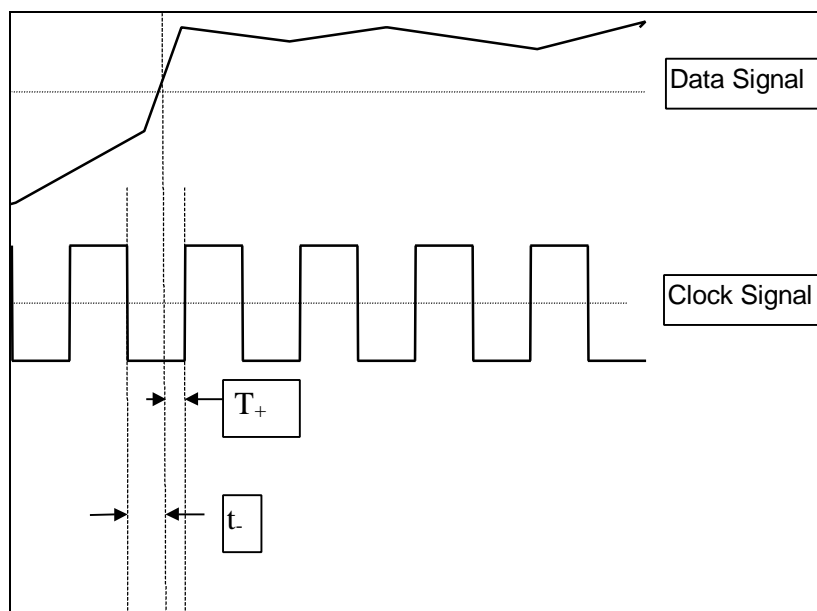


Figure 4.2: Zoom of Positive Polarity Pit Edge — example measurement.

The measurement has configurable units. If absolute time is specified, the value is simply the time indicated above. If percent is specified, the value of the measurement is the time normalized to the clock period:

$$bes = \Delta t_+ \cdot \frac{100\%}{T}$$

$$or \quad \Delta t_- \cdot \frac{100\%}{T}$$

For all pits, a valid measurement will be obtained only when both pit/space edges can be determined, *(that is, there is a hysteresis-qualified threshold crossing beginning and ending the pit/space pair of interest between the parameter cursors)*, and there is a clock edge of both polarities surrounding the leading pit or space edge between the parameter cursors.



Measurement Parameters

Display Options

ORM parameter calculations can be displayed, histogrammed, and trended in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average time between beginning edge of the subject <i>n</i> pit (space) and nearest clock edges for all subject pits (spaces) preceded by the spaces (pits) within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the beginning edge shift calculated for all identified pit/space pairs within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the average beginning edge shift for each 'nT' space (pit) within the selected range preceding the subject pit (space) for the last acquisition.
Histogram Function	Histogram graph of the value of the beginning edge shift calculated for all pit/space pairs within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the beginning edge shift calculated for all pit/space pairs within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.

bess

Beginning Edge Shift Sigma

Description

BESS provides a measurement of the mean, normalized standard deviation of the Beginning Edge Shift measurements (see **BES**). When a single n is specified, or when you are in 'list by nT ' display mode, the value calculated for the n^{th} index is calculated using the following equation for standard deviation:

Beginning Edge Shift Sigma cannot be calculated for a given index n unless there are at least two Beginning Edge Shift values

$$BESS_n = s(BES_n)$$

$$BESS_n = \sqrt{\frac{\sum BES_n^2 - \frac{(\sum BES_n)^2}{N_n}}{N_n - 1}}$$

calculated or that n index.

When Beginning Edge Shift is configured as a custom parameter with a range of n , the value calculated is the standard deviation of the distribution which results by normalizing each independent distribution categorized by the space (pit) nT preceding the subject pit (space). Distributions are normalized by subtracting the mean of the distribution from all of the elements in the distribution. This results in the following equation for overall Beginning Edge Shift Sigma resulting from the individually categorized Beginning Edge Shift Sigma values:

$$BESS_{overall} = \sqrt{\frac{\sum (BESS_n^2 \cdot (N_n - 1))}{\sum N_n - 1}}$$

Note: The value calculated by BESS will generally not be the same as the sigma of BES the measurement displayed on the parameter line when a range of n is used and statistics is on. This is because the two measurements are not the same. The BESS measurement normalizes the results for each n by subtracting the mean BES from each BES in the n^{th} distribution. This results in a superposition of mean-centered distributions, not a superposition of 0-centered distributions contributing to BES measurements. BESS will always be less than or equal to the standard deviation of BES measurements.



Measurement Parameters

Display Options

ORM parameter calculations can be displayed, histogrammed (see Chapter 6) and trended (Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single σ value of the standard deviation of the mean normalized beginning edge shift σ values for pits/spaces of interest for last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the beginning edge shift sigma σ value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of σ values of the standard deviation of the beginning edge shift σ values for each 'nT' spaces (pit) within the selected range preceding the subject pit (space) for the last acquisition.
Histogram Function	Histogram of beginning edge shift sigma σ values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the beginning edge shift sigma σ values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.

Description

EES provides a measurement of the time between the ending edge of the subject *n* in a specified space/pit pair and the nearest specified clock edge. The measurement is calculated between the points where the data and clock signals cross selected voltage thresholds. The clock period *T* can be entered by the user or measured from a user supplied clock signal, as described below.

The value calculated depends on the clock and data edges selected, as shown in the table below. The **data edge** menu selects the polarity of the **subject *n* pit/space**. If **Pos** (positive) is selected, the measurement is performed from the ending edges of positive polarity pits and categorized by the following space. If **Neg** (negative) is selected, the measurement is performed from the ending edges of negative polarity spaces and categorized by the following pit. If **All** is selected, the ending edges of both pits and spaces are used in the calculation and categorized by the following inverse polarity space/pit. The sizes of pits or spaces used in the measurement are also determined by the range of '*nT*' values chosen.

Clock Edge	Data Edge		
	Pos	Neg	All
Positive	time between ending edge of positive polarity subject pit and nearest positive clock edge	time between ending edge of negative polarity subject space and nearest positive clock edge	time between ending edge of subject pits and spaces to nearest positive clock edge
Negative	time between ending edge of positive polarity subject pit and nearest negative clock edge	time between ending edge of negative polarity subject space and nearest negative clock edge	time between ending edge of subject pits and spaces to nearest negative clock edge
Near	time between ending edge of positive polarity subject pit and nearest clock edge	time between ending edge of negative polarity subject space and nearest clock edge	time between ending edge of subject pits and spaces and nearest clock edge

Figure 4.3 demonstrates the measurement of the ending edge shift on a single subject 4T pit followed by a 3T space. In this example, the clock is specified as the positive edge. For each pit/space combination, the ending edge shift is calculated as the time difference between the ending pit edge and the clock edge. Additionally, the measurements will be sorted by the pit/space pairs. For the positive polarity pit example shown in Figure 4.4, the measurements t_+ and t_- are for a single ending edge shift measurement configured for positive edge, or negative edge. If nearest is selected the smaller of t_- or t_+ is used.

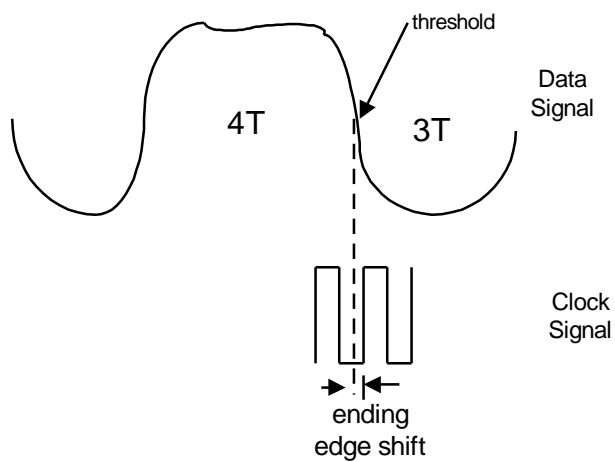


Figure 4.3: Ending Edge Shift Measurement of subject 4T pit

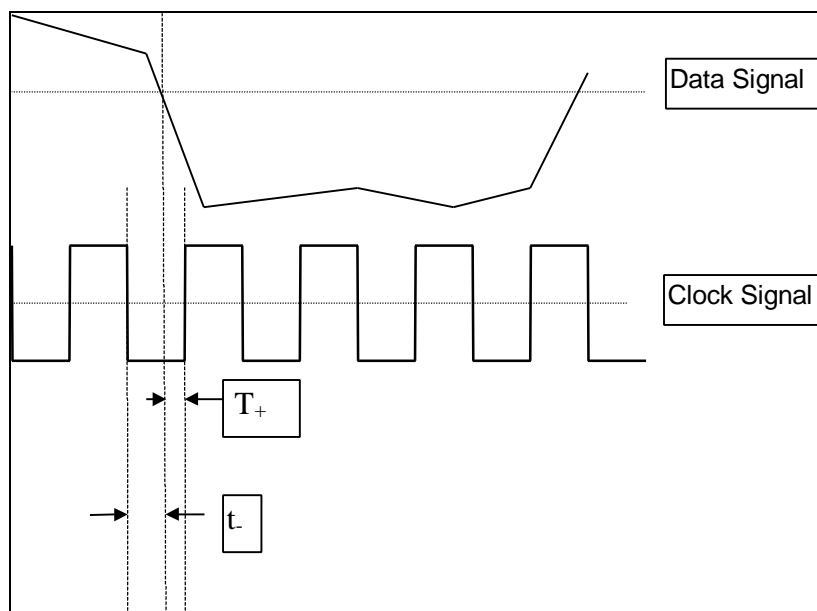


Figure 4.4: Zoom of Positive Polarity Pit Ending Edge — example.

The measurement has configurable units. If absolute time is specified, the value is simply the time as indicated above. If percent is specified, the value of the measurement is the time normalized to the clock period:

$$ees = \Delta t_+ \cdot \frac{100\%}{T}$$

$$\text{or } \Delta t_- \cdot \frac{100\%}{T}$$

For all pits, a valid measurement will be obtained only when both pit/space edges can be determined (*that is, there is a hysteresis-qualified threshold crossing beginning and ending the pit/space pair of interest between the parameter cursors*), and there is a clock edge of both polarities surrounding the ending pit or space edge between the parameter cursors.



Measurement Parameters

Display Options

ORM parameter calculations can be displayed, histogrammed, and trended in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average time between ending edge of the subject <i>n</i> pit (space) and nearest clock edge <i>s</i> for all subject pits (spaces) followed by the spaces (pits) within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the ending edge shift calculated for all identified pits/spaces pairs within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the average ending edge shift for each 'nT' space (pit) within the selected range following the subject pit (space) for the last acquisition.
Histogram Function	Histogram graph of the value of the ending edge shift calculated for all pit/space pairs within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the ending edge shift calculated for all pit/space pairs within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.

eess

Ending Edge Shift Sigma

$$EES_n = s(EES_n)$$

$$EES_n = \sqrt{\frac{\sum EES_n^2 - \frac{(\sum EES_n)^2}{N_n}}{N_n - 1}}$$

Description

EES provides a measurement of the mean, normalized standard deviation of the Ending Edge Shift measurements (see **EES**). When a single n is specified, or when you are in 'list by nT' display mode, the value calculated for the n^{th} index is calculated using the following equation for standard deviation:

Ending Edge Shift Sigma cannot be calculated for a given index n unless there are at least two Ending Edge Shift values calculated for that n index.

When Ending Edge Shift is configured as a custom parameter with a range of n , the value calculated is the standard deviation of the distribution which results by normalizing each independent distribution categorized by the space (pit) nT following the subject pit (space). Distributions are normalized by subtracting the mean of the distribution from all of the elements in the distribution. This results in the following equation for overall Ending Edge Shift Sigma resulting from the individually categorized Ending Edge Shift Sigma values:

$$EES_{\text{overall}} = \sqrt{\frac{\sum (EES_n^2 \cdot (N_n - 1))}{\sum N_n - 1}}$$

Note: The value calculated by EESS will generally not be the same as the sigma of EES measurement displayed on the parameter line when a range of n is used and statistics is on. This is because the two measurements are not the same. EESS measurement normalizes the results for each n by subtracting the mean EES from each EES in the n^{th} distribution. This results in a superposition of mean-centered distributions, not a superposition of 0-centered distributions contributing to EES measurements. EESS will always be less than or equal to the standard deviation of EES measurements.



Measurement Parameters

Display Options

ORM parameter calculations can be displayed, histogrammed (see Chapter 6) and trended (Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single v value of the standard deviation of the mean normalized ending edge shift v values for pits/spaces of interest for last acquisition.
Parameter Statistics On	average, minimum, maximum, and sigma of the ending edge shift sigma v value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of v values of the standard deviation of the ending edge shift v values for each 'nT' spaces (pit) within the selected range following the subject pit (space) for the last acquisition.
Histogram Function	Histogram of ending edge shift sigma v values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the ending edge shift sigma v values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.

bees

Beginning Ending Edge Shift

Description

BEES provides a measurement of both the beginning and ending edge shift for a subject *n* pit (space) preceded and followed by a specified space (pit) (see **BES** and **EES**). The measurement is calculated between the points where the data and clock signals cross selected voltage thresholds. The clock period *T* can be entered by the user, or measured from a user supplied clock signal, as described below.

The value calculated depends on the clock and data edges selected, as shown in the table below. The **data edge** menu selects the polarity of the **subject n** pit/space. If **Pos** (positive) is selected, the measurement is performed from the beginning and ending edges of positive polarity pits and is preceded and followed by a space of the specified width. If **Neg** (negative) is selected, the measurement is performed from the edges of negative polarity spaces and is preceded and followed by a pit of the specified width.

Clock Edge	Data Edge	
	Pos	Neg
Positive	times between edges of positive polarity subject pit and nearest positive clock edge	times between edges of negative polarity subject space and nearest positive clock edge
Negative	times between edges of positive polarity subject pit and nearest negative clock edge	times between edges of negative polarity subject space and nearest negative clock edge
Near	times between edges of positive polarity subject pit and nearest clock edge	times between edges of negative polarity subject space and nearest clock edge

Figure 4.5 demonstrates the measurement of the beginning edge shift on a single subject 4T pit preceded and followed by a 3T space. In this example, the clock is specified as the positive edge. The beginning edge shift is calculated as the time difference between the beginning pit edge and the clock edge while the ending edge shift is calculated as the time difference between the ending pit edge and the clock edge.

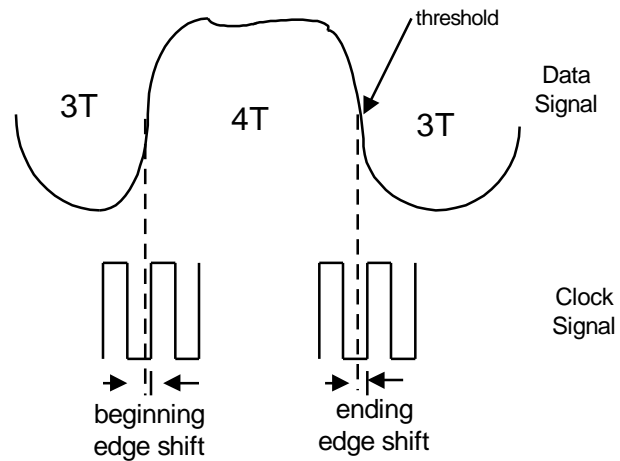


Figure 4.5: Beginning and Ending Edge Shift Measurement of subject 4T pit

The measurement has configurable units. If absolute time is specified, the value is simply the time as indicated above. If percent is specified, the value of the measurement is the time normalized to the clock period:

$$bees = \Delta t_{+} \cdot \frac{100\%}{T}$$

$$\text{or} \quad \Delta t_{-} \cdot \frac{100\%}{T}$$

For all pits, a valid measurement will be obtained only when both edges of the leading and trailing pits/spaces can be determined (that is, there is a hysteresis-qualified threshold crossing beginning the

start pit/space and ending the end pit/space of interest between the parameter cursors), and there is a clock edge of both polarities surrounding the leading pit or space edge between the parameter cursors.

Display Options

ORM parameter calculations can be displayed, histogrammed, and trended in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single v value of the average time between the edges of the subject n pit (space) and nearest clock edge s for all subject pits (spaces) that are preceded and followed by the specified space (pits) for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the beginning and ending edge shift calculated for all subject pits (spaces) that are preceded and followed by the specified space (pits) for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of v values of the beginning edge shift and the ending edge shift for all subject pits (spaces) that are preceded and followed by the specified space (pits) for the last acquisition.
Histogram Function	Histogram graph of the v values of the beginning and ending edge shift calculated for all subject pits (spaces) that are preceded and followed by the specified space (pits) for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the v value of the beginning and ending edge shift calculated for all subject pits (spaces) that are preceded and followed by the specified space (pits) for all acquisitions since the last CLEAR SWEEPS operation.

Dp2c

Delta Pit-to-Clock

Description

Dp2c provides a measurement of the time between the leading edge of the pit (or spaces of interest) and the nearest specified clock edge . The measurement is calculated between the points where the data and clock signals cross selected voltage thresholds.

The value calculated depends on the clock and data edges selected, as shown in the table below. If in the “data edge” menu **Pos** (positive) is selected, the measurement is performed from the leading edges of positive polarity pits. If **Neg** (negative) is selected, the measurement is performed from the leading edges of negative polarity spaces. And if **All** is selected, the leading edges of both pits and spaces are used in the calculation. The sizes of pits or spaces used in the measurement are also determined by the range of ‘nT’ values chosen.

Clock Edge	Data Edge		
	Pos	Neg	All
positive	time between leading edge of positive polarity pit and nearest positive clock edge	time between leading edge of negative polarity space and nearest positive clock edge	time between leading edge of pits and spaces to nearest positive clock edge
negative	time between leading edge of positive polarity pit and nearest negative clock edge	time between leading edge of negative polarity space and nearest negative clock edge	time between leading edge of pits and spaces to nearest negative clock edge
near	time between leading edge of positive polarity pit and nearest clock edge	time between leading edge of negative polarity space and nearest clock edge	time between leading edge of pits and spaces and nearest clock edge

For the positive polarity pit example shown as the zoom of the measurement (Figures 4.6 and 4.7), the measurements t_+ , t_- , t_n are for

a single Delta Pit-to-Clock measurement configured for positive edge, negative edge, or nearest edge, respectively.

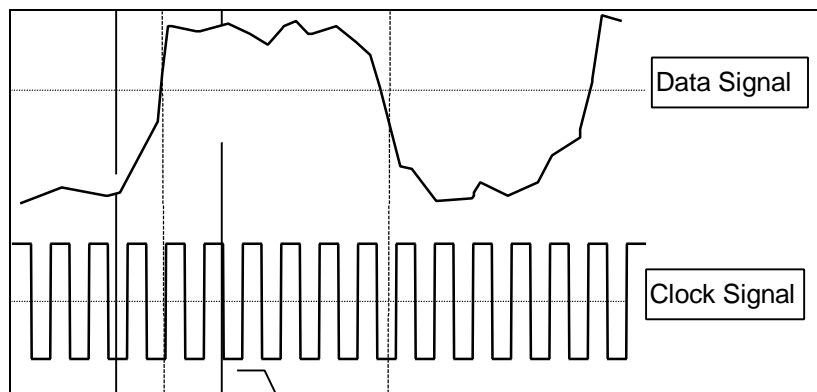


Figure 4.6: Delta Pit-to-Clock Measurement

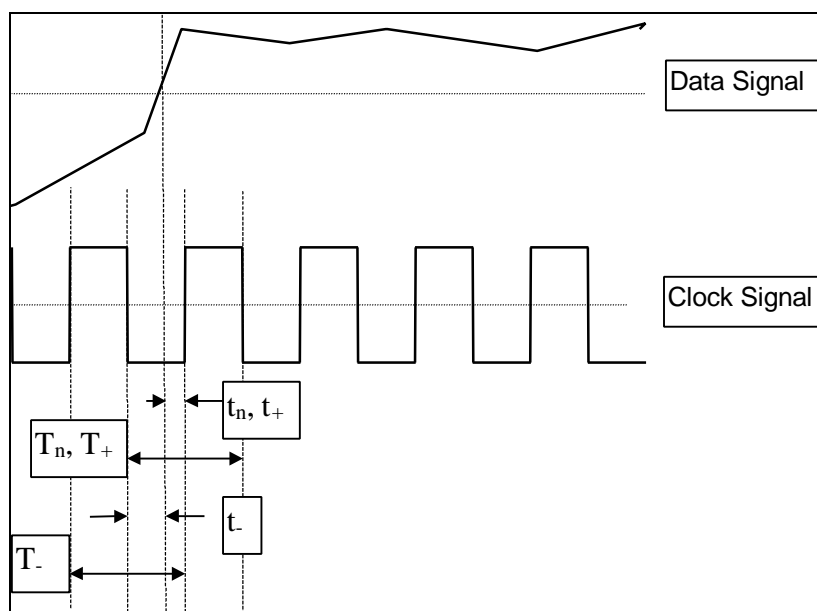


Figure 4.7: Zoom of Positive Polarity Pit Edge — example measurement.



Measurement Parameters

The measurement has configurable units. If absolute time is specified, the value is simply the time as indicated above. If percent is specified, the value of the measurement is the time normalized to the local clock period. The local clock period is calculated as the time between the two clock edges bracketing the clock edge used for the delta time measurement:

$$\Delta p2c = \Delta t_+ \cdot \frac{100\%}{T_+}$$

$$\text{or} \quad \Delta t_- \cdot \frac{100\%}{T_-}$$

$$\text{or} \quad \Delta t_n \cdot \frac{100\%}{T_n}$$

For all pits, a valid measurement will be obtained only when both pit/space edges can be determined (*that is, there is a hysteresis qualified threshold crossing that begins and ends the pit/space of interest between the parameter cursors*), and when there is a clock edge of both polarities surrounding the leading pit or space edge between the parameter cursors.

Display Options

ORM parameter calculations can be displayed, histogrammed and trended in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average time between leading pit/space edges and nearest clock edge s for all pits/spaces within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the Delta Pit-to-Clock calculated for all identified pits/spaces within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the average Delta Pit-to-Clock for each group of pits/spaces of common 'nT' width for the last acquisition.
Histogram Function	Histogram graph of the value of the Delta Pit-to-Clock calculated for all pits/spaces within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the Delta Pit-to-Clock calculated for all pit/space within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.



Dp2cs

Delta Pit-to-Clock Sigma

Description

Dp2cs provides a measurement of the mean, normalized standard deviation of the Delta Pit-to-Clock measurements (see **Dp2c**). When a single n is specified, or in 'list by nT ' display mode, the value calculated for the n^{th} index is calculated using the following equation for standard deviation:

$$\Delta P2CS_n = s(\Delta P2C_n)$$
$$\Delta P2CS_n = \sqrt{\frac{\sum \Delta P2C_n^2 - \frac{(\sum \Delta P2C_n)^2}{N_n}}{N_n - 1}}$$

Delta Pit-to-Clock Sigma cannot be calculated for a given index n unless there are at least two Delta Pit-to-Clock values calculated for that n index.

When Delta Pit-to-Clock is configured as a custom parameter with a range of n , the value calculated is the standard deviation of the distribution which results by normalizing each independent distribution categorized by nT . Distributions are normalized by subtracting the mean of the distribution from all of the elements in the distribution. This results in the following equation for overall Delta Pit-to-Clock Sigma resulting from the individually categorized Delta Pit-to-Clock Sigma values:

$$\Delta P2CS_{\text{overall}} = \sqrt{\frac{\sum (\Delta P2CS_n^2 \cdot (N_n - 1))}{\sum N_n - 1}}$$

Note: the value calculated by DP2CS will generally not be the same as the sigma of DP2C measurement displayed on the parameter line when a range of n is used and statistics is on. This is because the two measurements are not the same. DP2CS measurement normalizes the results for each n by subtracting the mean DP2C from each DP2C in the n^{th} distribution. This results in a superposition of mean centered distributions, not a superposition of 0 centered distributions contributing to DP2C measurements. DP2CS will always be less than or equal to the standard deviation of DP2C measurements.

Display Options

ORM parameter calculations can be displayed, histogrammed (see Chapter 6), and trended (see Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the standard deviation of the mean normalized Delta Pit-to-Clock values for pits/spaces of interest for last acquisition.
Parameter Statistics On	Average, minimum, maximum and sigma of the Delta Pit-to-Clock sigma value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the standard deviation of the Delta Pit-to-Clock values for each individual 'nT' in the selected range of 'nT' for the last acquisition.
Histogram Function	Histogram of Delta Pit-to-Clock sigma values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the Delta Pit-to-Clock sigma values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.



edgsh

Edge Shift

Description

Edge Shift provides a measurement of the difference between the width of pits, spaces, or both, and their ideal widths. These ideal widths are integer multiples of the clock period 'T'. The width of the pit or space is determined by the time between crossings of the selected voltage threshold (see **pwid**).

When a single n is specified for the Edge Shift custom parameter, for each pit-width value calculated, the Edge Shift is calculated as:

$$edgsh_i = (w_i - n_i \cdot T) \text{ when absolute time units are specified}$$
or

$$edgsh_i = (w_i - n_i \cdot T) \cdot \frac{100.0\%}{T} \text{ when percent is specified,}$$

where n_i is the n that makes the width closest to nT (i.e., n is the n category to which the width belongs). Thus:

$$(n_i - 0.5) \cdot T \leq w_i < (n_i + 0.5) \cdot T$$

where T is the configured period. It is very important for this parameter calculation that you enter exactly the ideal T.

For 'list by nT' display mode, or custom mode with one n specified, the value displayed for the n^{th} index is the average of all of the edge shift values calculated that belong to that index:

$$edgsh_n = \left(\frac{\sum w_i}{N_n} - n \cdot T \right) \cdot \frac{100.0\%}{T}$$

Where N_n is the number of pits belonging to the n^{th} index. When edge shift is configured as a custom parameter with a range of n, the overall edge shift is calculated and displayed as the weighted average of the edge shift values calculated above:

$$edgsh_{\text{overall}} = \frac{\sum (edgsh_n \cdot N_n)}{\sum N_n}$$

The measurement calculation is compliant with the definition of Edge Shift as defined by ISO/IEC JTC1.23.14517 Section 22.4.

Display Options

ORM parameter calculations can be displayed, histogrammed (see Chapter 6), and trended (see Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the overall edge shift for all pits/spaces within the selected 'nT' range for last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the single overall edge shift value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the overall edge shift for each group of pits/spaces of common 'nT' width for the last acquisition.
Histogram Function	Histogram of the single overall edge shift value calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the single overall Edge Shift value calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.

Example

The example shows the CD data signal measured at the selected voltage threshold containing, in sequence, a 5T pit, 3T space, 3T pit and 4T space. If the clock period 'T' is 231.5 ns, then the 5T and 4T edge shift value is simply the difference between the width calculated and the ideal width (since there is only one pit/space of that 'nT' width), thus:

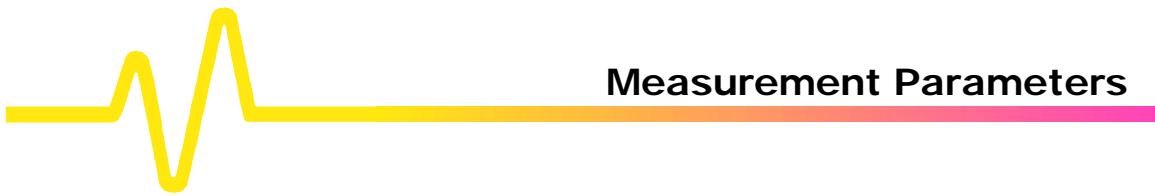
$$edgsh(4T) = (920 - 4 \cdot 231.5) \cdot \frac{100\%}{231.5} = -2.59\%$$

$$edgsh(5T) = (1160 - 5 \cdot 231.5) \cdot \frac{100\%}{231.5} = +1.08\%$$

The 3T edge shift value is the average difference:

$$edgsh(3T) = \frac{\left((690 - 3 \cdot 231.5) \cdot \frac{100\%}{231.5} \right) + \left((695 - 3 \cdot 231.5) \cdot \frac{100\%}{231.5} \right)}{2} = +0.86\%$$

In a list by nT display, these three values would be shown in the appropriate nT location. In custom display, the overall edge shift is calculated as the weighted average edge shift:



Measurement Parameters

$$edgsh_{overall} = \frac{-2.59 + 1.08 + 2 \cdot -0.86}{4} = -0.81\%$$

More On Edge Shift

A good approach to understanding the operation of the edge shift parameter with different modes of operation starts by considering Figure 4.8, a histogram of 3T to 5T pit widths.

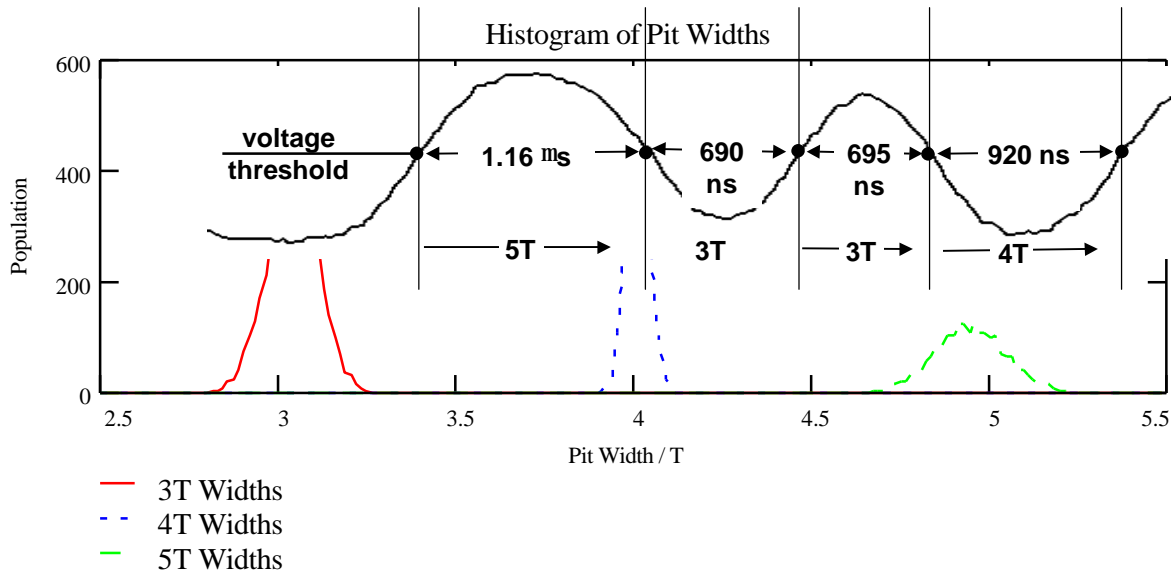


Figure 4.8

The Edge Shift parameter takes on each of these distributions separately. For each distribution, the ideal width (nT) is subtracted from the pit widths and the difference is calculated in percent. As a result, the Edge Shift distributions are calculated, shown in Figure 4.9.

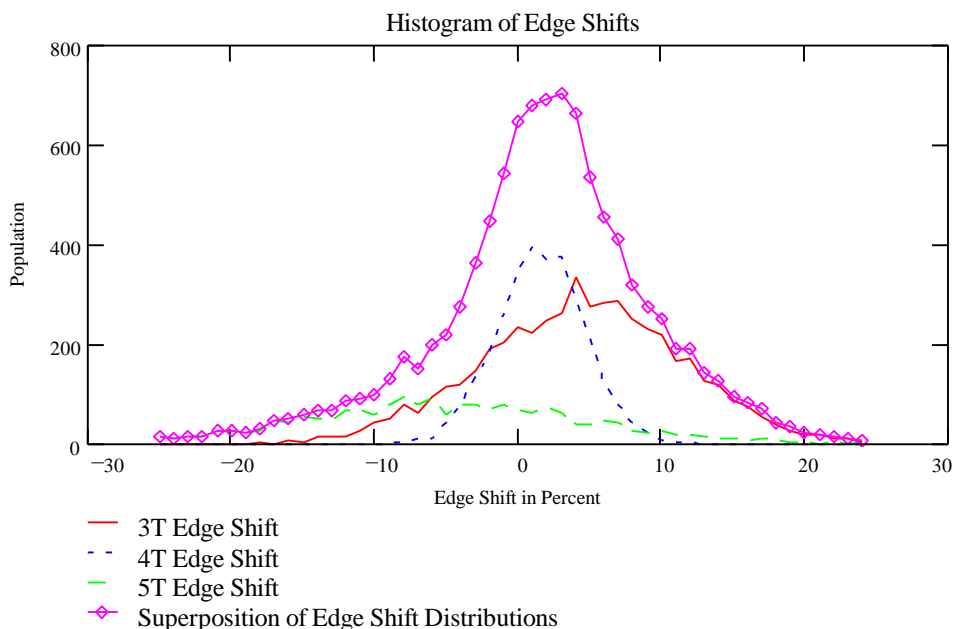
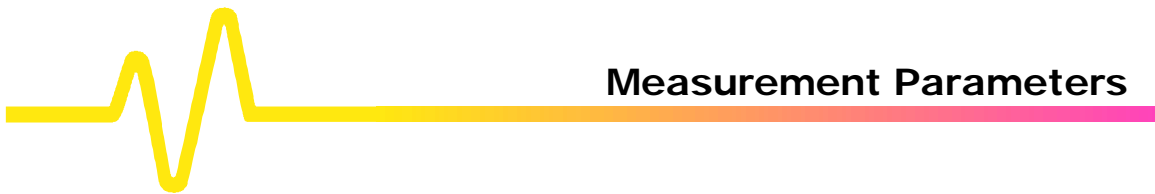


Figure 4.9

The 3T, 4T, and 5T distributions are obtained when the Edge Shift custom parameter is configured for single *n* values and histogrammed. The final superposition distribution is obtained when the Edge Shift custom parameter is configured for ranges of *n* values (in this case 3T to 5T) and histogrammed.

The value displayed on the custom parameter line (with statistics off) is the mean of any of the resulting distributions *for the last acquisition only*. This average edge shift value is calculated internally without actually histogramming the values. The values displayed in 'List by *nT*' mode are the mean of the Edge Shift distributions resulting from each *nT* distribution *for the last acquisition*.

Note: The standard deviation of superimposed Edge Shift distributions is not the same as Timing Jitter.



Iper

Local Period

Description

Local Period provides a measurement of the clock period of each clock cycle (up to the maximum number of cycles governed by memory limitations). Histogramming and statistics can be used to provide a clock jitter measurement. The starting edge (the edge that begins each cycle) is configurable.

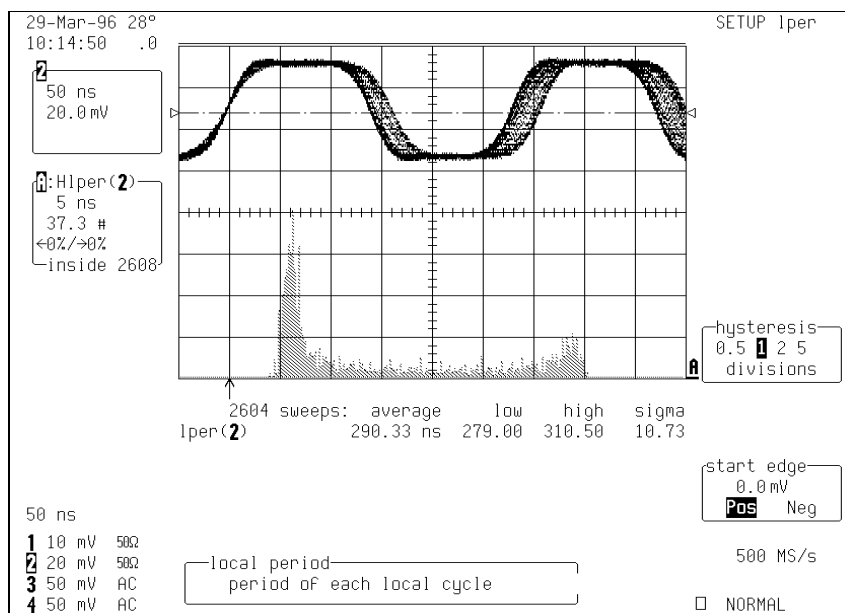
Display Options

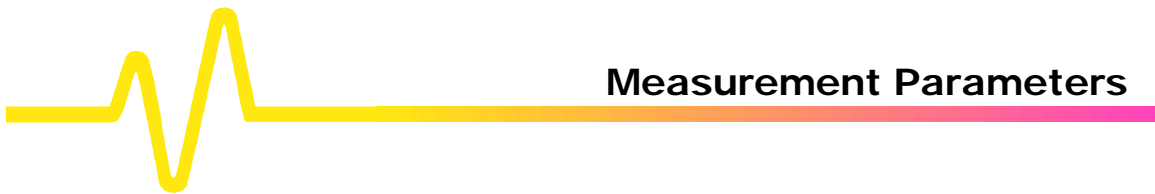
ORM parameter calculations can be displayed, histogrammed (see Chapter 6), and trended (Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of average period for all clock cycles for last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the clock period for all clock cycles for all acquisitions since last CLEAR SWEEPS operation.
Histogram Function	Histogram graph of the value of the period for all clock cycles for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the period for all clock cycles for all acquisitions since the last CLEAR SWEEPS operation.

Example

Histogramming the local period jittery clock signal shows that there are two frequency modes, one at a period of about 292 ns and the other at around 308 ns.





paa

Pit Average Amplitude

Description

Pit Average Amplitude provides a measurement of the average amplitude of pits and spaces. The calculation is performed by calculating the difference between the average value of the base (pbase) for spaces of a particular 'nT' width and the average value of the top (ptop) of pits of the same 'nT' width. For example, the average value of the base for all 3T spaces is subtracted from the average value of the top for all 3T pits to obtain the 3T pit average amplitude. If a range of 'nT' values is selected and is displayed as a parameter, the measurement provides the weighted average amplitude based on the number of occurrences of each 'nT' pit/space width.

Display Options

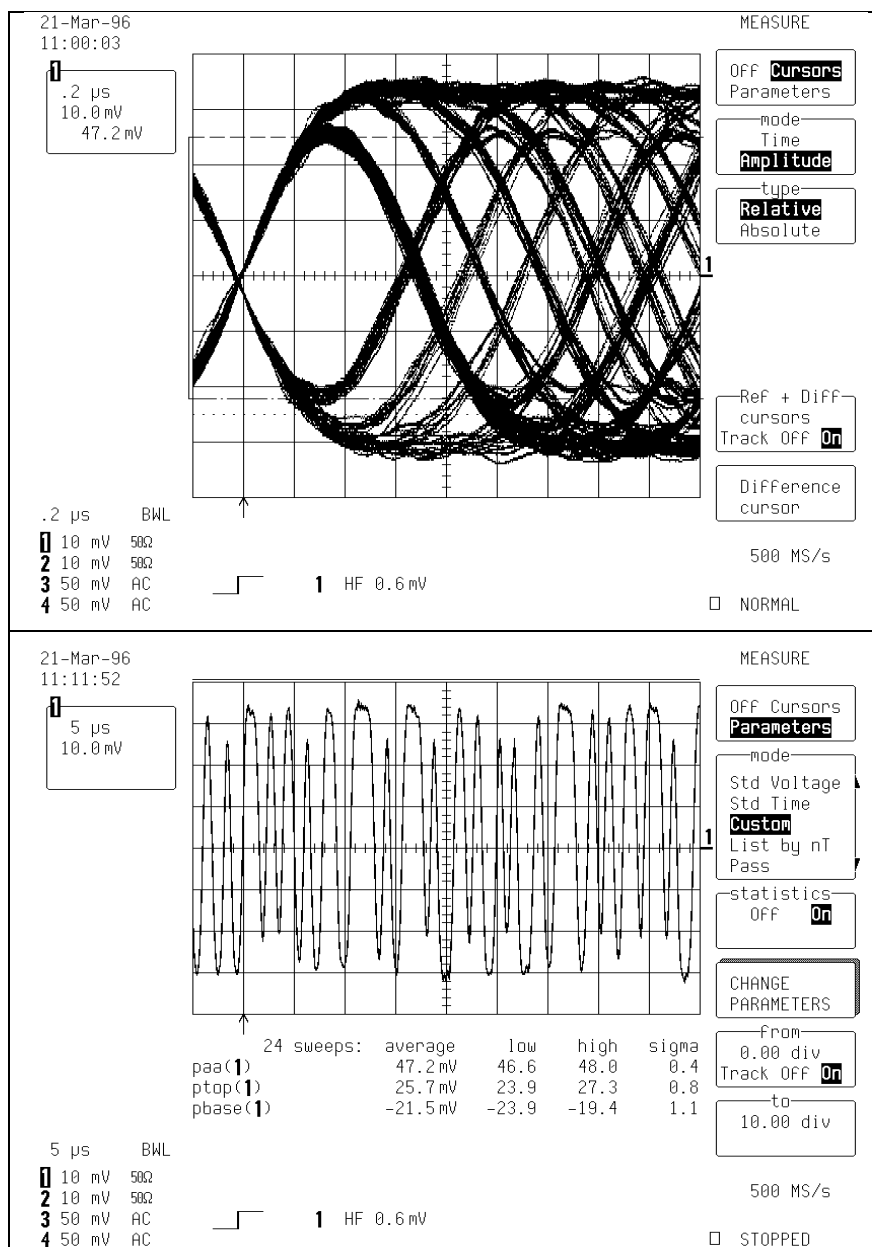
ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average amplitude for all pits/spaces of interest for last acquisition.
Parameter Statistics On	Overall average, minimum, maximum, and sigma of the single average amplitude value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of the average amplitude values for each group of pits/spaces of common 'nT' width for the last acquisition.
Histogram Function	Histogram of the single average amplitude value calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the single average amplitude value calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.

Example

Consider this persistence plot of an optical data waveform. Using cursors, the average amplitude of the 3T pits/spaces can be estimated using the measurement cursors. In this case, the value obtained is 47.2 mV.

When the parameter **paa** is configured for 3T widths, the measurement result is also 47.2mV. This value is calculated automatically.





pasym

Pit Asymmetry

Description

Pit Asymmetry provides a measurement of the asymmetry of the middle voltage level for the high nT index pits/spaces compared to the middle voltage level of the low 'nT' index pits/spaces. The measurement calculation is compliant with the definition of Pit Asymmetry as defined by IEC 908:1987 Section 3.1. The negative value of the measurement is referred to as Pit Symmetry as defined by ISO/IEC 10149:1995 (E) Section 12.2. Pit Asymmetry is calculated by the formula:

$$PASYM = \frac{pmidl_{high_n} - pmidl_{low_n}}{paa_{high_n}} \cdot 100\%$$

where paa is the average peak-peak amplitude. The low (smallest) and high (largest) 'nT' values to use in performing the calculation are provided by the user through the associated measurement configuration options. Midpoint designates the midpoint value between the average top and base for a specified 'nT.' The value shown is in units of percent.

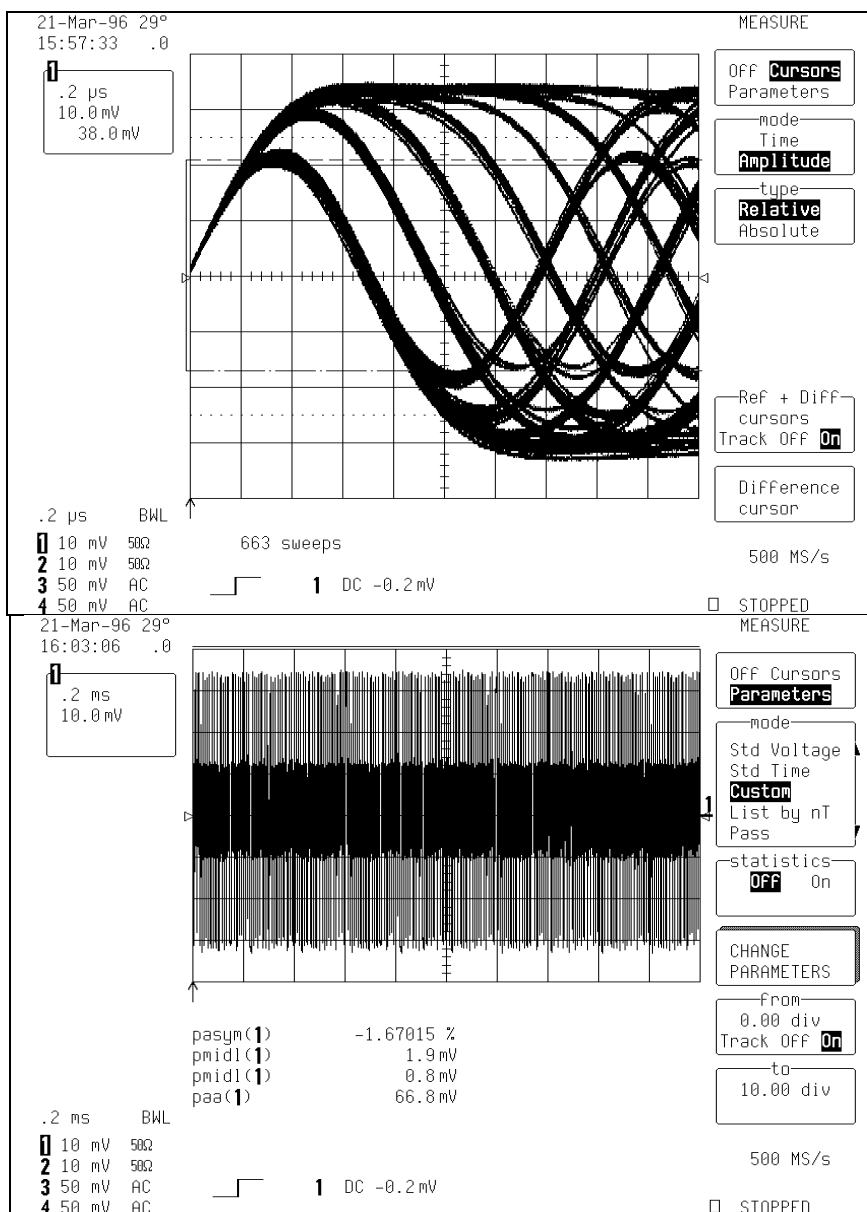
Display Options

ORM parameter calculations can be displayed, histogrammed, and trended in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the asymmetry for the last acquisition.
Parameter Statistics On	Average, minimum, maximum and sigma of the single asymmetry value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Histogram Function	Histogram of asymmetry value calculated per acquisition for all acquisitions since last CLEAR SWEEPS operation.
Trend Function	Trend of single asymmetry value calculated per acquisition for all acquisitions since last CLEAR SWEEPS operation.

Notice that the mid-level of the $3T$ waveform is offset from 0 V , and that the mid-level of the $11T$ waveform is approximately 0 V .

Since the 3T middle level is offset, the expected asymmetry value is negative. This is the asymmetry calculated from a waveform with several thousand widths. The values are the asymmetry, the 3T middle level, the 11T middle level, and the 11T average amplitude.



pbase

Pit Base

Description

Pit Base provides a measurement of the best estimate of the bottom amplitude of a space. The concept of the base calculation is to automatically provide the same measurement that would be obtained from a persistence plot. The base of each space is determined through histogramming techniques described under *Base and Top Calculation Details, page 4-74*.

When **pbase** is configured as a custom parameter, all bases within the single nT or range of nT are calculated. Histogramming or trending such a configuration would result in one v value per space in the nT range contributing a value to the histogram or trend. The v value displayed on the custom parameter display line is the average of all such base calculations. 'List by nT' mode provides an average base measurement for each n index.

Display Options

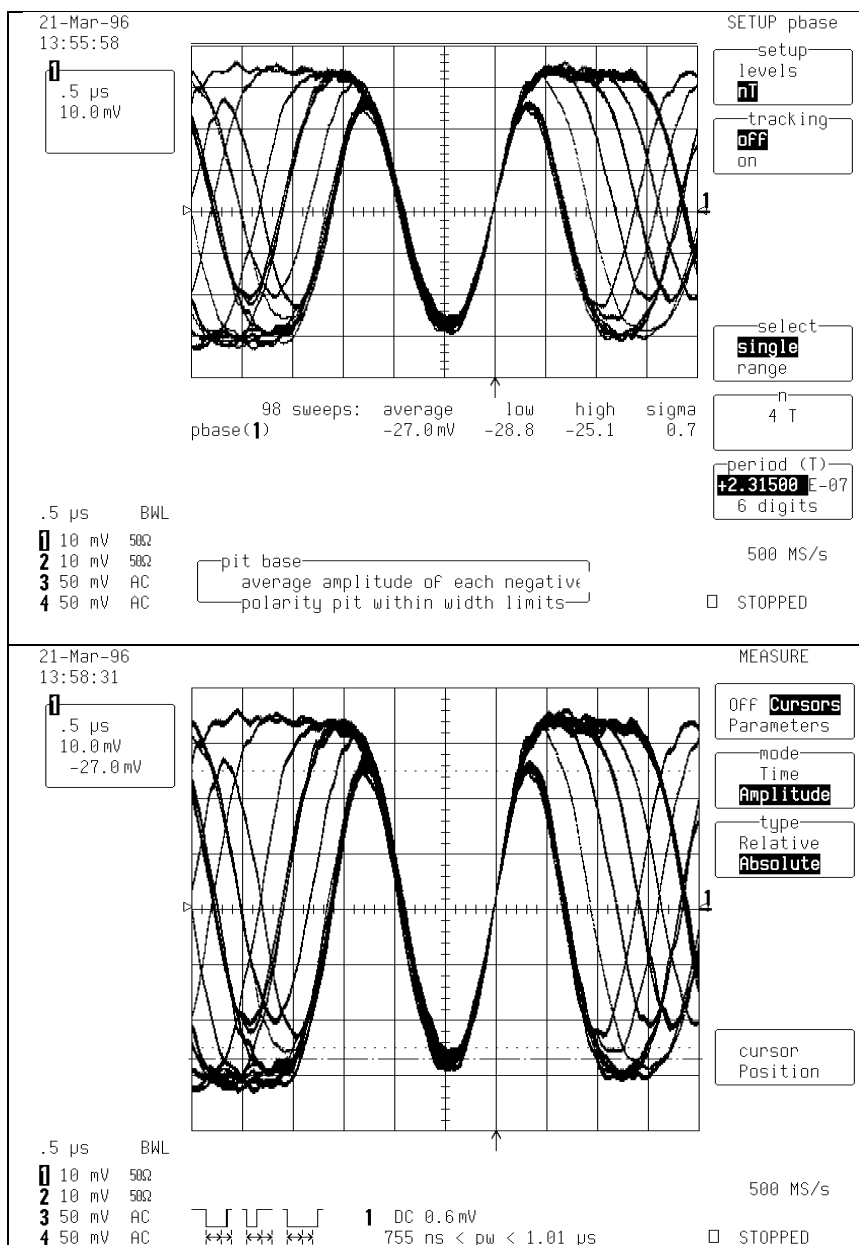
ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways. The following table provides a concise description of the value or v values displayed using each approach.

Display Type	Value Displayed
Parameter Statistics Off	Single v value of the average base for all spaces within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the base for all spaces that are within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of v values of the average base for each group of spaces of common 'nT' width for the last acquisition.
Histogram Function	Histogram graph of the v value of the base for all spaces within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the v value of the base calculated for space that is within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.

Example

The following persistence waveform is created by setting a SMART Trigger® to capture only 4T spaces. The 4T base computed is -27.0 mV.

When the same measurement is taken with the parameter cursors, it seems that -27.0 mV is a reasonable value for the base.





Measurement Parameters

pmax

Pit Maximum

Description

Pit Maximum provides a measurement of the maximum voltage value of pits of interest. It provides a comparison of how the maximum point in the waveform corresponds to the **ptop** value. When **pmax** is configured as a custom parameter, all maximums within the single nT or range of nT are calculated. Histogramming or trending such a configuration would result in one value per pit in the nT range contributing a value to the histogram or trend. The value displayed on the custom parameter display line is the average of all such maximum calculations. 'List by nT' mode provides an average maximum value for the pits in each n index.

Display Options

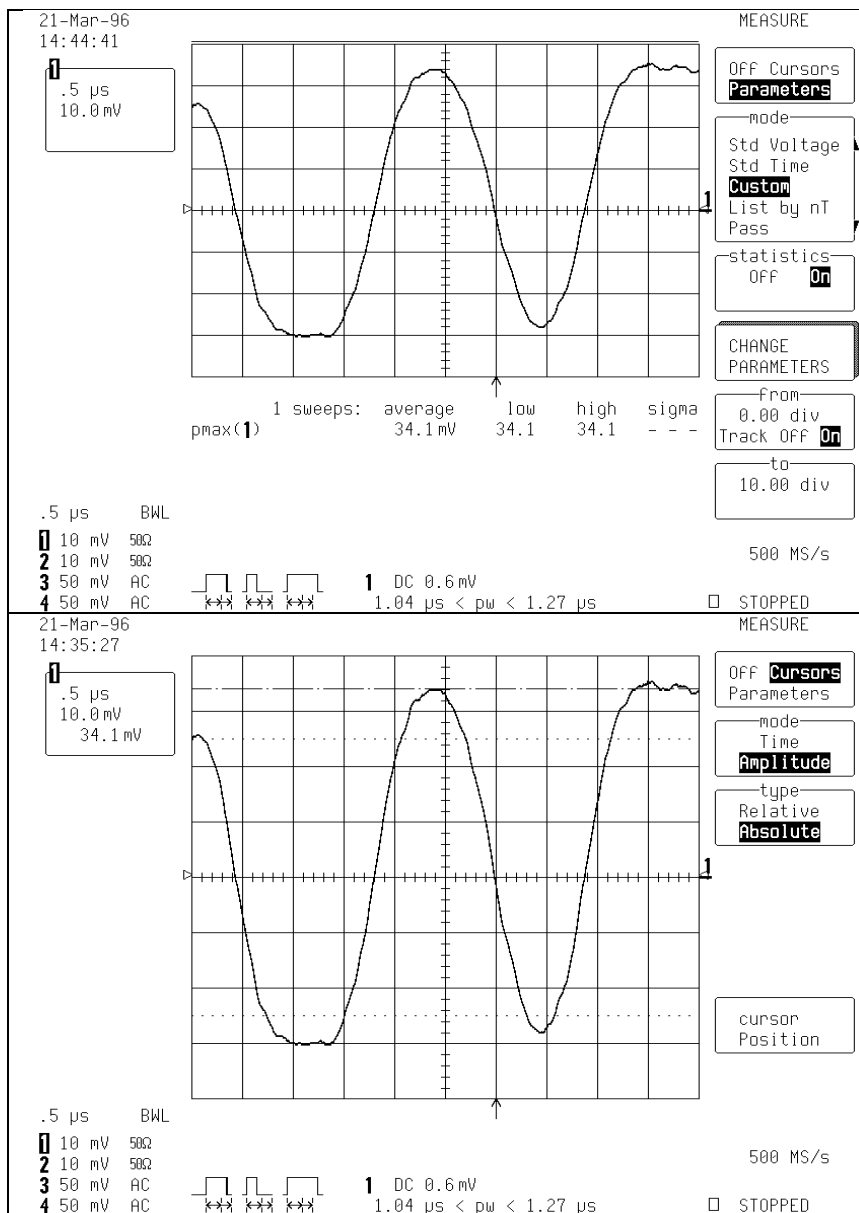
ORM parameter calculations can be displayed, histogrammed (Chapter 6) and trended (Chapter 5) in a variety of ways. The table provides a concise description of the value or values displayed using each approach.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average maximum for all pits within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the maximum for all pits that are within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the average maximum for each group of pits of common 'nT' width for the last acquisition.
Histogram Function	Histogram graph of the value of the maximum for all pits within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the maximum calculated for each pit that is within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.

Example:

This waveform contains a single pit, whose max is computed as 34.1 mV.

The same measurement is verified using the measurement cursors.





pmidl

Pit Middle Level

Description

Pit Middle Level provides a measurement of the middle voltage level of pits or spaces. It is performed by first calculating the midpoint of the average value of the base (**pbase**) for spaces and the average value of the top of pits (**ptop**). If only 3T pits are specified, the resulting measurement is the 'decision level' (see ISO/IEC 10149:1995 (E) Section 12.1). If a range of 'nT' values is selected and is displayed as a parameter, the measurement provides the weighted average midpoint based on the number of occurrences of each 'nT' pit/space width. The measurement value can be used to determine not only the differences of the midpoint of different 'nT' width pits, but also the overall best data waveform voltage *threshold* setting to use for all ORMs.

Display Options

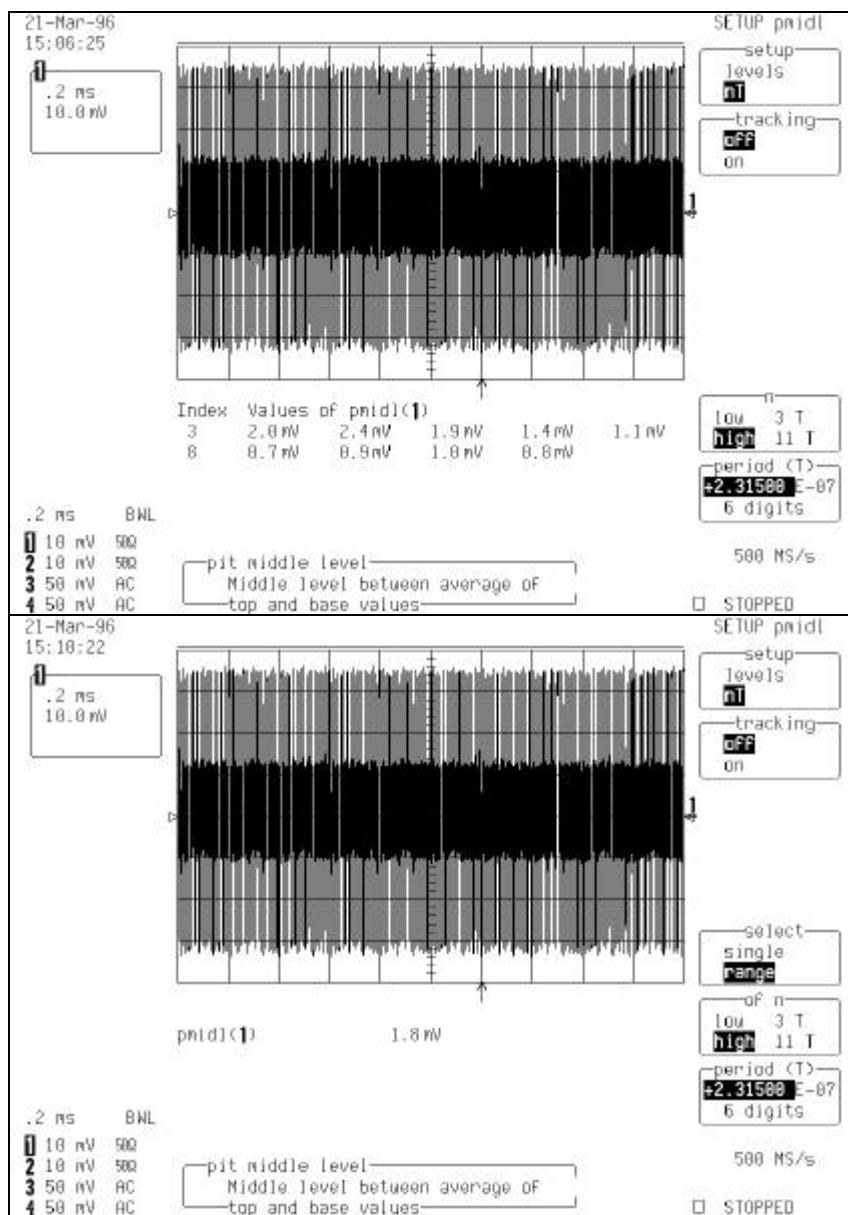
ORM parameter calculations can be displayed, histogrammed, (Chapter 5) and trended (Chapter 4) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the middle level for all pits/spaces of interest for last acquisition.
Parameter Statistics On	Overall average, minimum, maximum, and sigma of the single middle level value calculated per acquisition, for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of the middle level values for each group of pits/spaces of common 'nT' width for the last acquisition.
Histogram Function	Histogram of the single middle level value calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the single middle level value calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.

Example

This waveform contains thousands of pits. In 'list by nT' mode, the middle levels are displayed for each nT index. These values are the midlevels of the tops and bases for pits/spaces within the nT indices.

The overall middle level is calculated based on a weighted average of the middle level for each nT. This value is the overall best threshold value for all pits/spaces within the 3T to 11T range.





pmin

Pit Minimum

Description

Pit Minimum provides a measurement of the minimum voltage value of pits of interest, and a comparison of how the minimum point in the waveform corresponds to the **ptop** value. When **pmin** is configured as a custom parameter, all minimums within the single nT or range of nT are calculated. Histogramming or trending such a configuration would result in one value per pit in the nT range contributing a value to the histogram or trend. The value displayed on the custom parameter display line is the average of all such minimum calculations. 'List by nT' mode provides an average minimum value for the pits in each n index.

Display Options

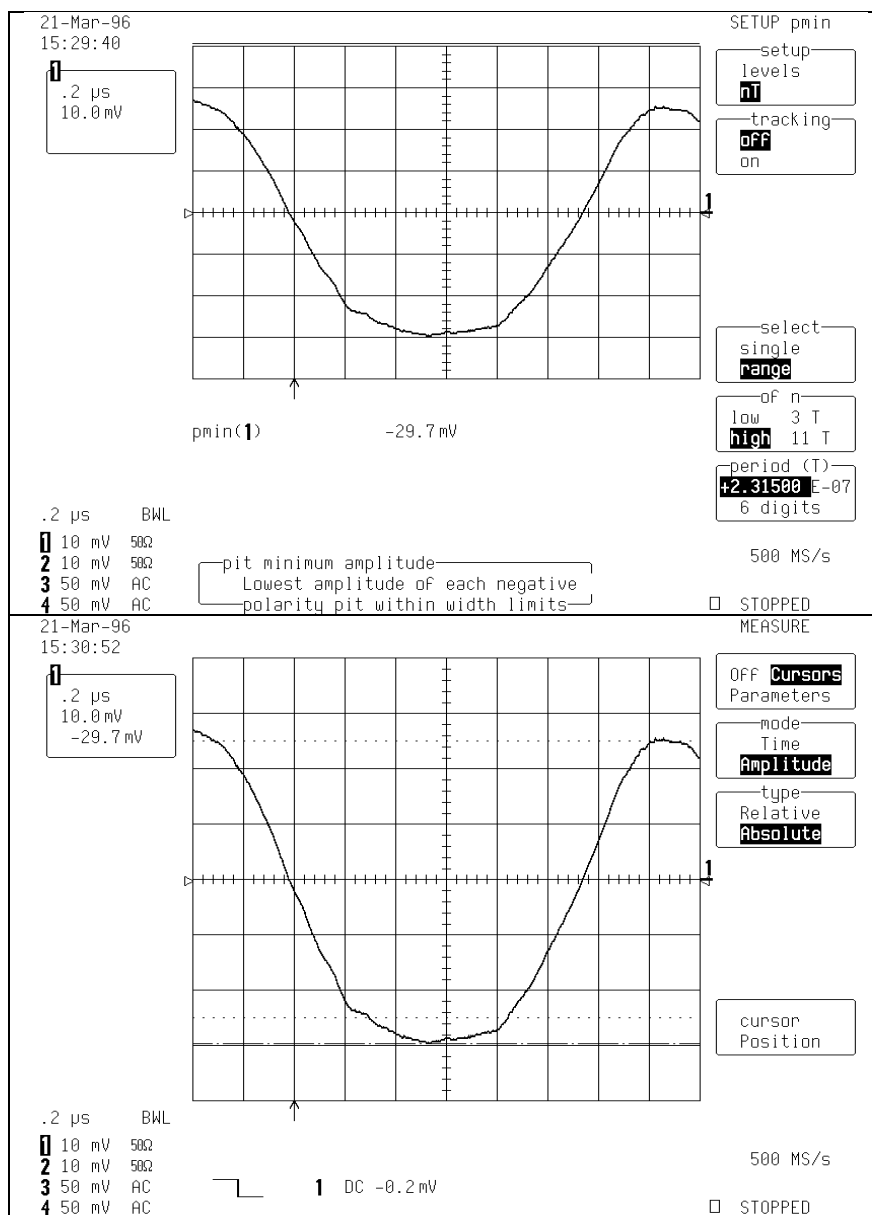
ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average minimum for all pits within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the minimum for all pits that are within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the average minimum for each group of pits of common 'nT' width for the last acquisition.
Histogram Function	Histogram graph of the value of the minimum for all pits within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the minimum calculated for each pit that is within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.

Example

This waveform contains a single space. The pit min is computed as -29.7 mV.

The measurement can be verified with the measurement cursors.





pmoda

Pit Modulation Amplitude

Description

Pit Modulation Amplitude provides a measurement of the ratio of the Pit Average Amplitude (**paa**) for the low 'nT' pits/spaces in the data signal to the Pit Top (**ptop**) of the high 'nT' pits in the data signal:

$$PMODA = \frac{paa_{low_n}}{avg(top)_{high_n}}$$

Note: this measurement must be performed on the DC-coupled optical data waveform, otherwise incorrect values will result.

The *low* and *high* 'nT' v values to be used for performing the calculation are provided by the user through the associated measurement configuration options. Some measurements of modulation amplitude require the low and high n index to be identical. The v value is shown is decimal. The measurement calculation is compliant with the definition of Modulation Amplitude as defined by IEC 908:1987 Section 9.2 and ISO/IEC 10149:1995 (E) Section 12.2.

Display Options

ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways.

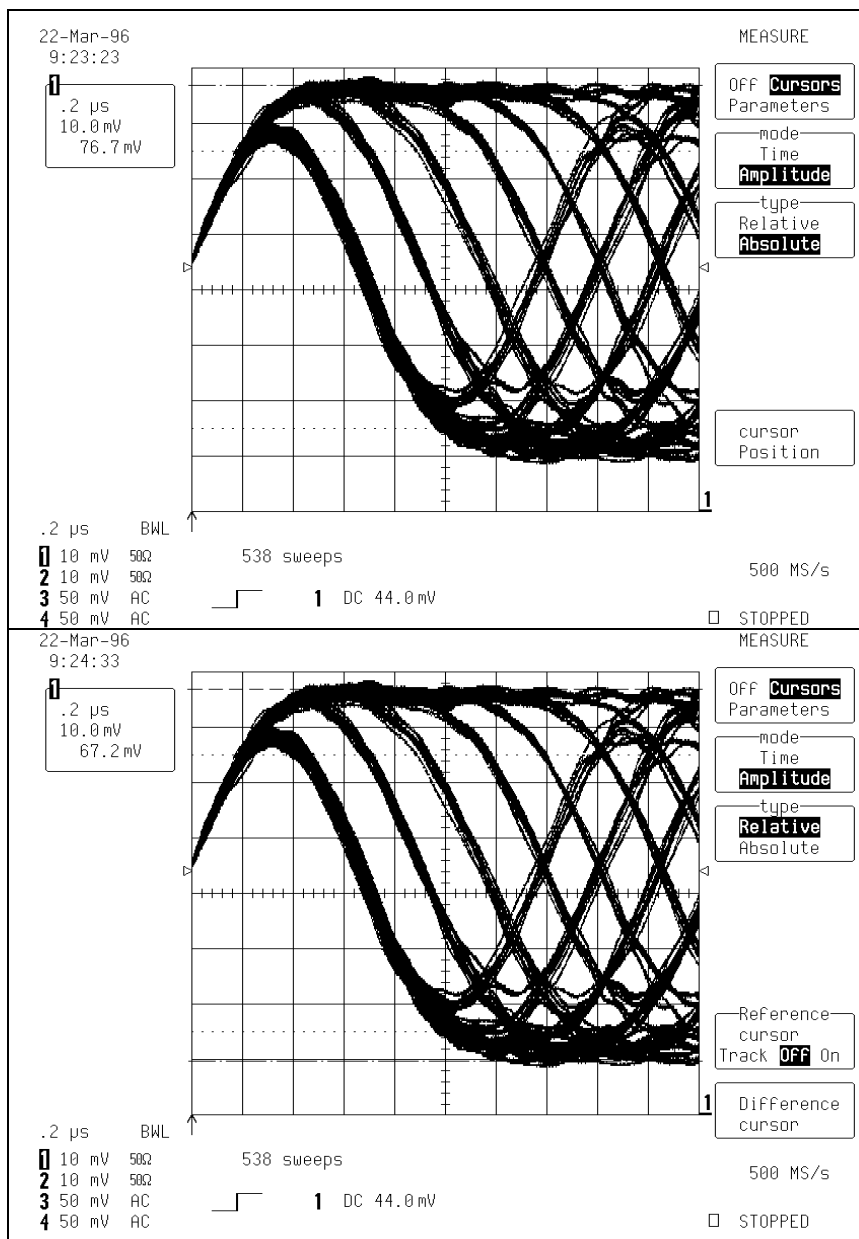
Display Type	Value Displayed
Parameter Statistics Off	Single v value of the modulation amplitude for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the single modulation amplitude v value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Histogram Function	Histogram of the modulation amplitude v value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the single modulation amplitude v value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.

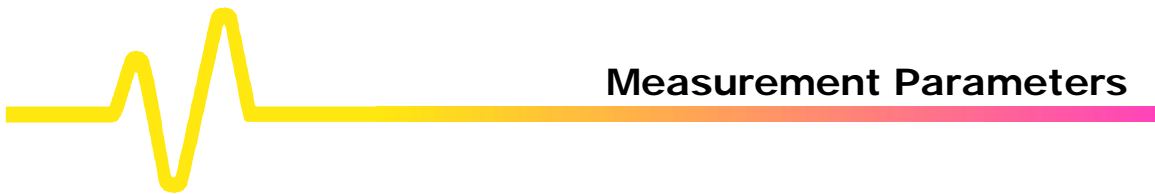
Example

The following persistence plots were generated using the DC-coupled signal.

In the first plot, the amplitude measurement cursor is reading the 11T top voltage of 76.7 mV

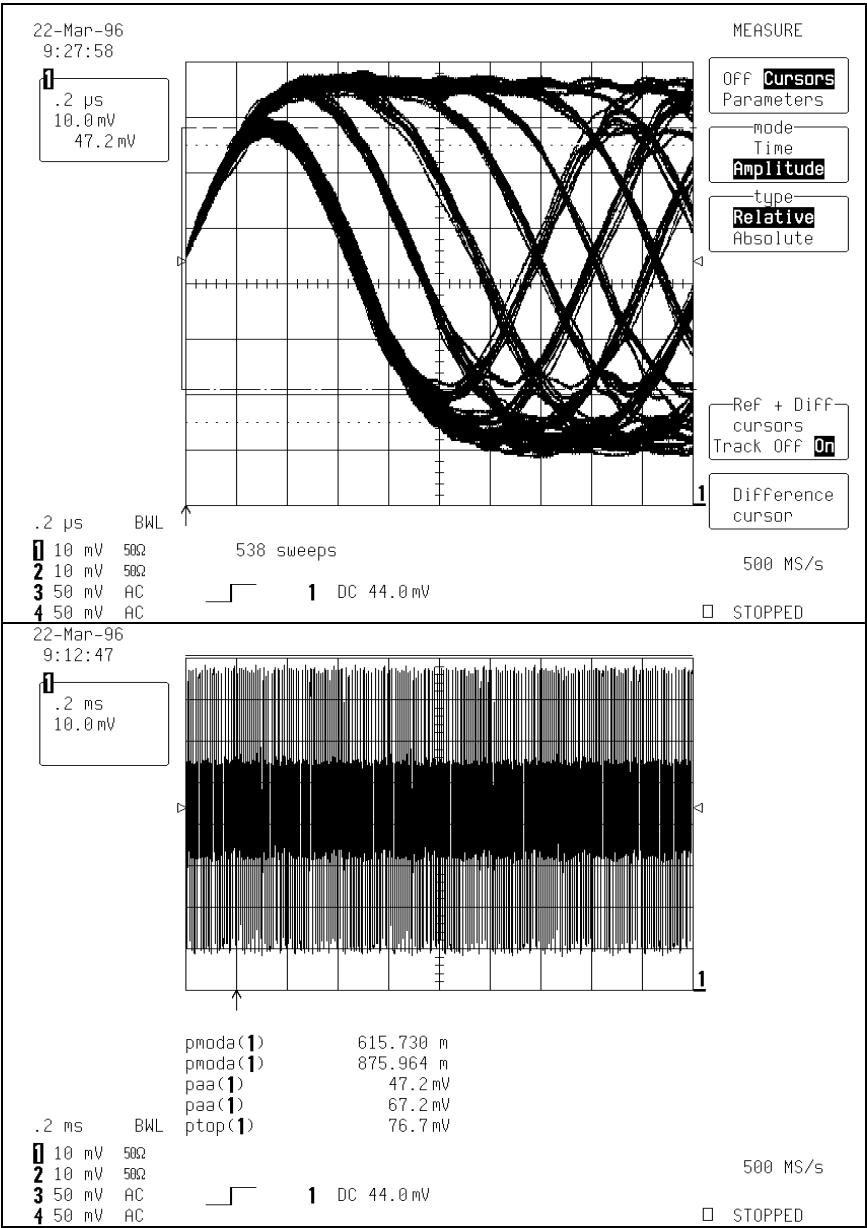
In the second, the cursor reads the difference between the 11T top and base of 67.2 mV.





Measurement Parameters

In the third plot, the cursor reads the difference between the 3T top and base of 47.2 mV.



The last plot shows the waveform with the parameters calculated automatically.

1. *pmoda 3T paa/11T top*
2. *pmoda 11T paa/11T top*
3. *paa 3T*
4. *paa 11T*
5. *top 11T*

Line 1 contains the ratio of line 3 to line 5.
Line 2 contains the ratio of line 4 to line 5.

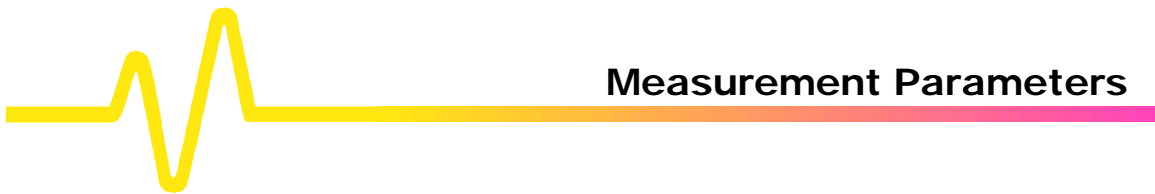
pnum**Pit Number****Description**

Pit Number provides a measurement of the number of pits or spaces of interest or both. When **pnum** is selected as a parameter measurement the total number of pits and/or spaces for the selected 'nT' range is displayed. In the List by nT mode the number for each 'nT' value is displayed.

Display Options

ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways. The table provides a concise description of the value or values displayed using each approach.

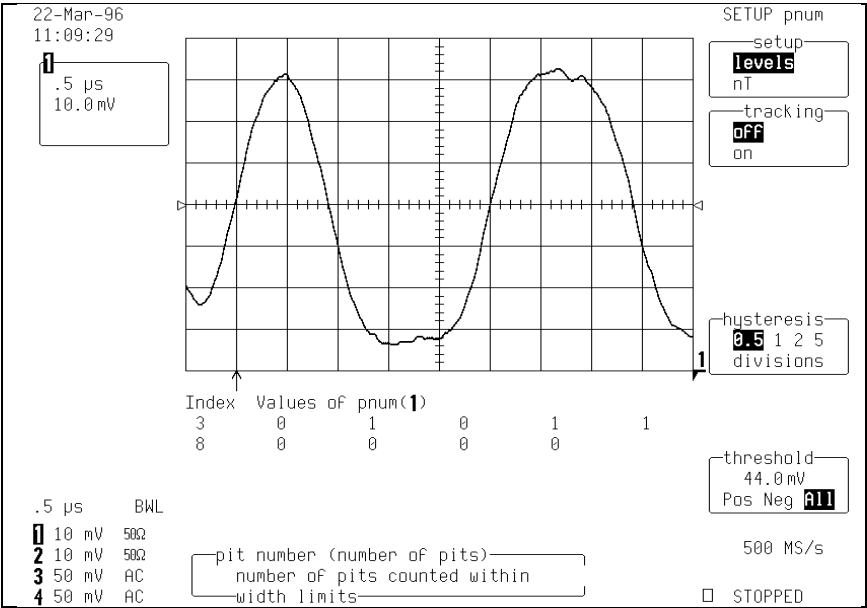
Display Type	Value Displayed
Parameter Statistics Off	Single value of the total number of pits/spaces within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the single value of the total number of pits/spaces within the selected 'nT' range, calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the number pits/spaces for each individual 'nT' in the selected range of 'nT' for the last acquisition.
Histogram Function	Histogram graph of the single value of the number of pits/spaces within the selected 'nT' range calculated each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the single value of the number of pits/spaces within the selected 'nT' range calculated each acquisition for all acquisitions since the last CLEAR SWEEPS operation.



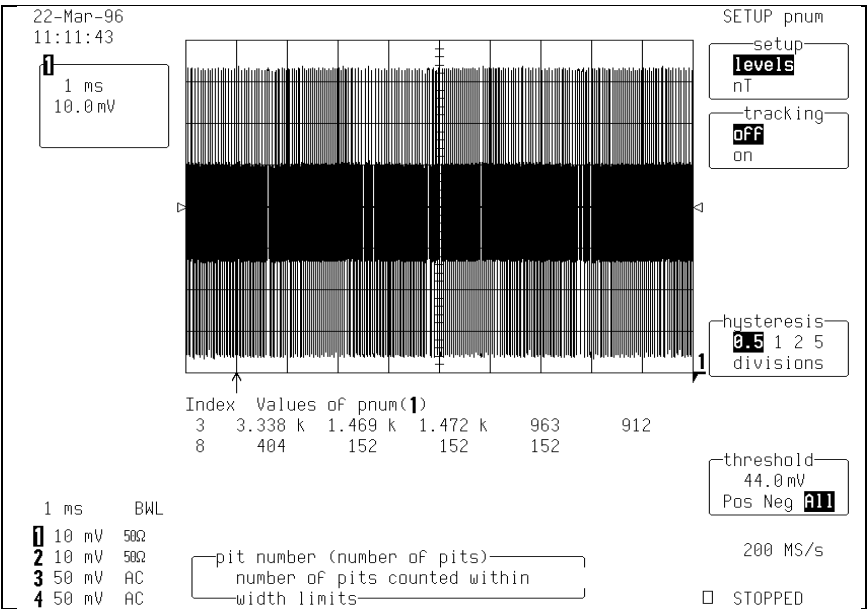
Measurement Parameters

Example

In this waveform, each of the 3 pits/spaces is easily identified. There is a 4T pit, a 6T space, and a 5T pit. Each is counted and displayed in 'List by nT' mode.



This is the long waveform showing the number of pits/spaces obtained: approx. 9,000.



pres**Pit Resolution****Description**

Pit Resolution measures the ratio of the Pit Average Amplitude (see **paa** measurement description) of the smallest of the 'nT' pits or spaces in the data signal to that of the largest:

$$PRES = \frac{paa_{low_n}}{paa_{high_n}} \cdot 100\%$$

The *low* and *high* 'nT' values for performing the calculation must be provided by the user through the associated measurement configuration options. The value shown is in units of percent. The measurement calculation is compliant with the definition of Pit Resolution as defined by IEC 13549:1993 Section 15.3.1.

Display Options

ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways. The table provides a concise description of the value or values displayed using each approach.

Display Type	Value Displayed
Parameter Statistics Off	Single v value of the pit resolution for the last acquisition.
Parameter Statistics On	Overall average, minimum, maximum, and sigma of the single pit resolution v value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Histogram Function	Histogram of the single pit resolution v value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the single pit resolution v value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.



Consider the following persistence plots. In the first, the amplitude measurement cursor reads the difference between the 3T top and base of 47.3 mV.

Therefore, the resolution is:

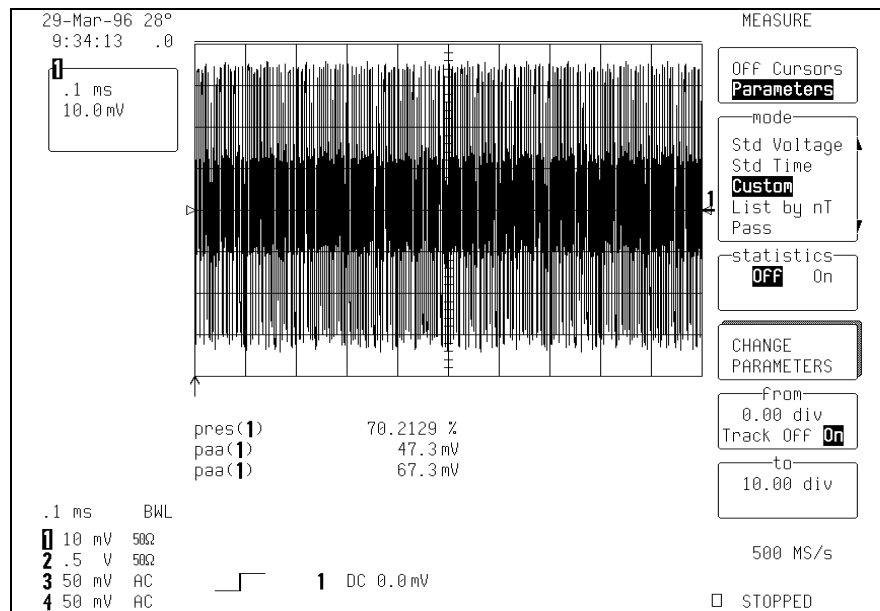
$$\frac{47.3}{67.3} \cdot 100\% = 70.3\%$$



This is the same waveform with the parameters calculated automatically.

1. $\text{pres}3T_{\text{paa}}/11T_{\text{paa}}$
2. $\text{paa}3T$
3. $\text{paa}11T$

Line 1 contains the ratio of line 2 to line 3 in percent.





ptop

Pit Top

Description

Pit Top provides a measurement of the best estimate of the top amplitude of a pit. The concept of the top calculation is to automatically provide the same measurement which would be obtained from a persistence plot. The top of each pit is determined through histogramming techniques described in detail under *Base and Top Calculation Details, page 4-74*. When **ptop** is configured as a custom parameter, all tops within the single nT or range of nT are calculated. Histogramming or trending such a configuration would result in one value per pit in the nT range contributing a value to the histogram or trend. The value displayed on the custom parameter display line is the average of all such top calculations. 'List by nT' mode provides an average top measurement for each n index.

Display Options

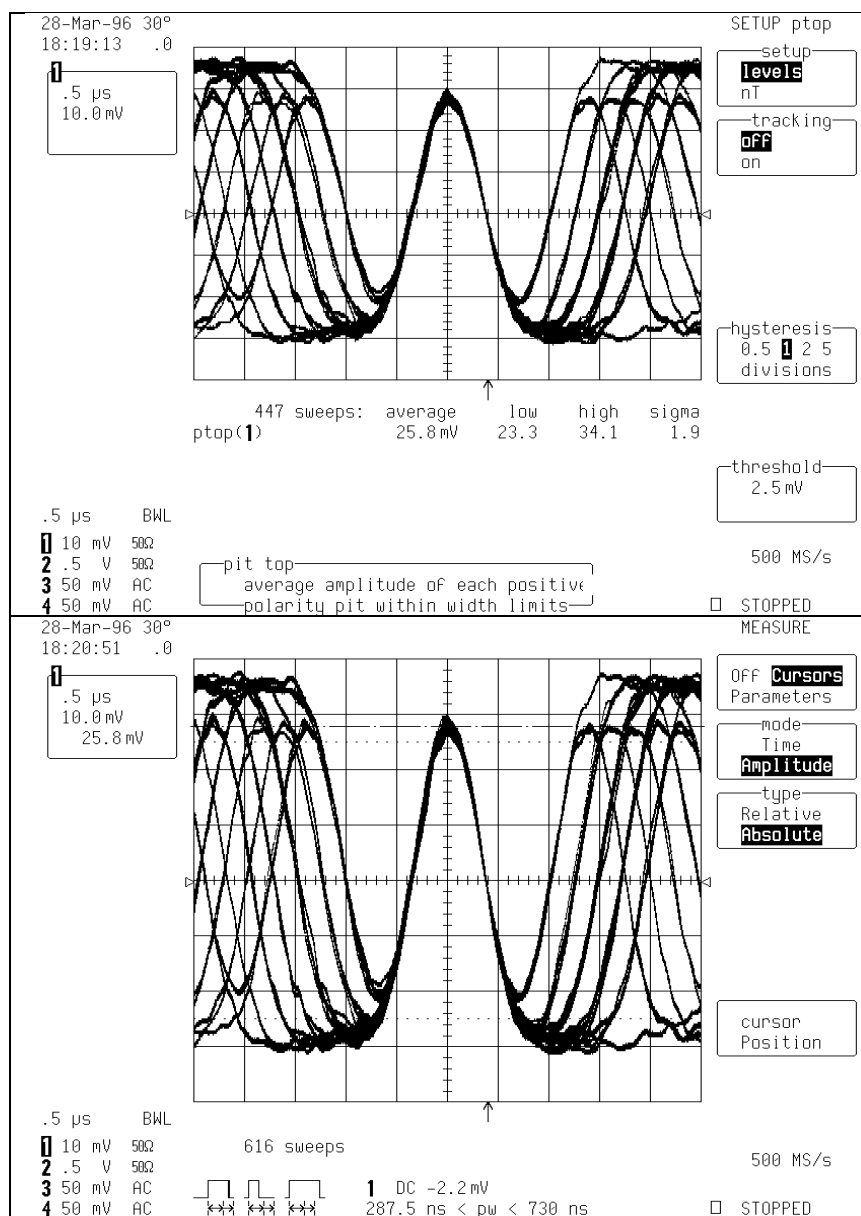
ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average top for all pits within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the top for all pits within the selected 'nT' range for all acquisitions since last CLEAR SWEEPS operation.
List by nT	List of values of the average top for each group of pits of common 'nT' width for the last acquisition.
Histogram Function	Histogram graph of the value of the top for all pits within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the top calculated for pit that is within the selected 'nT' range for all acquisitions since last CLEAR SWEEPS operation.

Example

This persistence waveform was created by setting a SMART Trigger to capture only 3T pits. The computed 3T top is 25.8 mV.

When the same measurement is taken with the parameter cursors, it seems that 25.8 mV is a reasonable value for the top.





Measurement Parameters

pwid

Pit Width

Description

Pit Width provides a measurement of the width of pits or spaces or both of interest. The width of the pit or space is determined by the crossing of the selected voltage threshold. When **pwid** is selected as a parameter measurement it is generally useful to display the measurement calculation for a single 'nT' value. Otherwise the measurement will calculate the average width of 3T pits, 4T pits, and so on, which is meaningless. However, it is also often desirable to histogram the width of all pits and/or spaces. In this case the *range* of 'nT' values should be set to include all pit/space widths of interest.

Display Options

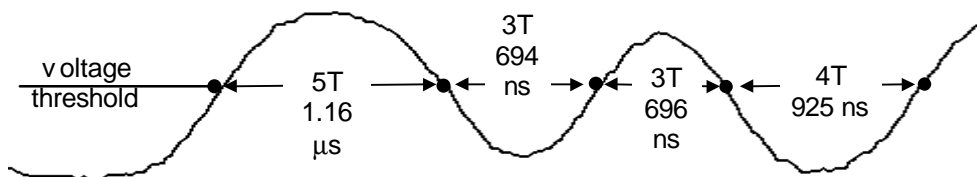
ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways. The table provides a concise description of the value or values displayed using each approach.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the average pit width for all pits/spaces within the selected 'nT' range for the last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the pit width for all pits/spaces that are within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the average pit width for each group of pits/spaces of common 'nT' width for the last acquisition.
Histogram Function	Histogram graph of the value of the pit width for all pits/spaces within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend graph of the value of the pit width for all pits/spaces within the selected 'nT' range for all acquisitions since the last CLEAR SWEEPS operation.

Example

The example shows that, measured at the selected voltage threshold, the CD data signal contains sequentially a 5T pit, 3T space, 3T pit, and 4T space. If the measurement is configured to select only 3T pits or spaces then the value displayed will be:

$$pwid = (694 \text{ ns} + 696 \text{ ns}) / 2 = 695 \text{ ns}$$

**Example 2:
Histogramming**

Consider the problem of determining the error margin in an optical recording system. As the data is encoded in the widths of the pits/spaces, it would be ideal for the widths to be exact integer multiples of the period of the clock used to sample the data signal. In practice this is not the case, but in order to ensure error-free data recovery, it is important for the widths to be grouped and separated.

Histogramming (Chapter 6) can be used to analyze the grouping of pit widths and to determine whether the separation is acceptable.

The scope is set up to acquire the optical data waveform by assigning Channel 1 to the data signal at a time/div of 0.2 ms, so that many pits/spaces can be gathered quickly. The signal is AC-coupled, so the threshold is set to 0 mV.



Measurement Parameters

The **pwid** custom parameter is assigned to line 1 and configured in the following manner:

hysteresis = 0.5 divisions
threshold = 0 mV
polarity = All
range of n
low $n = 3$
high $n = 11$
period = 231.5 ns.

Trace A is defined as a zoom of channel 1 (by turning math **off**), so that the waveform can be viewed expanded and the pits and spaces can be identified.

Using the Math Setup, Trace B is defined as the histogram of the **pwid** parameter on line 1, and is set up as follows:

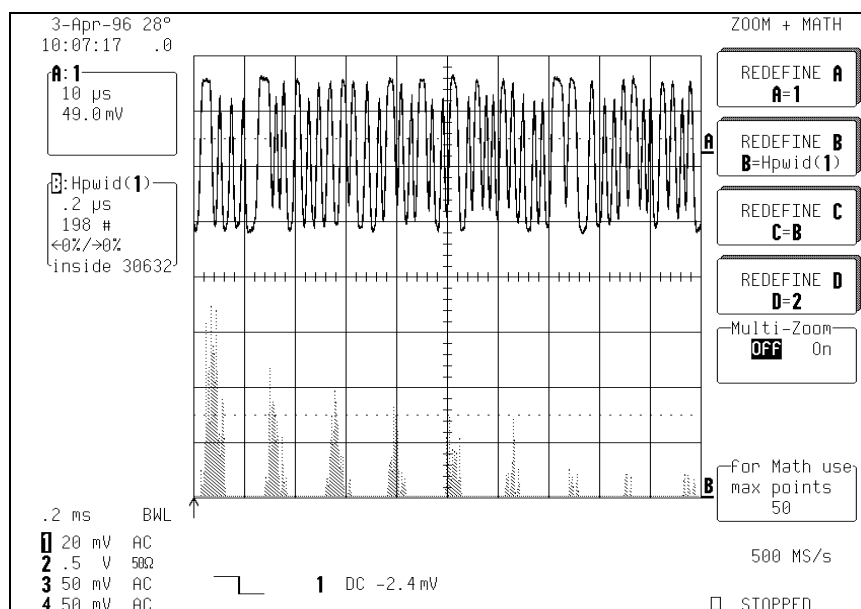
1. Use the maximum number of values (2 000 000 000)
2. Classify into 2000 bins
3. Linear vertical scale.

The trigger is set up to trigger on a pit edge and operated in normal trigger mode.

Note: Prior to acquisition, select each trace and press the **RESET** button to ensure that all the traces are reset.

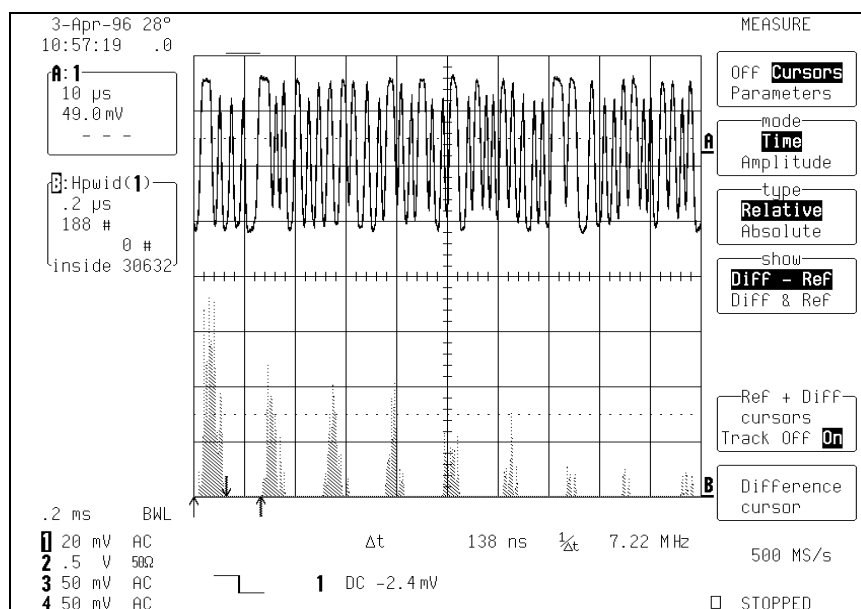
In normal trigger mode, multiple waveforms are acquired and processed. The histogram will typically have data which is not well centered or is off screen. Press the **FIND CENTER AND WIDTH** menu button (page 6-15) to see the pit width distributions as they accumulate. After enough measurements have been taken, stop the triggering. The screen will look as follows after the histogram has been centered:

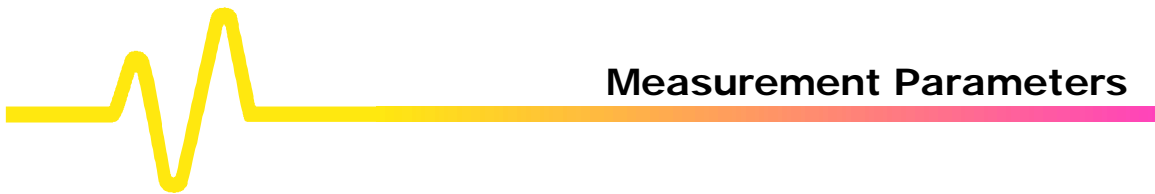
The optical data waveform is on the top and the histogram is on the bottom of the screen. Notice the clustering of width distributions.



As we are interested in measuring the spacing of the distributions set, relative time cursors should be chosen.

By setting cursor tracking to **On**, the difference cursors are swept across the histogram. As expected, the space between the 3T and 4T distributions is the shortest, because of inter-symbol interference and the many 3T widths. The spacing is 138 ns.





Measurement Parameters

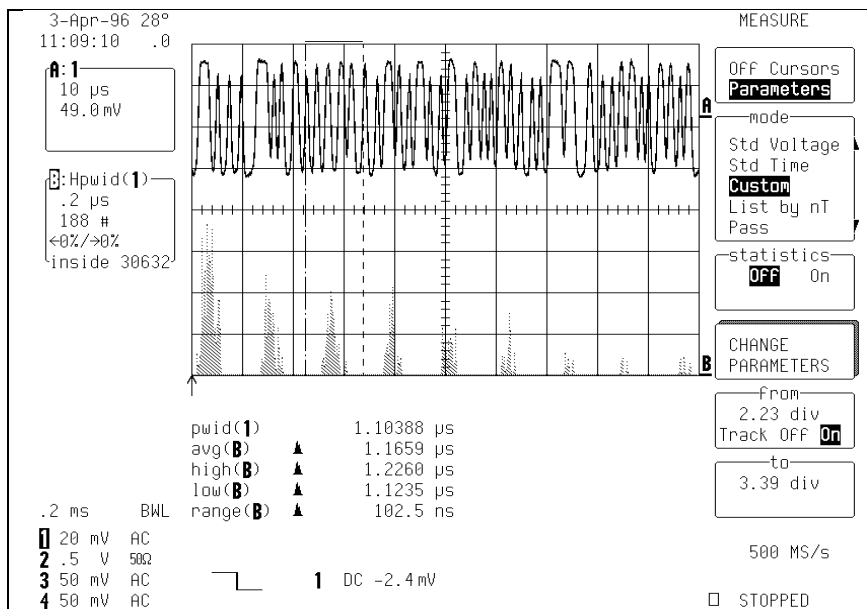
To measure the spread of widths for the distributions, set the cursor/measure mode to **Parameters** and configure the parameters:

1. line 2: average of trace B
2. line 3: high of trace B
3. line 4: low of trace B
4. line 5: range of trace B

Because parameter measurements are performed only on those portions of the waveform between the parameter cursors, activate tracking so that they can be swept across the histogram. Set the difference between the cursors so that they encompass one clock period. In this case, the histogram is shown at 0.2 μs per division. Set the difference between the parameter cursors to:

$$\frac{2315 \cdot 10^{-9}}{2 \cdot 10^{-6}} = 1.16 \text{ divisions}$$

This screen shows the histogram statistics taken on the 5T distribution. The distribution has the largest spread of values: 102.5 ns. The mean is 1.1659 μs , which is 3.6% higher than the ideal of 1.1575 μs .



Description

The Time-at-Pit parameter provides the time of each leading edge of every pit or space within the nT range specified from the trigger point (time = 0). The value displayed is the time of the *first* pit only.

The usefulness of this parameter is not in the displayed value, but in its trending. The intent is that two parameters (t@pit and another ORM parameter) can be configured with identical configurations — precisely the same number of pits or spaces are found in the waveform, and precisely the same number of parameter measurements are made. When both of these parameters are trended, the two trends will have the same number of events, and there will be a one-to-one correspondence between each event in each trend. If both trends are displayed, and time cursors are swept over each, values will be displayed for the ORM parameter value and the time within the acquisition where the parameter measurement was made. These times are useful when searching for abnormal events within a waveform.

Not only can the trend of **t@pit** provide the actual event time, it can be used as the x axis in an XY plot to examine modulation characteristics of particular parameter measurements.

Example

This example typifies the usage of the **t@pit** parameter. Step-by-step instructions are given.

A large optical recording waveform is to be acquired, and the ordinary pit/space widths that can cause errors in the system need to be found. The waveform contains pits/spaces that have widths that are ideal integer multiples of the clock period 231.5 ns in a range from 3 to 11 times this clock period.

The scope is set up to acquire this waveform by assigning Channel 1 to the data signal at a time/div of 0.2 ms. This signal will contain approximately 1800 pits/spaces. The ideal threshold (determined by the **pmidl** parameter) is 1.9 mV.



Measurement Parameters

The **pwid** custom parameter is assigned to line 1 and the **t@pit** parameter to line 2. Using configuration tracking, both parameters are configured in the following manner:

hysteresis = 0.5 divisions
threshold = 1.9 mV
polarity = All
range of n
low $n = 0$
high $n = 25$
period = 231.5 ns.

Using math setup, Trace A is defined as the trend of the **pwid** parameter, and Trace B as the trend of the **t@pit** parameter. For later use, C is defined as a zoom of Channel 1. We are expecting 1800 pits/spaces, so make sure that the trends are set to use up to 2000 values for each math setup.

The trigger is set up to trigger on a pit edge and is operated in single-shot mode. For convenience, the waveforms are ordered on the screen in a particular manner:

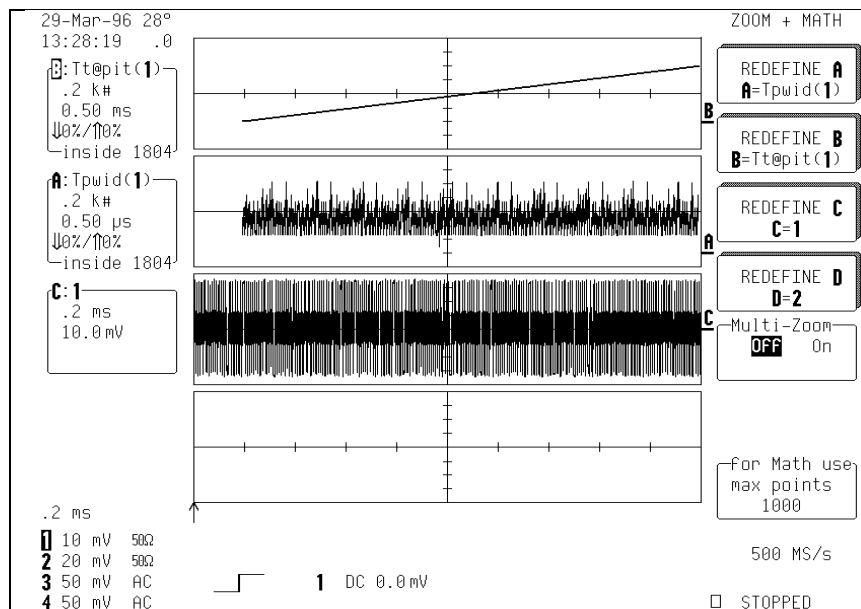
1. Trace B: Trend of **t@pit**
2. Trace A: Trend of **pwid**
3. Trace C: Zoom of optical recording waveform

The reason for this order will become apparent.

Press the single-shot trigger button to acquire the waveform. The waveform should be centered on the screen. Typically the trends will have data that is not well centered or is off screen. Centering is done by pressing the **FIND CENTER AND HEIGHT** menu button in each trend setup menu.

The next screen shows what each trace looks like after the waveform has been acquired and the trends centered.

The waveforms are displayed in Quad grids mode. The trend of **t@pit** is basically linear, as expected because the time at each pit from the trigger is ascending. The trend of the pit widths looks basically as expected. Notice that there are exactly as many events inside both trends, a necessary condition.



Set the display mode to **XY** (see next page and refer to the scope *Operator's Manual* for details on the available display modes). Bands of pit widths corresponding to widths that are ideal integer multiples of the clock period will be evident. Select Trace B (the trend of **t@pit**) and zoom to expand the time scale. Then select Trace A (the trend of **pwid**) and use the vertical ZOOM knob to adjust the band spacing. The vertical POSITION knob can be used to position the display vertically.

The next screens show the XY plot.



Measurement Parameters

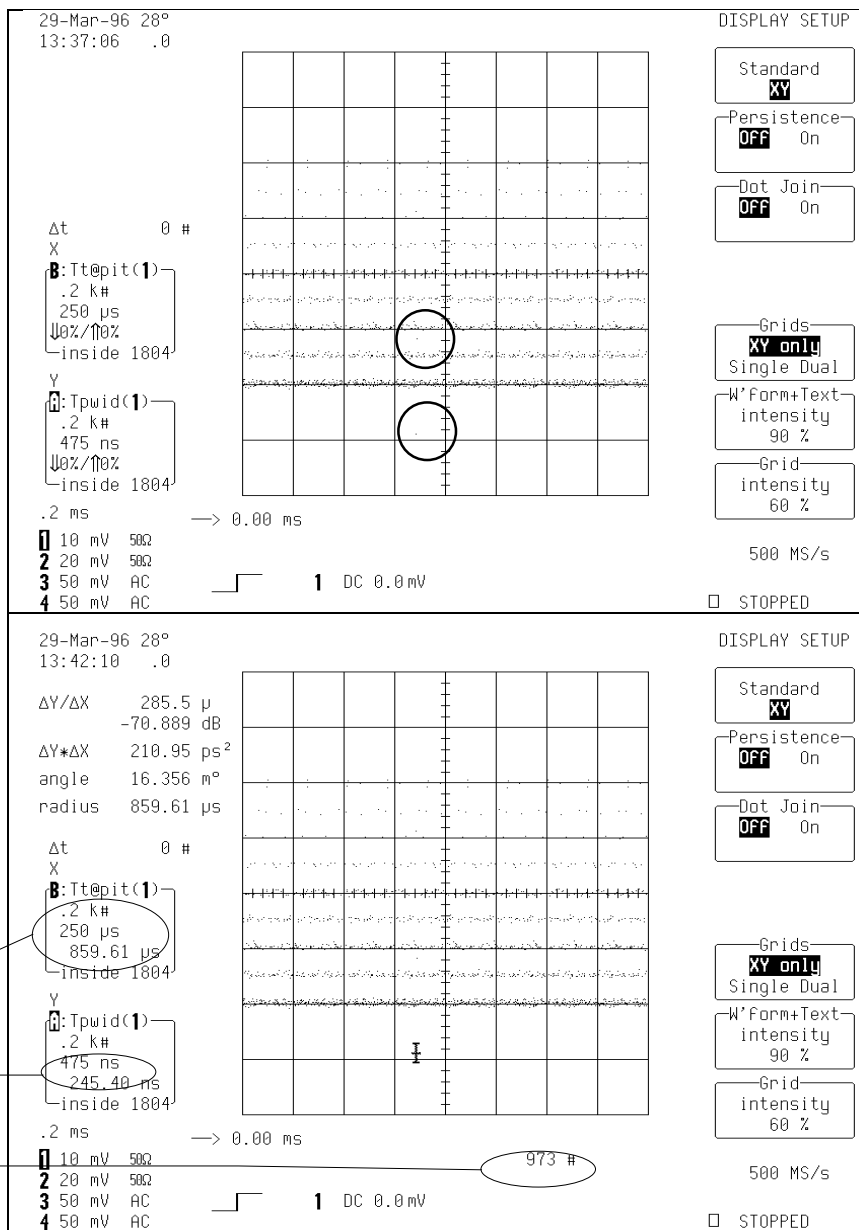
The XY plot has been adjusted so that all the pit widths are displayed vs. time. Notice that all form bands are sitting just below the 3T pit width band, and between the 4T and the 5T band. These strange pit widths, circled on the screen, occurred around the middle of the waveform.

Using time cursors, it can be seen that the beginning of this problematic pit width occurred at pit # 973, 859.61 μ s from the trigger. This smaller-than-normal pit is 245.40 ns.

Time of pit

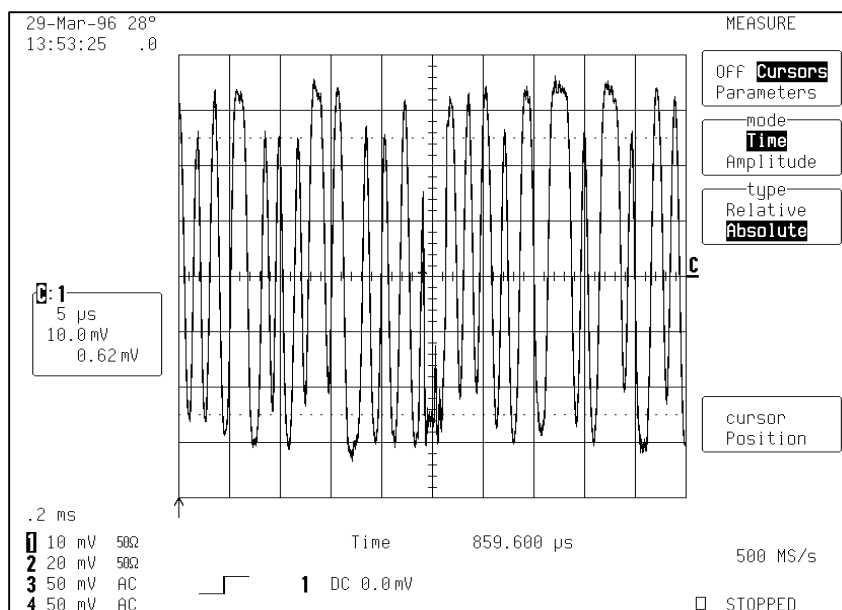
Width of pit

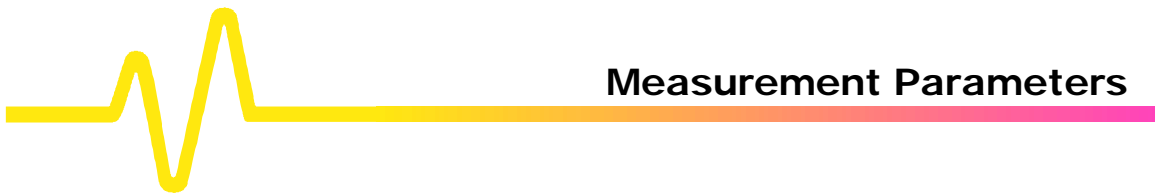
Pit event number



Now that a problem has been identified, we would like to view the portion of the waveform in which the problem occurred. Change the display mode to **Standard** and the grid to **Single**. Turn off the two trend traces, leaving only Trace C, which is the expanded trace of Channel 1. Move the absolute time cursor to the position in the trace at 859 μ s; and, using the **ANALYSIS CONTROL** position controls, position the waveform so that the cursor on the trace is at the center of the screen. Expand the waveform using the horizontal zoom control.

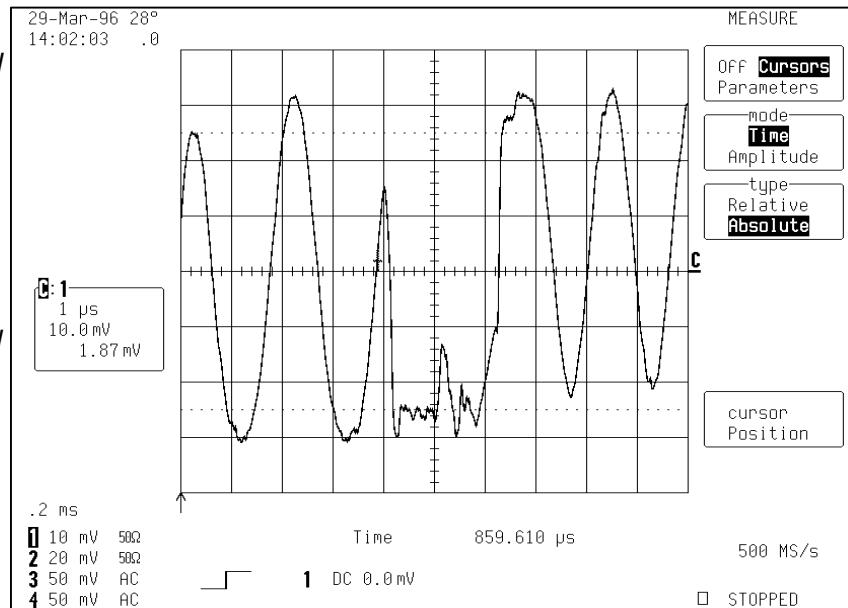
Here is the waveform zoomed in a bit with the measurement cursor placed at 859.600 μ s. As can be seen, there is some kind of aberration at the center of the trace.





Measurement Parameters

Further zooming clearly identifies the problem: a burst error that prevented the positive polarity width that starts at 859.61 μs from reaching its peak value. This defect caused the reflectivity to drop and to erratically fluctuate throughout the duration of the burst error. The defect affected the width of the next pit as well, which created the pit width centered between the 4T and 5T band of the XY plot.



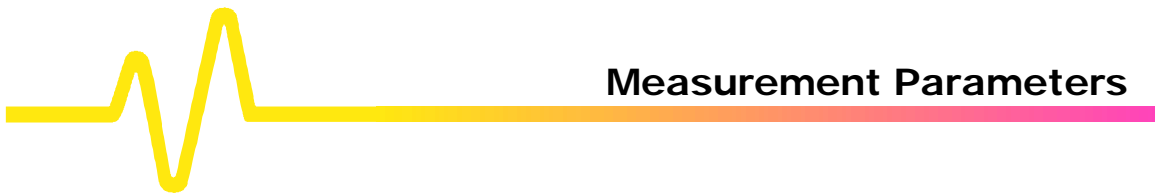
timj**Timing Jitter****Description**

Timing Jitter provides a measurement of the standard deviation of the difference of the width of pits and/or spaces from the mean width. The width of the pit/space is determined by the crossing of the selected voltage threshold. The measurement calculation is compliant with the definition of Timing Jitter as defined by ISO/IEC JTC1.23.14517 Section 22.4.

Display Options

ORM parameter calculations can be displayed, histogrammed (Chapter 6), and trended (Chapter 5) in a variety of ways. The table provides a concise description of the value or values displayed using each approach.

Display Type	Value Displayed
Parameter Statistics Off	Single value of the overall timing jitter for pits/spaces of interest for last acquisition.
Parameter Statistics On	Average, minimum, maximum, and sigma of the overall timing jitter value calculated per acquisition for all acquisitions since the last CLEAR SWEEPS operation.
List by nT	List of values of the timing jitter for each individual 'nT' in the selected range of 'nT' for the last acquisition.
Histogram Function	Histogram of the overall timing jitter values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.
Trend Function	Trend of the overall timing jitter values calculated for each acquisition for all acquisitions since the last CLEAR SWEEPS operation.



Example

A waveform is acquired which has 3T, 4T, and 5T pit widths as follows:

3T	4T	5T
695 ns	925 ns	1.16 μs
690 ns		1.18 μs
696 ns		

T is 231.5 ns, and the timing jitter parameter has been configured for a range of 3T through 5T.

The 3T mean is 693.66 ns. The 4T mean is 925 ns. The 5T mean is 1.17 μs.

The 3T timing jitter is calculated by taking the standard deviation of the difference between each width and the 3T mean. This is 3.214 ns, normalized by:

$$Timj_{3T} = 3.214 \cdot \frac{100\%}{231.5} = 1.389\%$$

The 4T timing jitter cannot be calculated because there is only one value (at least two values are required).

The 5T timing jitter is +6.109%.

The overall timing jitter is calculated using a weighting formula, which results in the standard deviation of the mean centered distributions. In this example, it is calculated as:

$$Timj_{overall} = \sqrt{\frac{1.389^2 \cdot (3 - 1) + 6.109^2 \cdot (2 - 1)}{(3 + 2 - 1)}} = 3.208\%$$

More On Timing Jitter

In order to understand the operation of the timing jitter parameter with different modes of operation, consider the histogram of 3T to 5T pit widths in Figure 4.10.

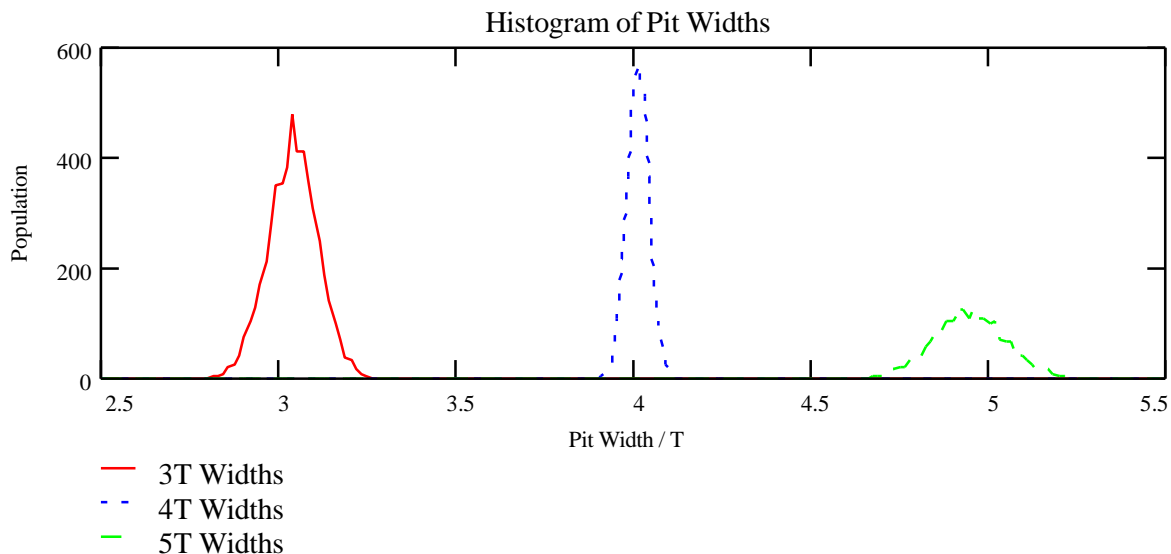


Figure 4.10

The Timing Jitter parameter considers each of these distributions separately. For each distribution the standard deviation is calculated. This is the timing jitter displayed for each nT distribution. Overall timing jitter is calculated by subtracting the mean width of each distribution from the widths in those distributions and considering the resulting superposition :

The sigma of the 3T, 4T, and 5T distributions are what is obtained when the Timing Jitter custom parameter is configured for single n values (the sigmas are the same as the sigma of the edge shift calculation). The sigma of the resulting superposition is what is obtained when the Timing Jitter custom parameter is configured for ranges of n values (in this case 3T to 5T).

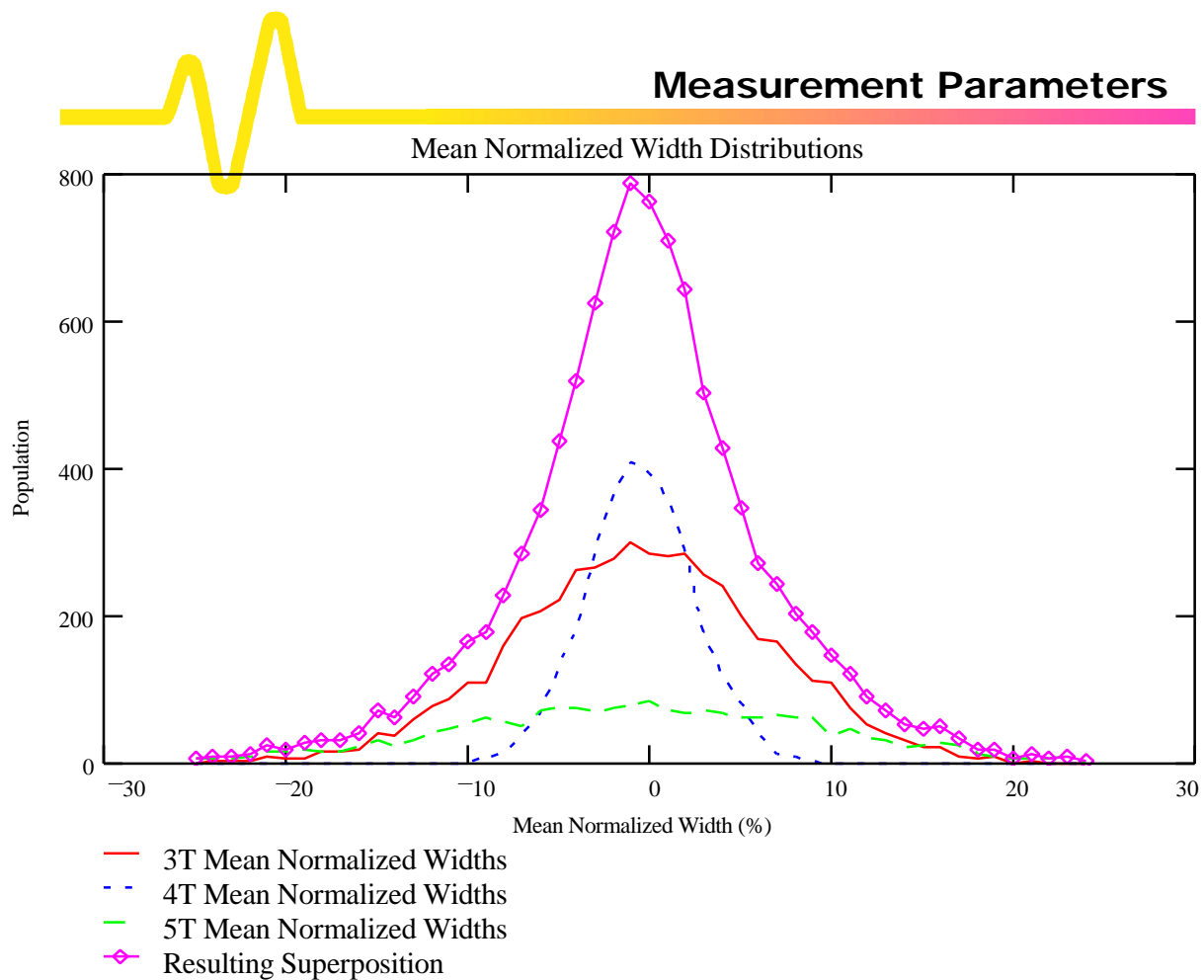


Figure 4.11

The value displayed on the custom parameter line (with statistics off) is the sigma of any of the resulting distributions *for the last acquisition only*. This timing jitter value is calculated internally without having to actually histogram the values. The values displayed in List by nT mode are the sigma of the width distributions resulting from each nT distribution *for the last acquisition*.

Note: Timing Jitter is always less than or equal to the standard deviation of superimposed Edge Shift distributions.

Signals, Coupling, and Threshold Settings

Which optical recording signal, or combination of signals should be used in a calculation? How should the signal be coupled, or the threshold set? The answers to these questions are sometimes uncertain. This appendix offers tips on how to answer them.

Choice of signals

Generally, the choice of signals depends on the aim of the measurement. For example, if the quality of the signal direct from the media is being examined, generally the signal at the output of the photo-detector should be used. Alternatively, a conditioned signal could serve the purpose.

A “sliced” or logic conditioned signal should normally be chosen when precise timing measurements are desired and propagation delay through the logic device (comparator) is not an issue. Timing measurement accuracy is improved when a fast signal is used, as opposed to the slower signals at the photo-detector, for the following reasons:

- A fast edge usually results in more accurate timing measurements because of interpolation algorithms, as long as points are sampled along the edge.
- A fast edge provides a threshold crossing time — and, therefore, measurement accuracy — more immune to noise.
- The use of the signal at the output of a logic device or comparator decreases the sensitivity of the measured threshold-crossing time to the exact value of the threshold level selected.
- The use of the signal at the output of a logic device or comparator typically solves other threshold problems as well, in systems that dynamically adjust the threshold based on the optical recording data signal. Sliced or logic signals facilitate the use of a fixed threshold.



Measurement Parameters

Coupling

DC coupling is required only for measurements of absolute DC values. Measurements requiring it include **ptop**, **pbase**, **pmin**, **pmax**, and **pmoda**. Otherwise, AC coupling is best used on signals that are not outputs of logic devices or comparators — those that might have varying thresholds.

Threshold Selection

If DC coupling must be used, there are some further considerations for threshold selection. While all of the optical recognition measurements specify thresholds used to extract the pits/spaces (by recording threshold crossings), there is a variance in the sensitivity of parameters to the exact threshold value selected. The sensitive parameters are those that are time related or whose values depend on the exact time of the threshold crossing. Those insensitive to the exact threshold value are parameters that use the threshold crossing time only to categorize the parameter result according to width (that is, they use the crossing time only to find the width for determining the nT index to which the pit/space belongs).

In the case of threshold-insensitive parameters, it usually suffices to use a fixed threshold somewhere in the middle of the optical recognition waveform. Even if the signal middle shifts, the fixed threshold is usually adequate.

Additionally, if the signal is AC coupled, it will tend not to shift much, and the fixed threshold will be perfectly adequate.

The problem arises when what is required is a DC-coupled signal with a threshold that changes dynamically throughout the waveform. There remains a possible solution, but the scope setup is slightly more complicated.

Consider the fact that AC coupling can be regarded as rejection of the DC component of a signal, or subtracting it from the signal. In many systems, the threshold is determined in precisely this manner by applying a low-pass filter to the signal, and then applying this value, with the signal itself, to the input of a comparator. If a threshold value determined in this manner is available in the circuit, the threshold signal, along with the optical recognition data signal itself, should be acquired. Waveform math can then be used to subtract the threshold signal. This is done by defining a trace as the Arithmetic

Difference of the raw data signal and the threshold signal. The new trace is then used as the optical recognition data signal in the parameter calculations.

Regardless of how the signal is coupled, there are other considerations involved in determining the appropriate threshold. If waveform math is used, the threshold is always 0 V. Otherwise, the optimum threshold is best determined using the **pmidl** parameter.

Some optical recognition standards define the middle level of the 3T signal as the “decision level.” **Pmidl** configured for the single 3T pits/spaces is an ideal candidate for the best threshold value. Another candidate is the **pmidl** value calculated using the entire range of n indices possible. In this way, **pmidl** calculates the best overall threshold level as a weighted average of middle levels calculated for each n index.

In AORM, the OR DATA function can be used to remove these effects. The “leveled” output subtracts the “threshold” (low frequency content of the signal) from the input data. When using this function, you should set the threshold to 0 V.



Using Parameters with Trends and XY Plots

X axis	Y axis
t@pit	$\Delta p2c$ edgsh pbase pmax pmin ptop pwid
pwid	pbase pmax pmin ptop
ptop	pmax
pbase	pmin

Example and Step-by-Step Instructions

We saw in the **t@pit** parameter description (page 4-55) how the ORM parameters have certain unique characteristics that make particular measurements useful when trended together with XY plots. And how the **t@pit** parameter is essential to those measurements. Plots that can be generated on single acquisitions include those listed in the table at left.

The reason that these plots are considered useful on single acquisitions is because the parameters are guaranteed to be configurable in a manner that meets the following criteria:

1. Each parameter is capable of providing multiple values per acquisition.
2. Each parameter pair is configurable in a manner that guarantees the same number of events per waveform.
3. Each parameter pair must be configurable in a manner that guarantees a one-to-one correspondence between parameter calculation values.

Here is an example typifying the use of XY plots without the **t@pit** parameter. A complete example using **t@pit** has been provided in the section dedicated to this parameter description.

Consider a situation in which it is desirable to find the relationship of the pit top value to the pit width in an optical recognition data waveform:

The scope is set up to acquire this waveform by assigning Channel 1 to the data signal at a time/div of 0.2 ms. This signal will contain approximately 1800 pits/spaces. The ideal threshold has been determined by the **pmidl** parameter as 1.9 mV.

The **ptop** custom parameter is assigned to line 1, and the **pwid** parameter is assigned to line 2. Use configuration **tracking** to configure both parameters in the following manner:

hysteresis = 0.5 divisions
threshold = 1.9 mV
polarity = Pos
range of n
low $n = 3$
high $n = 11$
period = 231.5 ns

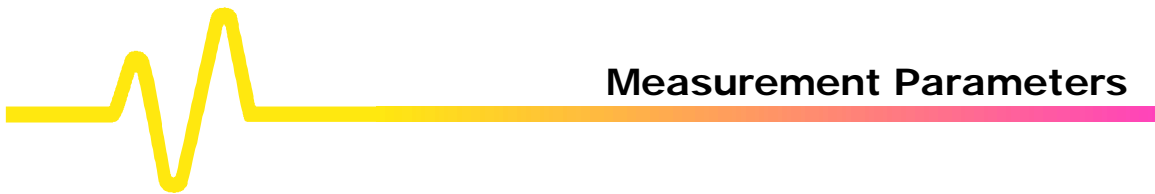
In math setup, Trace A is defined as the trend of the **ptop** parameter and Trace B as the trend of the **pwid** parameter. Because we are expecting 1800 pits/spaces, make sure that for each math setup the trends are set to use up to 20000 values, the maximum amount.

Note: *If configuration tracking is used on the ptop parameter, the pwid parameter must be visited in order to set the polarity to positive because ptop inherently implies positive polarity pits.*

The trigger is set to trigger on a pit edge and is operated initially in single-shot mode. For convenience, the waveforms are ordered on the screen in a particular manner so that they will automatically work correctly with XY display mode:

1. Trace B: Trend of **t@pit**
2. Trace A: Trend of **pwid**
3. Channel 1: optical recognition data signal

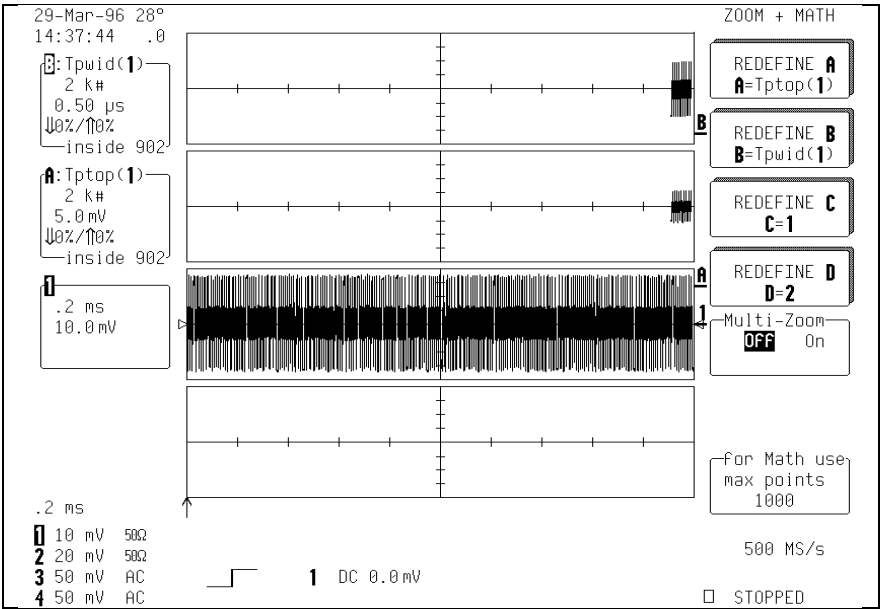
Note: *Prior to acquisition, select each trace and press the RESET button to ensure that all the traces are reset.*



Measurement Parameters

The single-shot trigger button is pressed and the waveform acquired. The waveform should be centered on the screen. The trends will typically have data not well centered or off-screen. These traces can be positioned on the grid by pressing the **FIND CENTER AND HEIGHT** menu button in each trend setup menu. The screen shown here is what each trace looks like after the waveform has been acquired and the trends centered.

The waveforms are displayed in Quad grid mode. Notice that there are exactly as many events inside both trends, a necessary condition. Although the trends are very short (containing only 902 out of the total 20,000 pits allowed) repeated triggering will eventually fill in both trends sufficiently.



Set the display mode to XY. Clusters of pit top values will be apparent: clustered because the tops tend to be approximately the same amplitude and the pit widths approximate multiples of the clock period. Select Trace B (the trend of **pwid**) and use the vertical **ZOOM** control to expand the X-axis scale. Select Trace A (the trend of **ptop**) and use the **ZOOM** knob to adjust the vertical scale. The vertical **POSITION** knob can be used to position the display vertically.

The XY plot has been adjusted so that all of the pit tops are displayed vs. Pit width. Notice that all of the pit widths form clusters.

Difference between x
cursor locations

29-Mar-96 28°
14:43:04 .0

Δt 0.00 kH
X
B: 1pwid(1)
2 kH
480 ns
100% / 100%
inside 902

Y
C: 1ptop(1)
2 kH
4.70 mV
100% / 100%
inside 902

.2 ms → 0.00 ms

1 10 mV 50Ω
2 20 mV 50Ω
3 50 mV AC
4 50 mV AC

1 DC 0.0 mV

Standard
XY

Persistence
OFF On

Dot Join
OFF On

Grids
XY only
Single Dual

Waveform+Text
intensity
90 %

Grid
intensity
60 %

500 MS/s

STOPPED

Difference between v cursor

Difference between y cursor	
locations	

The oscilloscope screen displays a waveform with the following settings and measurements:

- Top Left:** 28° -Mar-96 28° 14:54:51 .0
- Left Panel:**
 - $\Delta Y/\Delta X$ 32 kV/ 90.0 dB
 - $\Delta Y * \Delta X$ 0.21 nVs
 - angle 89.9982 °
 - radius - - -
 - At 0.00 k#
 - X:
 - B: Tpwid(1)
 - 2 k#
 - 255 ns
 - 82 ns
 - inside 20000
 - Y:
 - A: Tptop(1)
 - 2 k#
 - 1.72 mV
 - 2.58 mV
 - inside 20000
- Bottom Left:** .2 ms
- Bottom Center:** → 0.00 ms
- Bottom Right:** 1 DC 0.0 mV
- Right Panel:**
 - MEASURE
 - OFF Cursors Parameters
 - mode Time
 - Relative Absolute
 - Control X Y cursors
 - Ref + Diff cursors
 - Track OFF On
 - Difference cursor
 - 500 MS/s
 - STOPPED



Improving Horizontal Measurement Accuracy

Horizontal measurement accuracy pertains to timing-related measurements. In the ORM package, these are Dp2c, Dp2cs, edgsh, lper, pwid, t@pit, and timj. In many cases, measurement accuracy can be improved by considering certain items pertaining to how a DSO operates and how parameters are measured.

DSOs sample the signal, building a waveform that consists of points at intervals determined by the sample rate. One obvious consideration for maximizing horizontal measurement accuracy is to ensure that the highest sample rate possible is used. On low time/divs, waveforms become long. Thus it is important to set the **Record up to** value for the timebase menu to the largest possible value. This ensures the highest sample rate based on the time/div setting.

Times are calculated for optical recognition parameters by interpolating between points that straddle the threshold specified. Measurement accuracy is improved when the edge is:

1. fast enough to enable points straddling the threshold that are far from the threshold, and
2. slow enough, and the sample rate high enough, to enable points to be sampled on the edge.

In most cases, these considerations are taken into account by sampling at the highest rate possible and by ensuring that the volts/div setting is as low as practically possible.

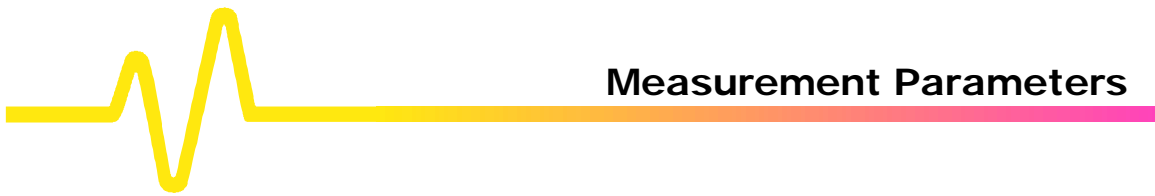
Note on RIS (Random Interleaved Sampling)

RIS is a mechanism used by the oscilloscope to increase the effective sample rate by interleaving samples taken over multiple waveform acquisitions. The scope enters RIS mode when the time/div setting is set extremely low.

Because multiple acquisitions are interleaved in RIS, a highly stable trigger signal must be maintained, and precisely the same waveform acquired on each acquisition.

For most ORMs, RIS is neither appropriate nor recommended. If not used properly, it will result in erroneous measurements.

(For more on RIS, see your scope's Operator's Manual.)



Base and Top Calculation Details

The base and top are designed to emulate results in the past obtained from persistence plots. In general, the top was calculated by examining the most intense region near the top of a waveform in an eye-pattern persistence map. The ORM package improves on this in that the tops of *all* pits are calculated independently: rogue amplitude variations in the waveform can be identified.

The waveform in Figure 4.12 contains two pits. We need only consider the first of these.

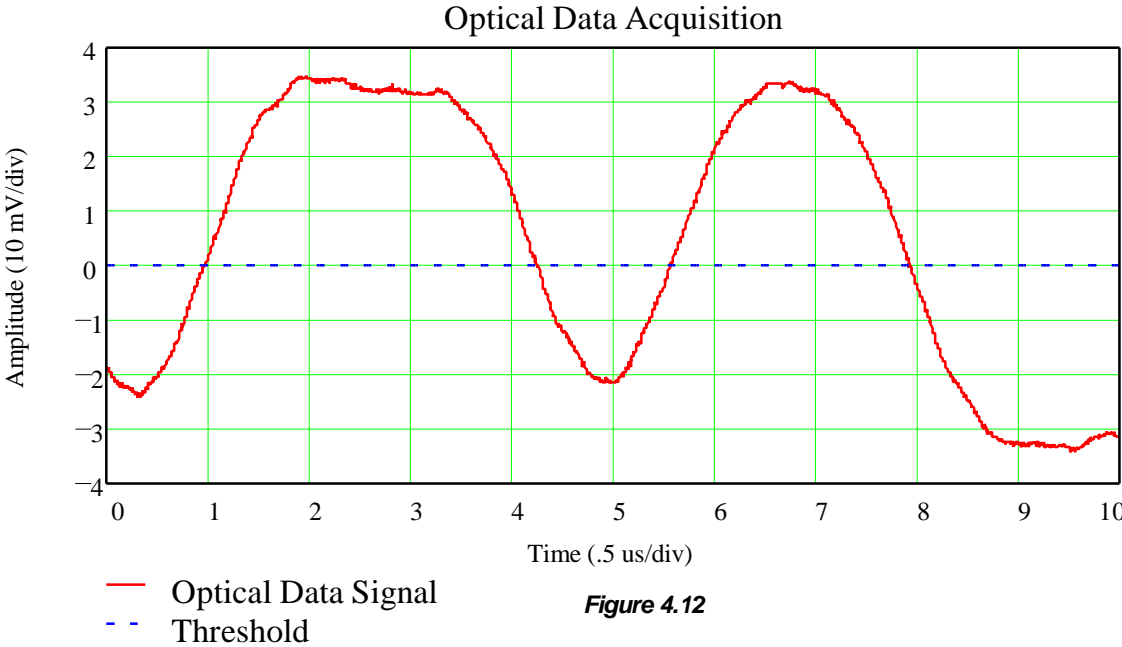


Figure 4.12

The ORM package histograms the values inside each pit to determine the most likely amplitude: the most densely populated region.

Figure 4.13 shows the histogram of the pits' amplitudes. It is easily seen that the most likely amplitude is approximately 32 mV (exactly 31.9 mV). The top is calculated by averaging all of the waveform data points at or above this, to give a result of 32.89 mV.

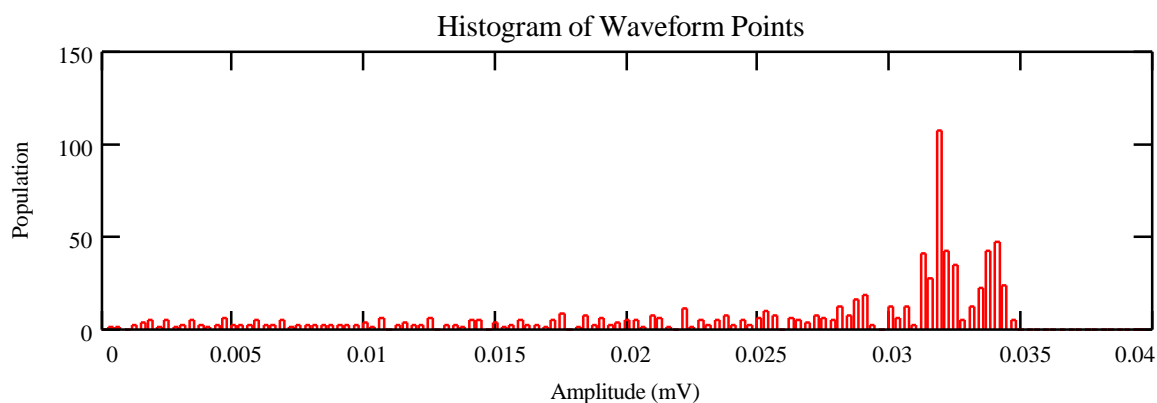
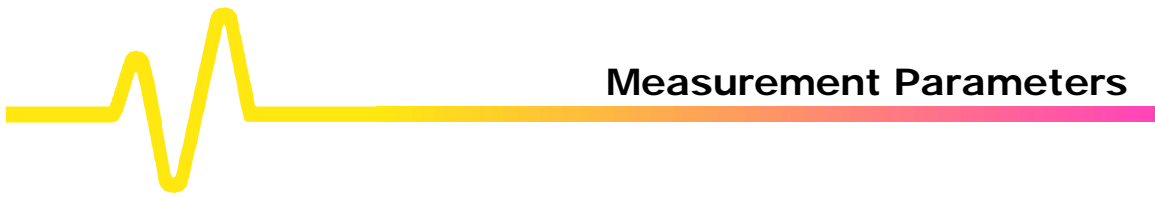


Figure 4.13

In Figure 4.14 (next page), the top bisects the two flattest regions at the top of the waveform and, in effect, calculates the value that would be estimated from examination of an eye-pattern persistence map.



Measurement Parameters

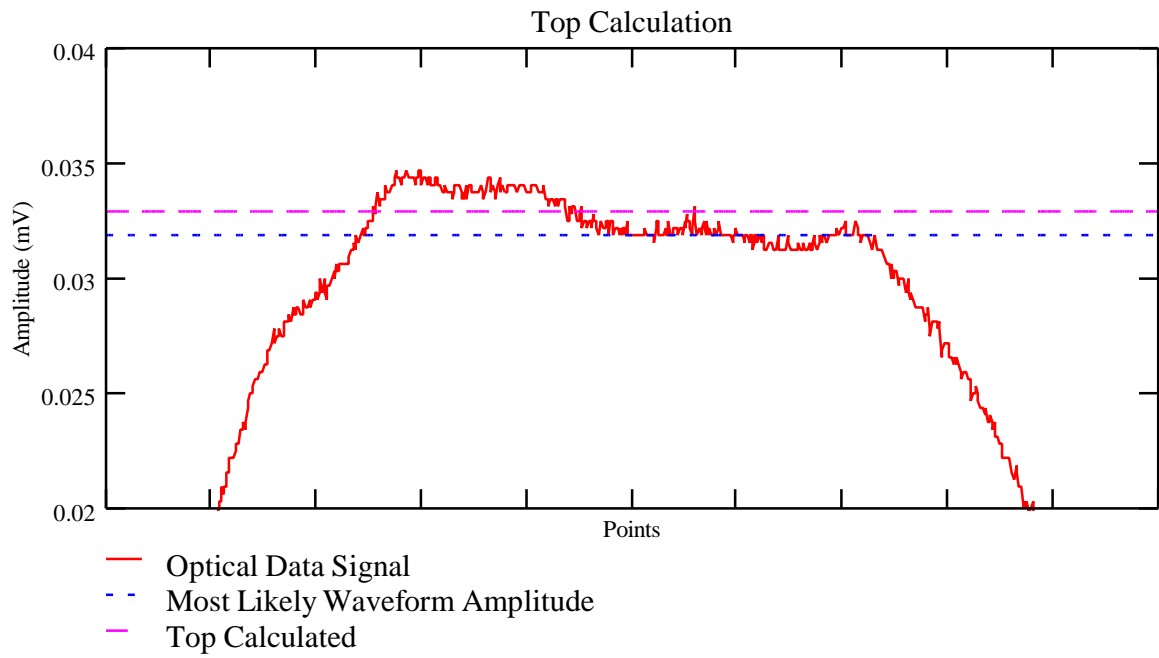


Figure 4.14

#

Displaying Trends

The Trend function for processing waveforms enables the creation of graphs of successive waveform parameter measurement values. It provides useful visual information on waveform parameter variation. Used together with other scope features, it allows you to graph certain parameters compared to others.

To Configure a Trend:

1. *Select and configure a custom parameter, which will be used to perform the measurement that is to be trended. This can be done either by:*
 - *choosing “Custom” mode from the “MEASURE” “Parameters” menu group as for histograms (see the oscilloscope Operator’s Manual), or*
 - *accessing the same menu group using the “PARAMETER SETUP” menu from the “TREND...” group (see this section).*

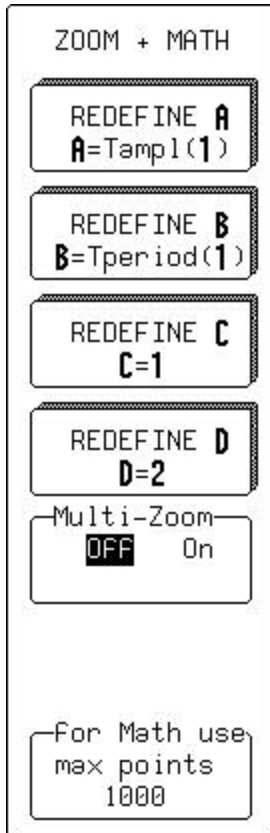
Then select the desired parameter from the “CHANGE PARAM” menus that will be displayed.
2. *Define one of the definable traces — A, B, C, or D — as using Math, and select “Trend” as the “Math Type” (see page 5– 4).*
3. *Select the custom parameter line to be used in the trend.*
4. *Choose the number of values to be placed in the generated trend (page 5– 5).*
5. *Decide whether all the parameters generated from the waveform or only the average of all parameter calculations for each waveform acquisition should be placed in the trend.*
6. *If desired, you can also configure the center and height of the trend at this stage, in the base units of the parameter being trended. However, this is not a requirement and “FIND CENTER AND HEIGHT” can be used to center the trend once the trend has been calculated.*



The Trend Configuration Menus

Press the **MATH TOOLS** button to access the **ZOOM + MATH** menus (see the “**MATH SETUP**” Chapter of the scope’s *Operator’s Manual*). These allow the redefinition of each of the four traces (A, B, C, and D) and access their “**SETUP**” menus.

This is illustrated in this example with Trace A defined as a trend of the parameter *amplitude*, and Trace B as a trend of *period*. C and D are zooms of Traces 1 and 2.



REDEFINE A

Defined as the trend of the custom parameter performed on Channel 1, **Trace A** can be set up by pressing the button corresponding to this menu.

REDEFINE B

Defined as the trend of the custom parameter performed on Channel 1, **Trace B** can be set up by pressing the button corresponding to this menu.

REDEFINE C

Defined as a zoom of Channel 1, **Trace C** can be set up by pressing the button corresponding to this menu.

REDEFINE D

Defined as a zoom of Channel 2, **Trace D** can be set up by pressing the button corresponding to this menu.

Multi-Zoom

When **On**, this enables zoom and position controls on all traces at once.

for Math Use

Use this to set the number of points in certain math functions, using the associated menu knob.

Note for Display of Trends:

- ***Expansion, or zooming, and positioning of traces is controlled by the horizontal and vertical ZOOM and POSITION knobs.***
- ***When Multi-zoom is on, the ZOOM and POSITION knobs are coupled and control all displayed traces at once. This is particularly useful when multiple trends of related parameters are displayed.***
- ***The button resets the multiplier for the trace expansion to '1' and the offset positioning to '0.' The button should be pressed for each reconfigured trace in order that traces can be cleanly and correctly positioned on-screen.***

SETUP OF A

This allows the selected trace (here Trace A) to be set up for trending.

SETUP OF A

use Math?
No Yes

Math Type
FFTAvg
Functions
Histogram
Rescale
Trend

MORE TREND SETUP

FIND CENTER AND HEIGHT

Trend of custom line 1 ampl(1)

using up to 20000 (values)

use Math?

Use this to define the trend as using math, which is necessary for the trend itself to be defined. Traces can be defined to use math or as zooms of other traces. Because trending is a math function, "use Math?" should be set to **Yes** by using the corresponding menu button.

Math Type

This is for selecting **Trend**.

MORE TREND SETUP

Use this to access more trend setup options and the final trend-dedicated menu (next page).

FIND CENTER AND HEIGHT

This is for positioning the trend automatically once it has been calculated. **FIND CENTER AND HEIGHT** places the trace appropriately, centering and scaling the trend without affecting the zoom and position settings. But ensure that these settings have been reset (as described on the previous page).

Trend of

Use this to select the parameter for trending, using the corresponding menu button or associated knob. Choose any of the configured parameters displayed on the line beneath the grid.

Using up to

Using the associated button or knob, this is for selecting the number of values in the trend. A maximum of 20 000 values can be chosen for any one trend. When this maximum is exceeded, the parameter results scroll off the trend.

TREND **A**

TREND **A**

Values

All Average
All/Trace

PARAMETER
SETUP

FIND CENTER
AND HEIGHT

Center

+6.22277 E-02
6 digits

Height

5.000
(per div)

This menu group appears when "MORE TREND SETUP" is selected (previous page).

Values

Use this to select **All**, which is for every parameter calculation on each waveform to be placed in the trend. Or use it to select **Average**, which is to trend only the average of all the given values calculated on a given acquisition, and to obtain one point in the trend per acquisition. Or **All/Trace**, which for each acquisition, clears the buffer and places all parameter calculations from the new data in the trend. Unless this is specifically required, **All** should be selected.

PARAMETER SETUP

Use this to access the setup menus for the selected parameter, the same menus as the "CHANGE PARAM" group.

FIND CENTER AND HEIGHT

This is for positioning the trend automatically after it is calculated. **FIND CENTER AND HEIGHT** places the trace appropriately, centering and scaling the trend without affecting the zoom and position settings. But ensure that these settings have been reset (as described in the panel on page 5-1).

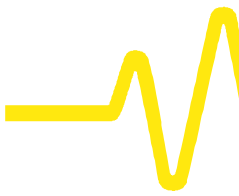
Center

This is for selecting the mantissa, exponent, or number of digits resolution, using the associated knob. The configuration is the value at the horizontal center line on the grid, while units are those of the parameter trended.

Height

Using button or knob, this selects the vertical value of each vertical screen division. Units are those of the parameter trended.

Note: Press the RESET button after you have configured the parameter in CHANGE PARAM to return to the menus shown on this page.



Trend Calculation

Once the trend has been configured, parameter values will be calculated and trended on each subsequent acquisition. Immediately following the acquisition, its trend values will be calculated. The resulting trend is a waveform of data points that can be used the same way as any other waveform. Parameters can be calculated on it, and it can be zoomed, serve as the x or y trace in an XY plot, and be used in cursor measurements.

The sequence for acquiring trend data is:

1. trigger
2. waveform acquisition
3. parameter calculation(s)
4. trend update
5. trigger rearm

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

Parameter Buffer

The oscilloscope maintains a circular parameter buffer of the last 20 000 measurements made, including values that fall outside the set trend range. If the maximum number of events to be used in a trend is a number 'N' less than 20 000, the trend will be continuously updated with the last 'N' events as new acquisitions occur. If the maximum number is greater than 20 000, the trend will be updated until the number of events is equal to 'N.' Then, if the number of bins or the trend range is modified, the scope will use the parameter buffer values to redraw the trend with either the last 'N' or 20 000 values acquired, whichever is less.

The parameter buffer thereby allows trends to be redisplayed using an acquired set of values and settings that produce a distribution shape with the most useful information.

In many cases, the optimal range is not readily apparent, so the scope has a powerful range-finding function. If necessary, it will examine the values in the parameter buffer to calculate an optimal range, and redisplay the trend using it. The instrument will also give a running count of the number of parameter values that fall within, below and above the range. If any fall below or above the range, the range-finder can then recalculate 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 trend events. For each standard parameter and for a waveform section between the parameter cursors, the following table provides a summary of the number of trend 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.



Reading Trends: A trend is like any other waveform: its horizontal axis is in units of events, with earlier events in the leftmost part of the waveform and later events to the right. And its vertical axis is in the same units as the trended parameter. When the trend is displayed, trace labels like the ones below (for Trace A in these examples) appear in their customary place on the screen, identifying the trace, the math function

horizontal and vertical information :

```
A:Temp1(1)
20 #
200 µV
49.731mV
inside 200
```

- < # number of events per horizontal division
- < Units per vertical division, in units of the parameter being measured
- < Vertical value at point in trend at cursor location when using cursors
- < Number of events in trend that are within unzoomed horizontal display range.

```
A:Temp1(1)
20 #
200 µV
↓1%/↑0%
inside 193
```

- < Percentage of values lying beyond the unzoomed vertical range when *not* in cursor measurement mode.

Using Measurement Cursors

The parameter cursors can be used to determine the value and population of selected areas.

Figure 5.1 shows the Time cursors (item ❶) positioned on the selected trend vertex, whose order number (❷) and value (❸) are also shown.

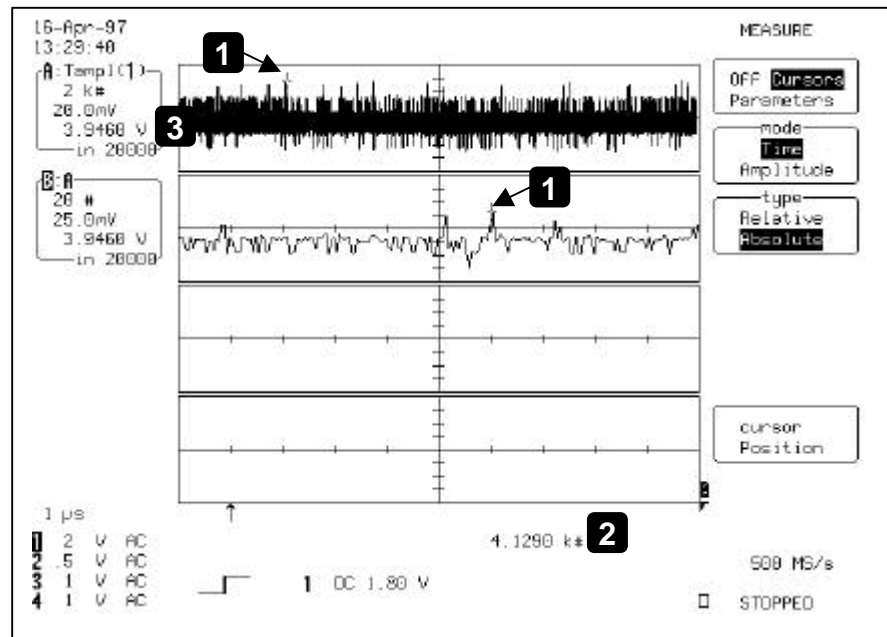
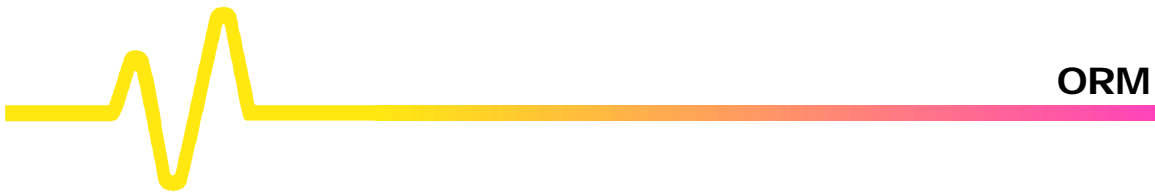


Figure 5.1

#



BLANK PAGE

Theory of Operation

An understanding of statistical variations in parameter values is needed for many waveform parameter measurements. Knowledge of the average, minimum, maximum, and standard deviation of the parameter may often be enough, 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. They divide a range of parameter values into sub-ranges called bins. A count of the number of parameter values calculated (events) that fall within its sub-range is maintained for each bin.

While the range can be infinite, for practical purposes it need only be defined 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 $4\text{ V} \pm 2.5\text{ V}$ 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 per 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 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 histogram is referred to as its population. Figure 6.1 shows a histogram's highest population bin as the one with a sub-range of 4.3 to 4.4 V, which is to be expected of a TTL signal. The lowest value bin with events is that with a sub-range of 3.0 to 3.1 V. Because 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.

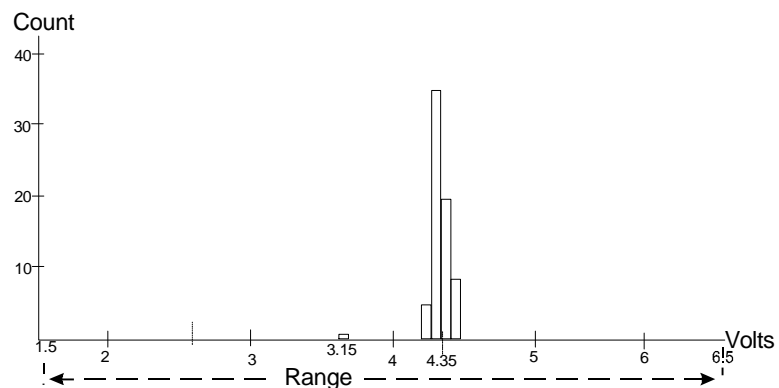


Figure 6.1

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 less. 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 necessary, 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 v alues in the region analyzed
duty, freq, period, width	Up to 49 ev ents 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 ev ent per acquisition
f@level, f80–20%, fall, r@level, r20–80%, rise	Up to 49 ev ents 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 v alue, standard deviation
- Most common v alue (parameter v alue of highest count bin)
- Leftmost bin position (representing the lowest measured wav eform parameter v alue)
- Rightmost bin (representing the highest measured wav eform parameter v alue).

Histogram parameters are provided to enable these measurements. Accessible by selecting **Statistics** from the **Category** menu, they are calculated for the selected wav eform section between the parameter cursors (for a full description of each parameter, see Chapter 7):



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 (with its associated bins) as a **histogram peak**.

Example

In Figure 6.2, 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.

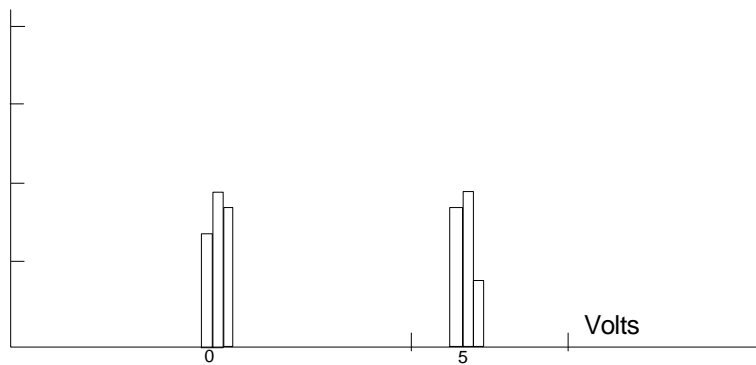


Figure 6.2

Determining such peaks is very useful because they indicate the dominant values in 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 distinguish peaks from background noise and from 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 on page 7-14.

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 the creation of gaps between populated bins that may make determination of peaks difficult.

Figure 6.3 shows a histogram display of 3672 parameter measurements divided into 2000 bins. The standard deviation of the histogram sigma (item ①) is 81.17 mV. Note the histogram's jagged appearance.

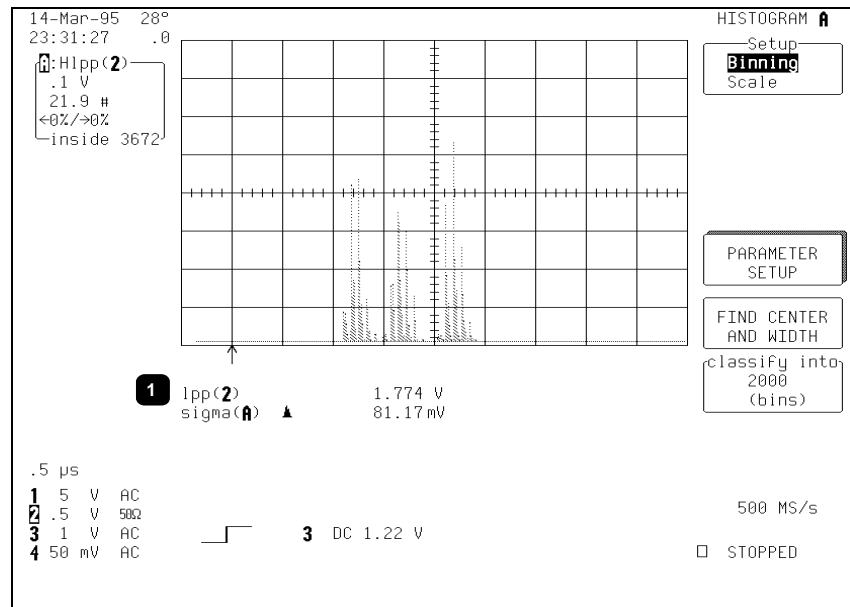


Figure 6.3

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

Histograms

the user. In addition, depending on the number of bins selected, the change in waveform parameter values can be seen.

In Figure 6.4, 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 v.s. 81 mV).

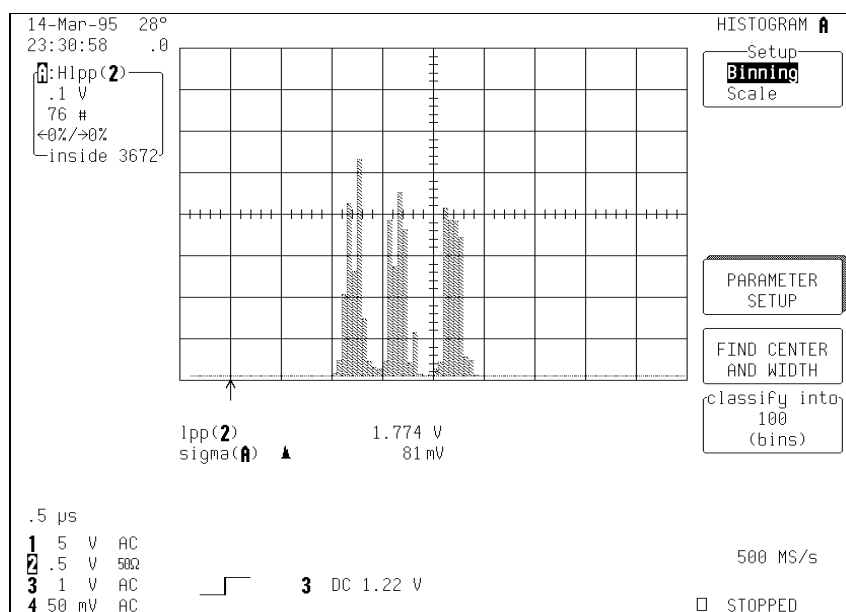


Figure 6.4



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 6.5 shows a screen display accompanying the selection of a frequency (**freq**) parameter measurement (item ❶) for a sine waveform on Channel 1.

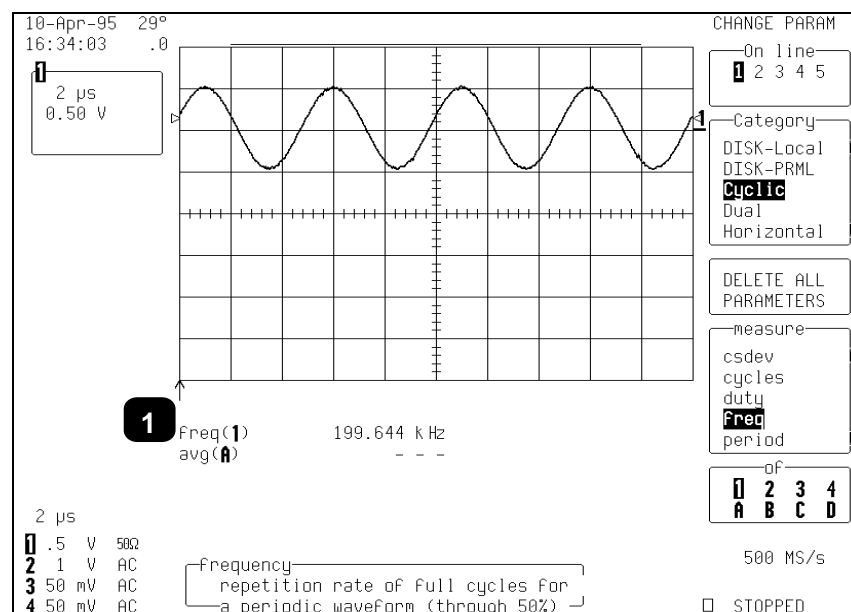


Figure 6.5

Histograms

The preceding figure shows four waveform cycles, which will provide four freq parameter values for each histogram on 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 TOOLS** button. Figure 6.6 shows the resulting display. To place the histogram on Trace A, press the menu button corresponding to the **REDEFINE A** menu.

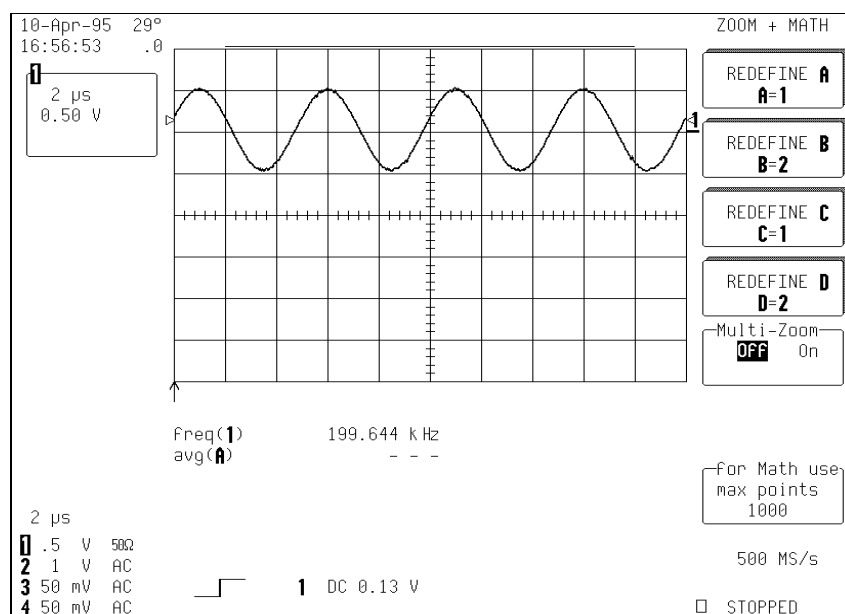


Figure 6.6



Once a trace is selected, the screen shown in Figure 6.7 appears. Selecting **Yes** from the **use Math?** menu enables mathematical functions, including histograms.

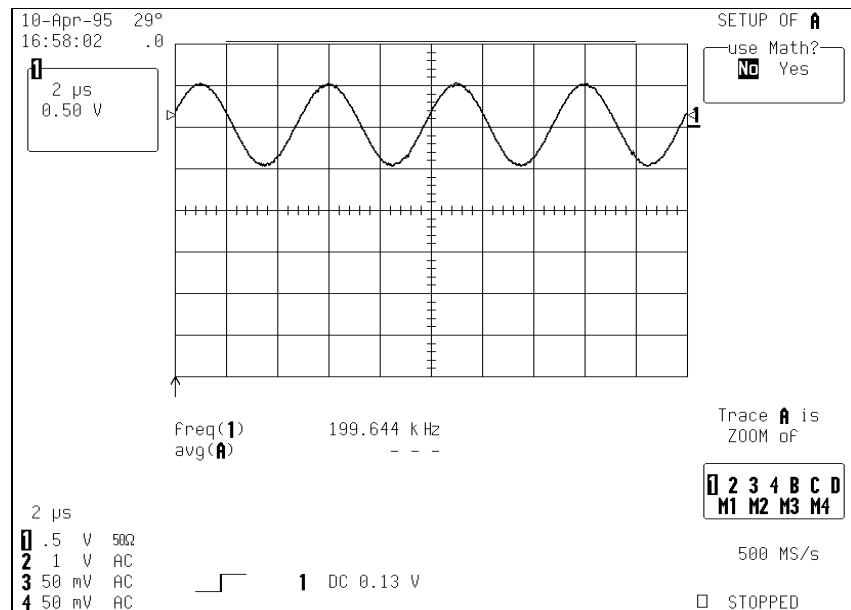


Figure 6.7

Histogram Trace Setup Menu Figure 6.8 (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.

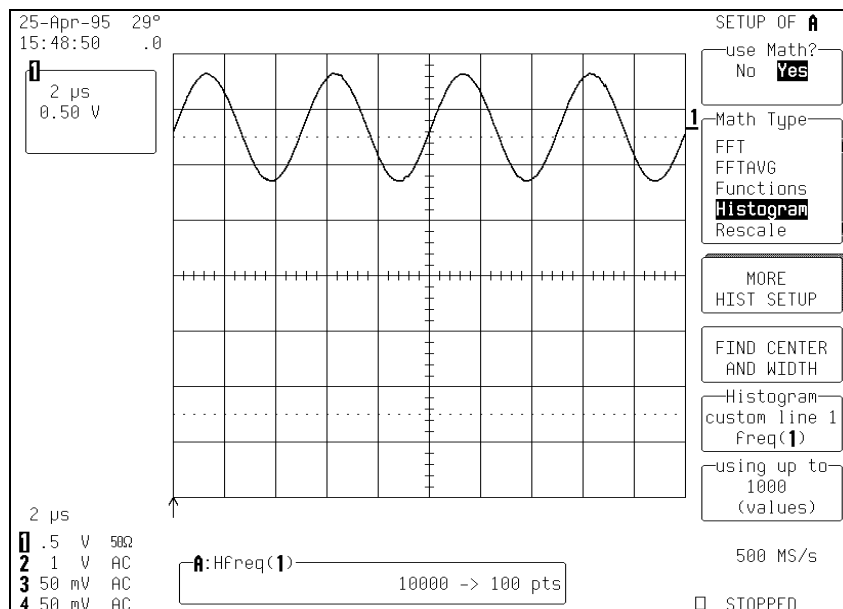


Figure 6.8

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 button. You will see a display similar to that shown in Figure 6.9.

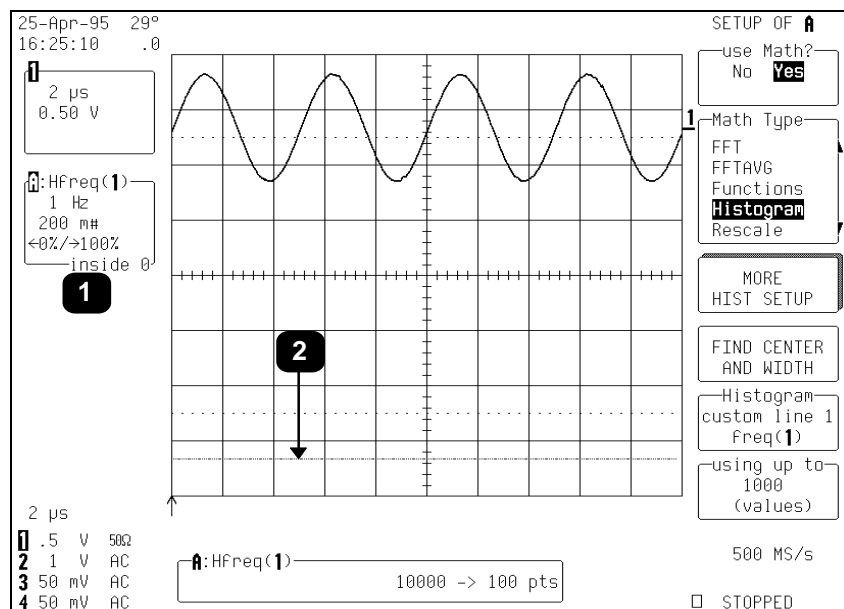


Figure 6.9

You set each histogram 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** (item 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%").

Histograms

- 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 (item ②) 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 6.10 shows a typical result.

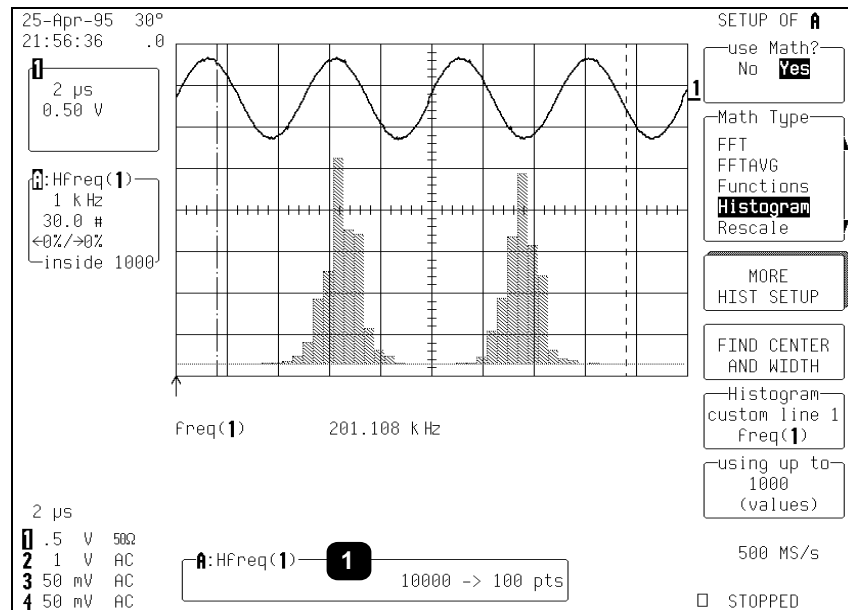


Figure 6.10



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

The **Information Window** (item 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 6.11 below.

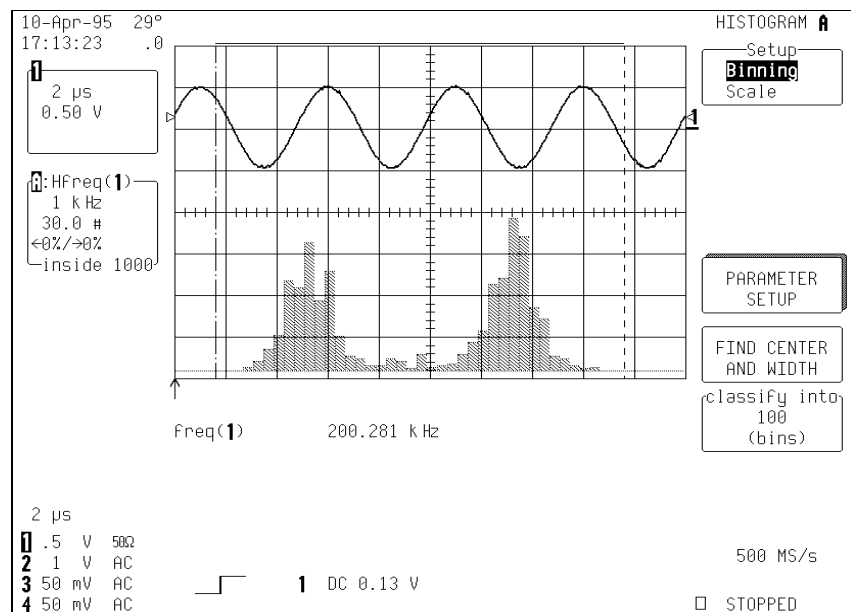


Figure 6.11

Setting Binning & Histogram Scale

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

The number of bins used can be set from a range of 20 to 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 to that of Figure 6.12 will be displayed.

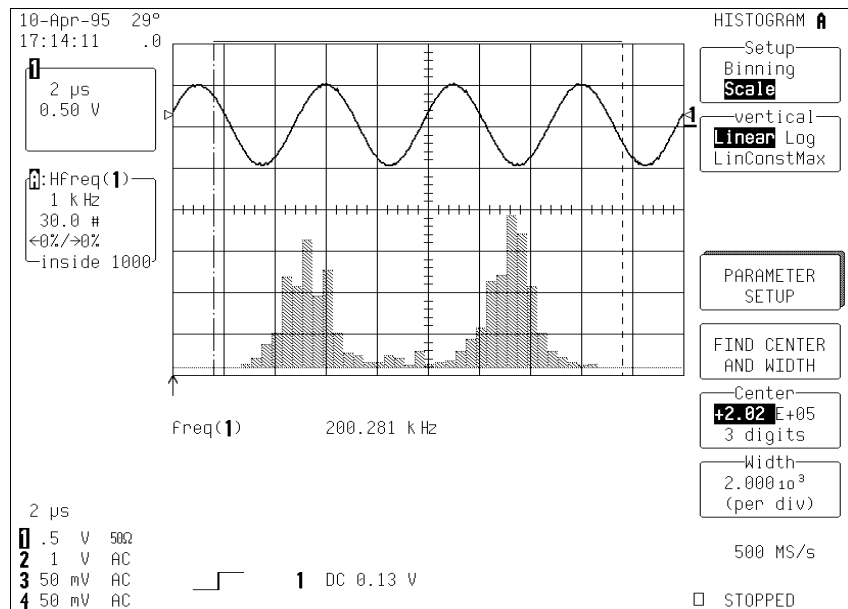


Figure 6.12

1. **Linear** makes the vertical scale 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** makes the vertical scale logarithmic (Figure 6.13). Because a value of '0' cannot be specified logarithmically, no baseline is provided.



Histograms

3. **LinConstMax** sets the vertical scaling to a linear value that uses close to the full vertical display capability of the scope (Figure 6.14). The height of the histogram will remain almost constant.

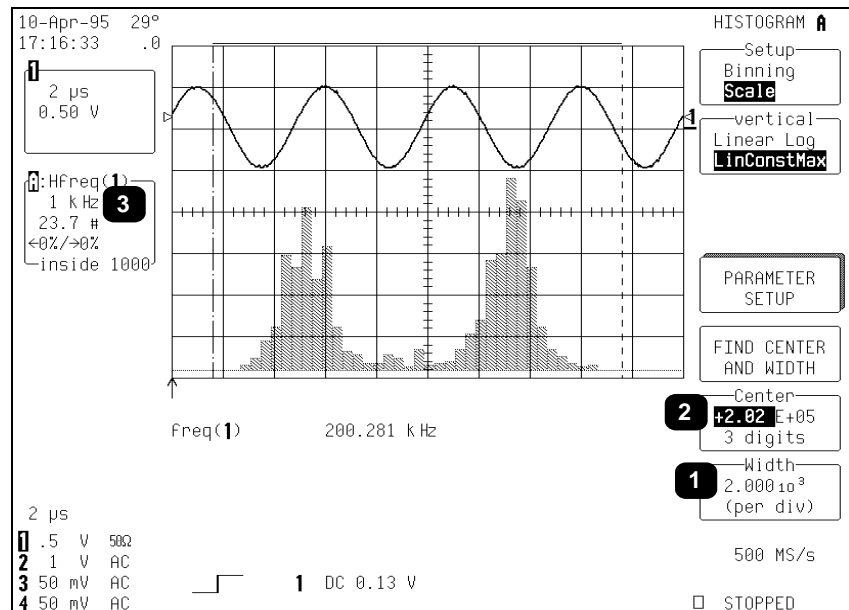


Figure 6.14

For any of these options, the scope automatically increases the vertical scale setting as required, ensuring that 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 multiplied by 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 2.000×10^3 (item ❶). Because the histogram is of a frequency parameter, the units of the measurement parameter is hertz.

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

$$(2 \text{ kHz/division}) \times (10 \text{ divisions}) = 20 \text{ kHz}$$

with a center of $2.02 \text{ E}+05 \text{ Hz}$ (❷).

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

$$20 \text{ kHz} / 100 \text{ bins, or}$$

$$0.2 \text{ kHz per bin}$$

The “Center” menu allows you 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 kHz/division, shown in the Trace Display Field, is indicated by item 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 kHz ± 10 kHz 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.

Histograms

Selecting the “PARAMETER SETUP” menu shown in the previous figure accesses the “CHANGE PARAM” menus, shown in Figure 6.15.

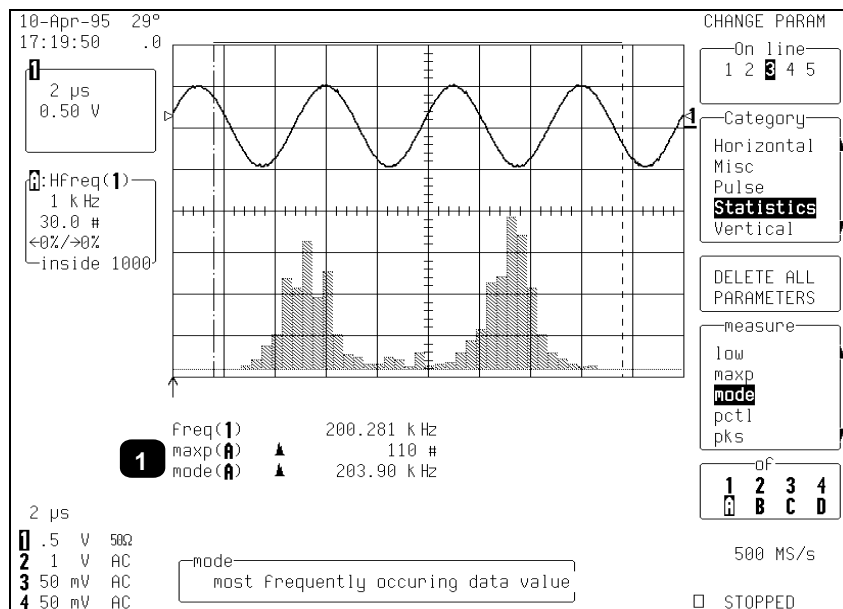



Figure 6.15

New parameters can now be selected, or previous ones modified. In this figure, the histogram parameters **maxp** and **mode** (item ①) 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 that the highest bin has a count of 110 events.
- The value of **mode(A)** is “203.90 kHz,” indicating that this bin is at 203.90 kHz.



- 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 6.16 shows the average (item 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.

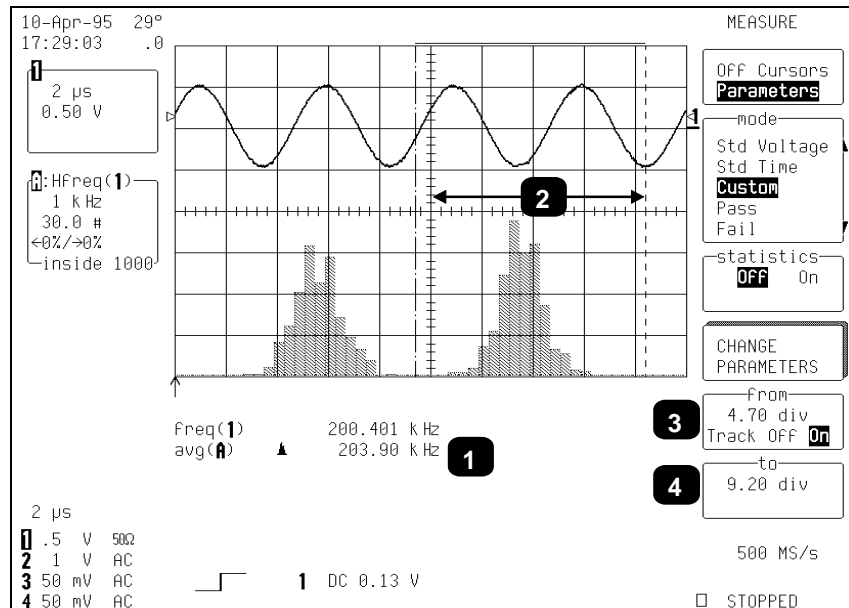


Figure 6.16

Histograms

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 which lies 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 6.17 shows “Selected” a histogram of the frequency (“freq”) parameter for **Segment 1** (item ①) of Trace “A,” which is a zoom of a 10-segment waveform on Channel 1.

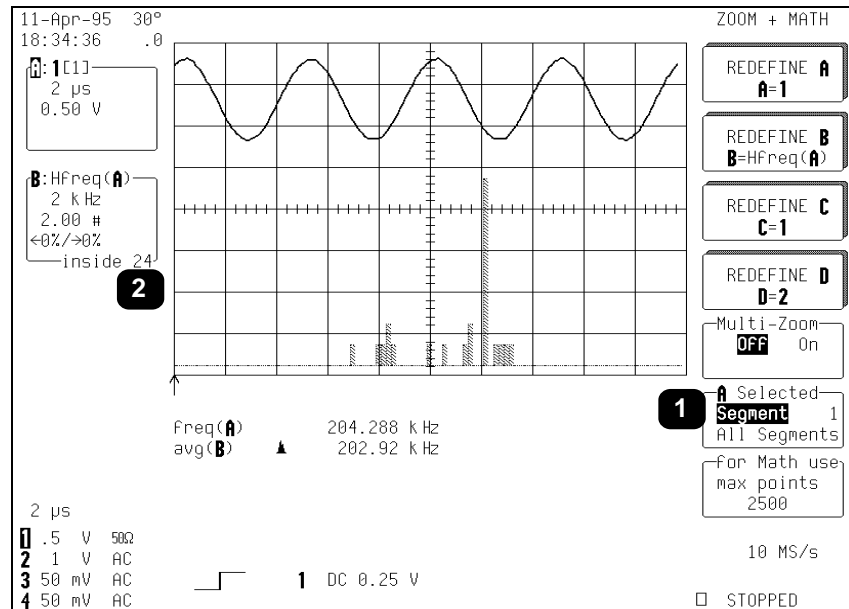
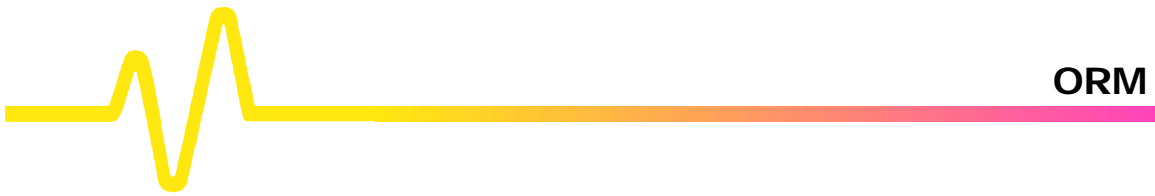


Figure 6.17

The Displayed Trace Field shows that 24 parameter events (item ②) have been captured into the histogram. The average



value for the freq parameter is displayed as the histogram parameter, “**avg(B).**”

Figure 6.18 shows the result of selecting **All Segments**.

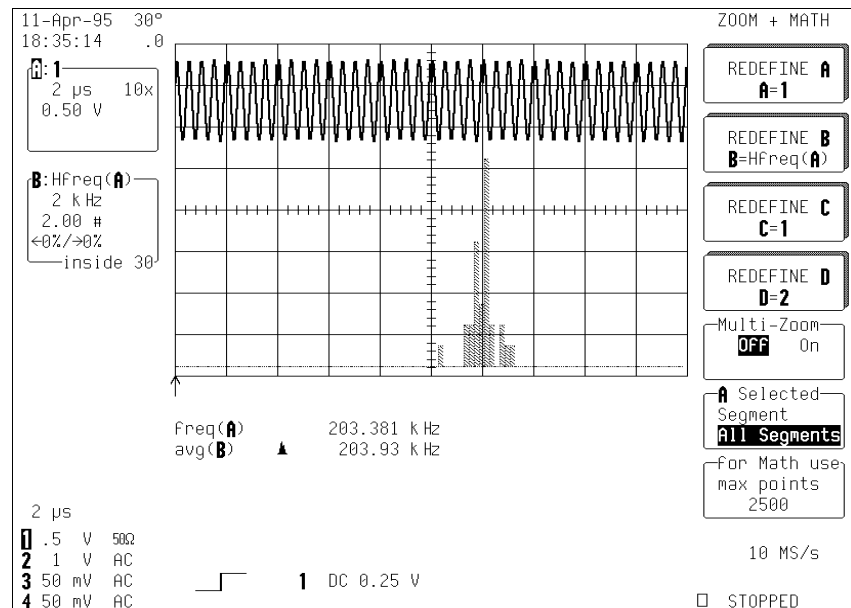


Figure 6.18

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 20k 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

Histograms

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.

The scope's measurement cursors are useful for determining the value and population of selected bins. Figure 6.19 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.

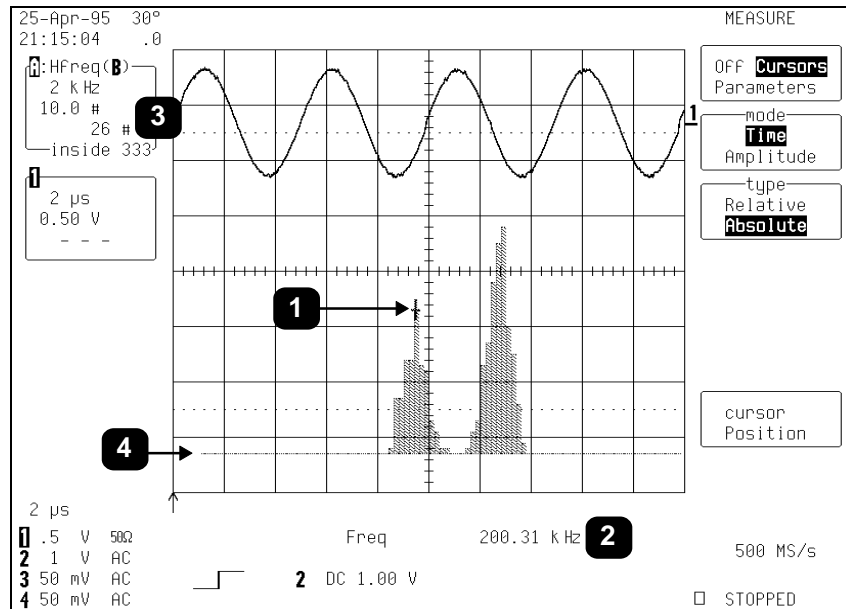


Figure 6.19

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).

#



ORM

BLANK PAGE

avg**Average****Definition**

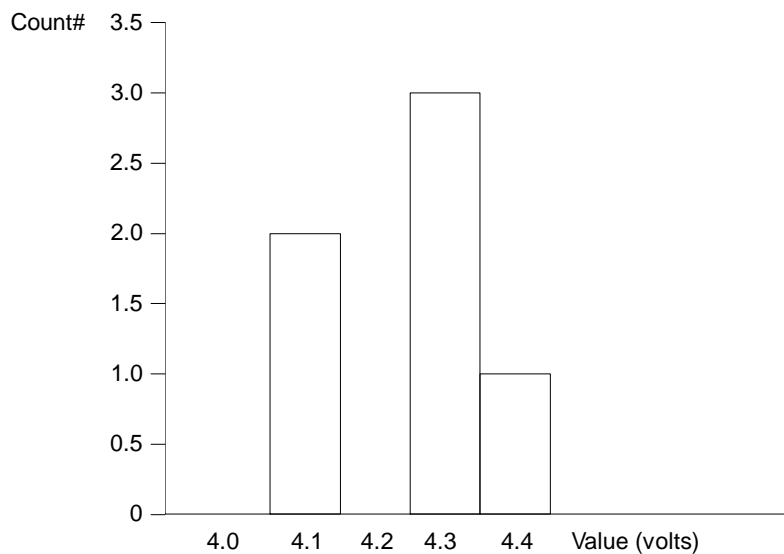
Average or mean value of data in a histogram.

Description

The average is calculated by the formula:

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

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

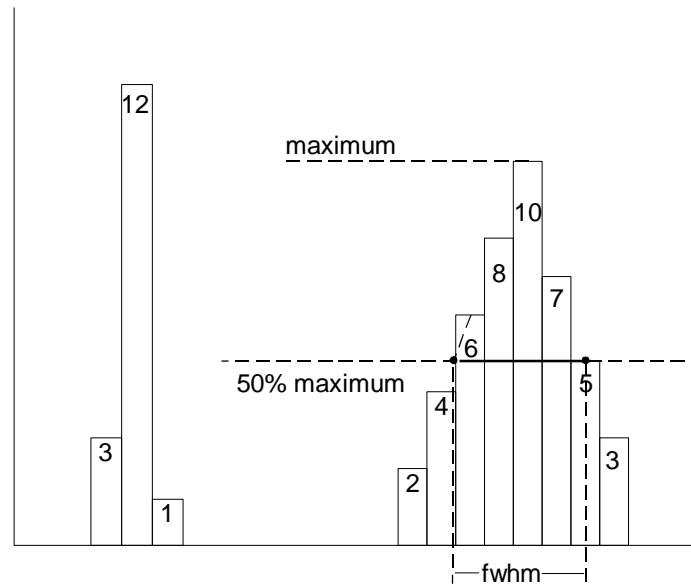
Definition

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) is determined (for a discussion of how peaks are determined see the **pks** parameter description). Next, the populations of bins to the right and left are determined, 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

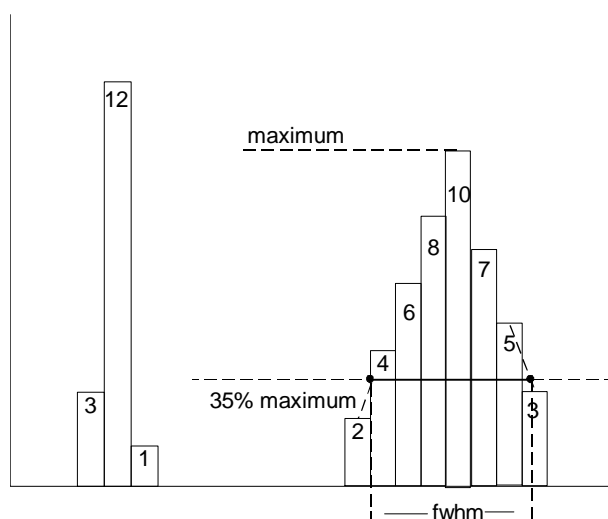
First, the highest population peak is identified, and the height of its highest bin (population) determined (see the **pks** description). Next, the bin populations to the right and left are determined until a bin on each side is found to have a population of less than xx% of that of the highest bin. 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 and 100% of the peak.

Example

fwxx with threshold set to 35%:





hampl

Histogram Amplitude

Definition

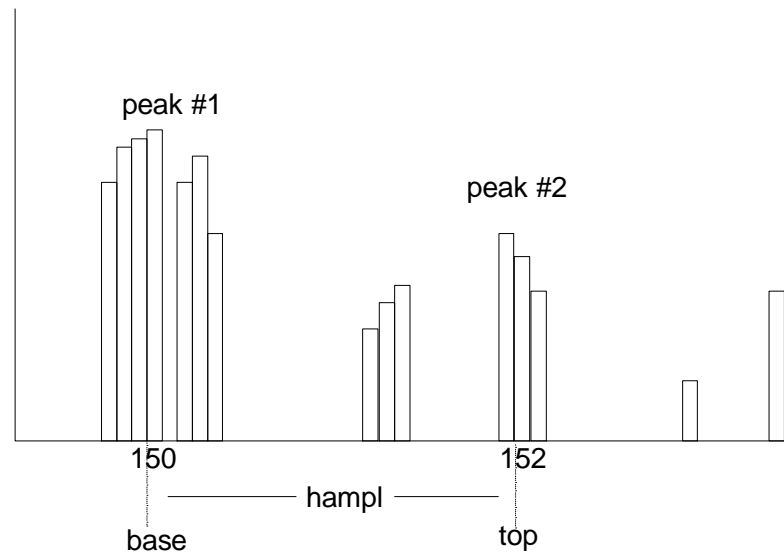
The difference in value of the two most populated peaks in a histogram. This parameter is useful for waveforms with two primary parameter values, such as TTL voltages, where **hampl** would indicate the difference between the binary '1' and '0' voltage values.

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:

$$\text{hampl} = \text{htop} - \text{hbase}$$

Example



In this histogram, **hampl** is $152 \text{ mV} - 150 \text{ mV} = 2 \text{ mV}$.

hbase

Histogram Base

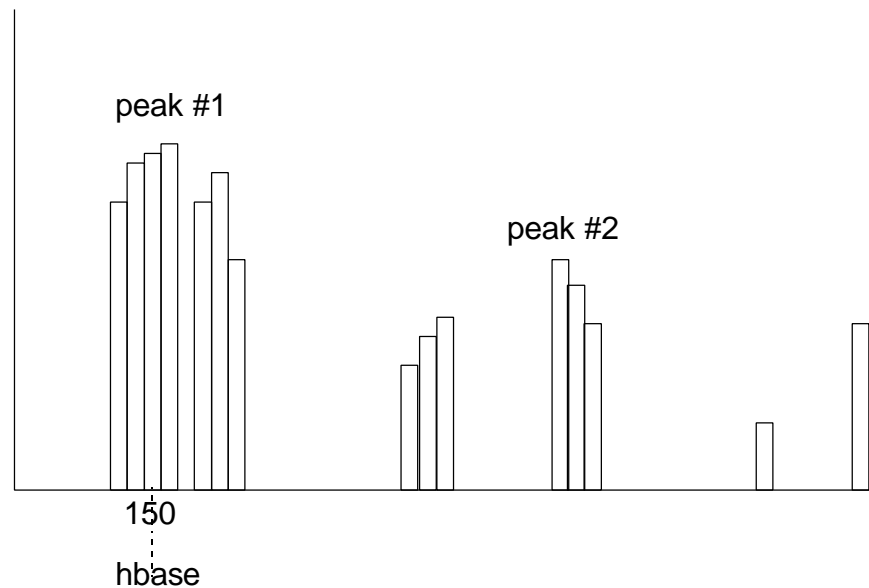
Definition

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

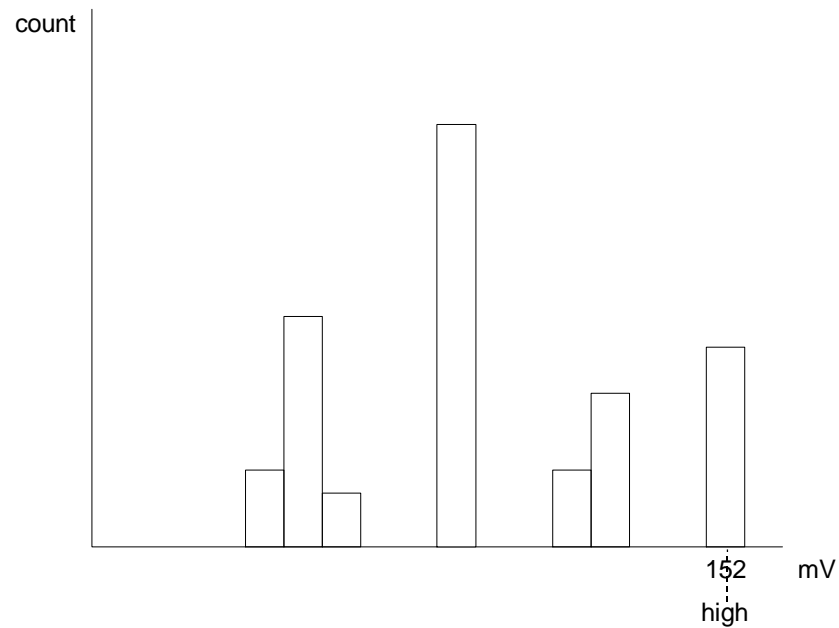
Definition

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 to 6.5 V. The ratio of counts needed for half- to total-bin population is:

$$2 \text{ counts needed} / 8 \text{ counts} = .25$$

The value for **hmedian** is:

$$6.1 \text{ volts} + 0.25 * (6.5 - 6.1) \text{ volts} = 6.2 \text{ volts}$$



hrms

Histogram Root Mean Square

Definition

The rms value of the values in a histogram.

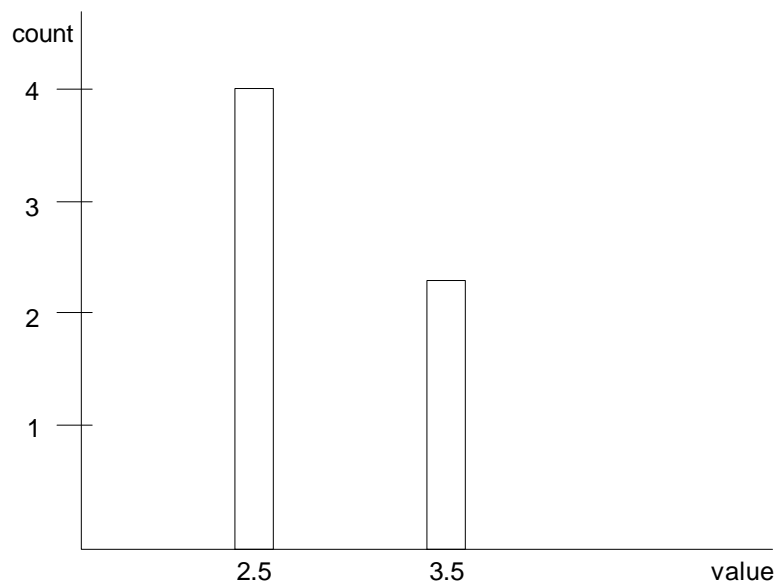
Description

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

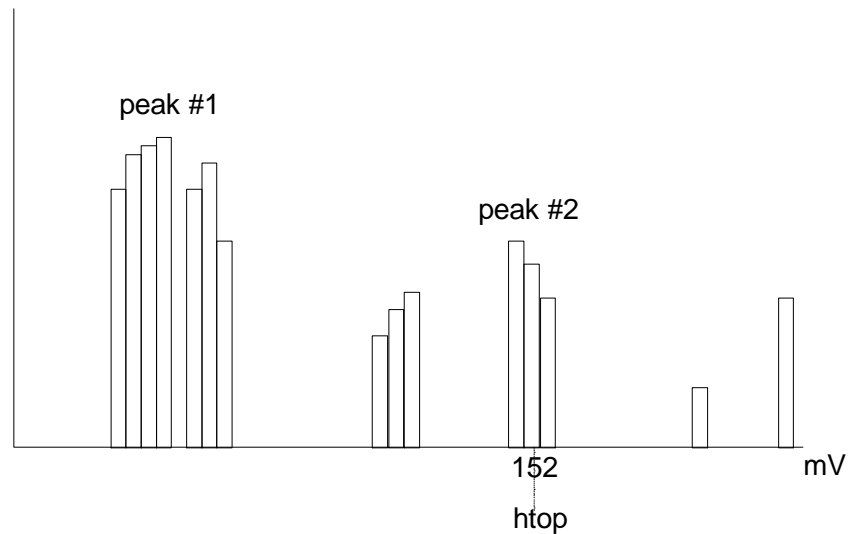
Definition

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

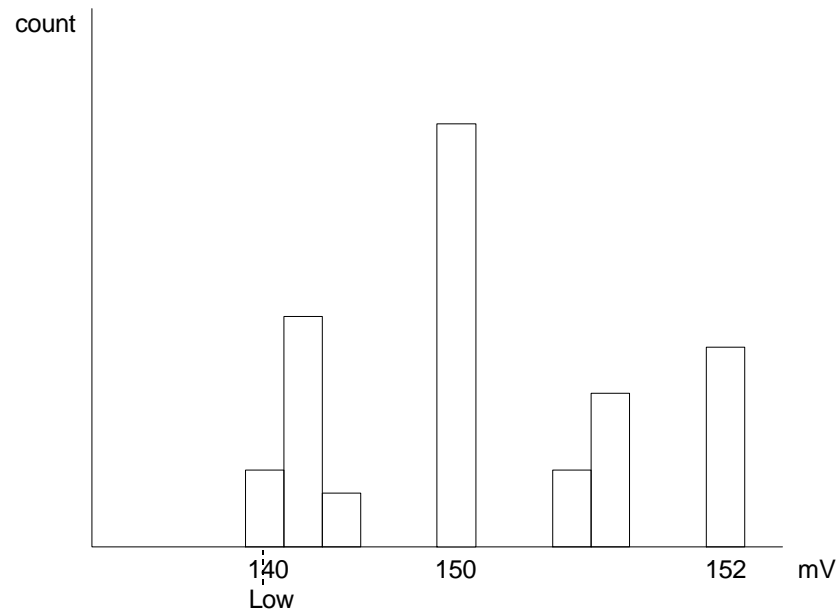
Definition

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

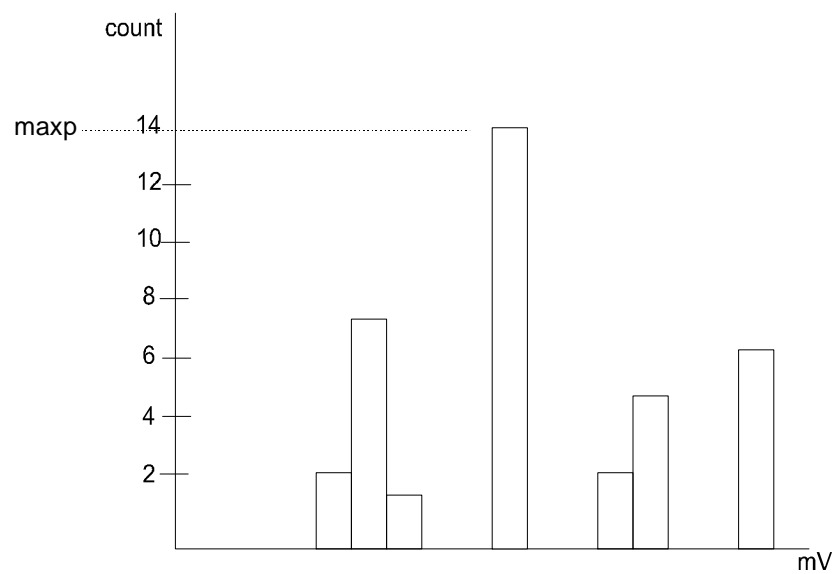
Definition

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

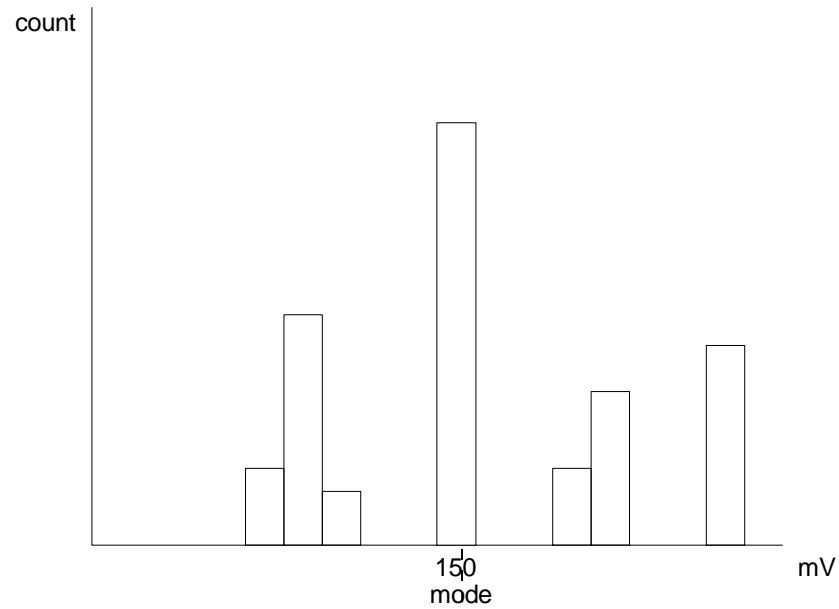
Definition

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 to 6.4 V. The ratio of counts needed for 25% population to total bin population is:

$$3 \text{ counts needed} / 9 \text{ counts} = 1/3.$$

The value for **pctl** is:

$$6.1 \text{ volts} + 0.33 * (6.4 - 6.1) \text{ volts} = 6.2 \text{ volts}.$$

Parameter Settings Selection of the **pctl** parameter in the "CHANGE PARAM" menu group causes the "MORE pctl SETUP" menu to appear. Pressing the corresponding menu button displays a threshold setting menu. With the associated knob, you can set the percentage value to between 1% and 100% of the total population.

Definition The number of peaks in a histogram.

Description The instrument 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:

$$T1 = \text{mean} + 2 \sqrt{\text{mean}}$$

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

$$T2 = \text{mean} + 2 * \sigma$$

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

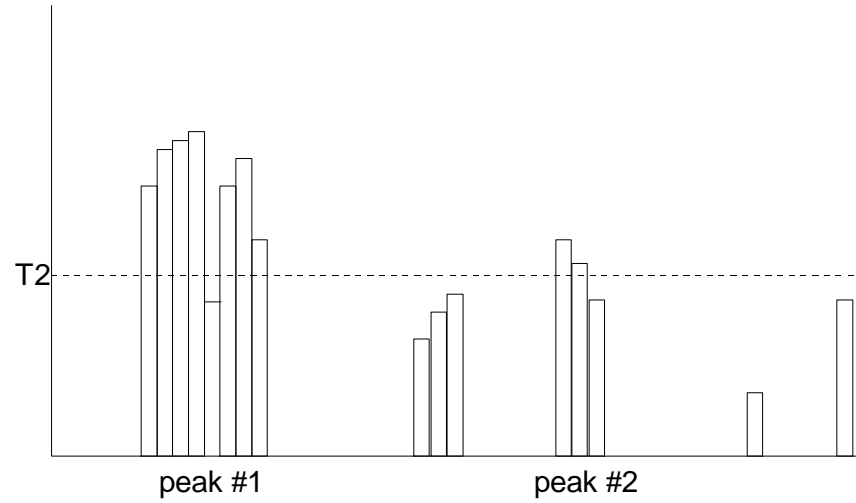
- 3) Once T2 is defined, the histogram distribution is scanned from left to right. Any bin that crosses above T2 signifies the existence of a peak. Scanning continues to the right until one bin or more crosses below T2. However, if the bin(s) cross below T2 for less than a hundredth of the histogram range, they are ignored, and scanning continues in search of a peak(s) that crosses under T2 for more than a hundredth 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 bin 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.

Histogram Parameters

Example

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





range

Range

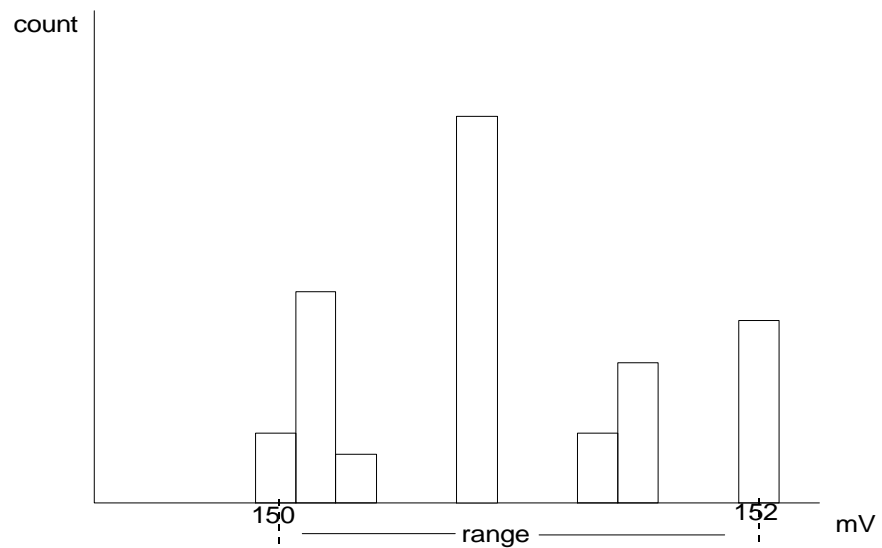
Definition

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:

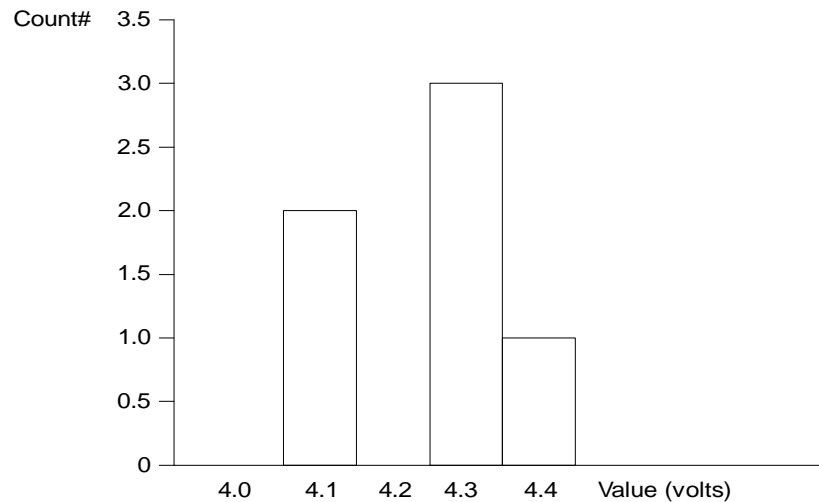
$$\text{mean} = \sum_{i=1}^n [\text{bin count}_i * \text{bin value}_i] / \left(\sum_{i=1}^n \text{bin count}_i \right);$$

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

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

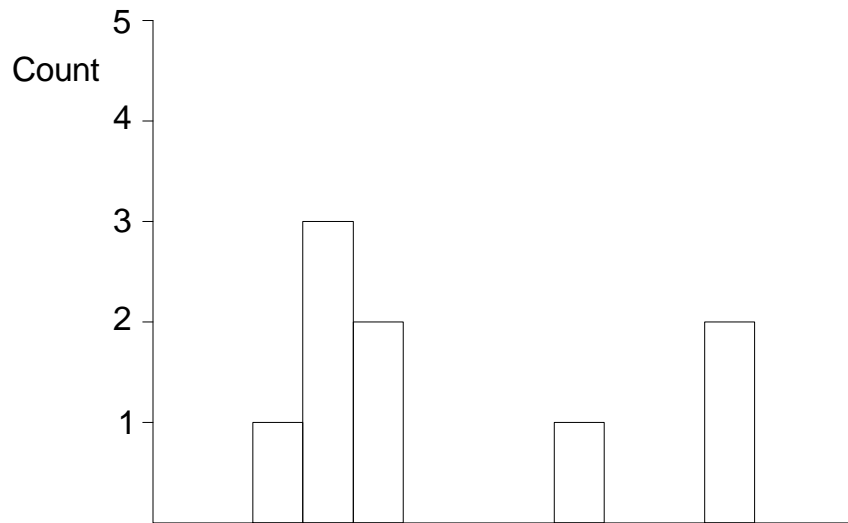
Definition

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



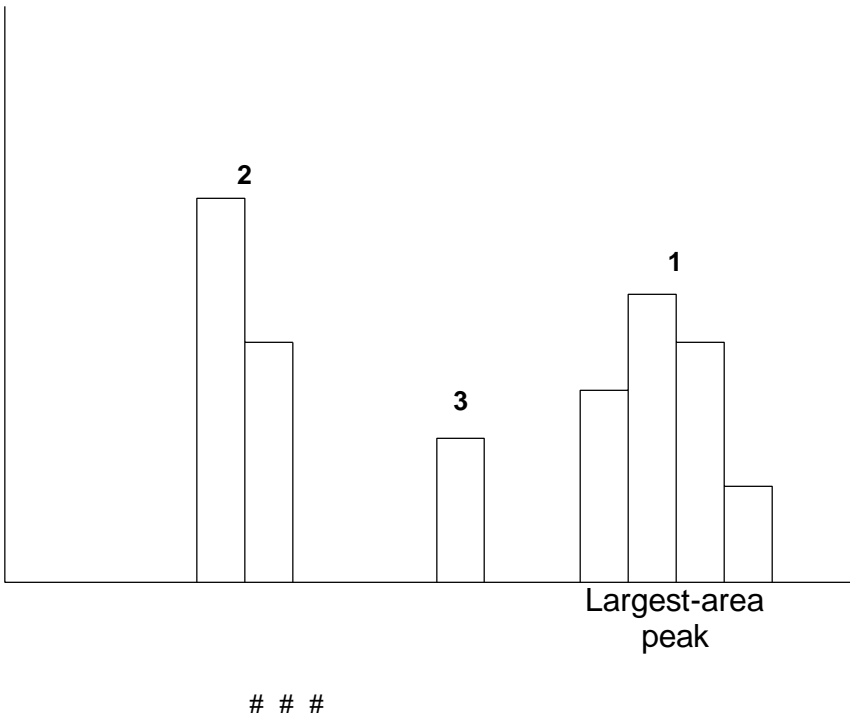
The total population of this histogram is 9.

xapk X Coordinate of xx'th Peak

Definition Returns the value of the xx'th peak that is the largest by area 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 nth 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**.

Example The rightmost peak is the largest, and thus the first-ranked, in area (1). The leftmost peak, although higher, is ranked second by area (2). The lowest peak is also the smallest in area (3).





BLANK PAGE

DVD Processing Model

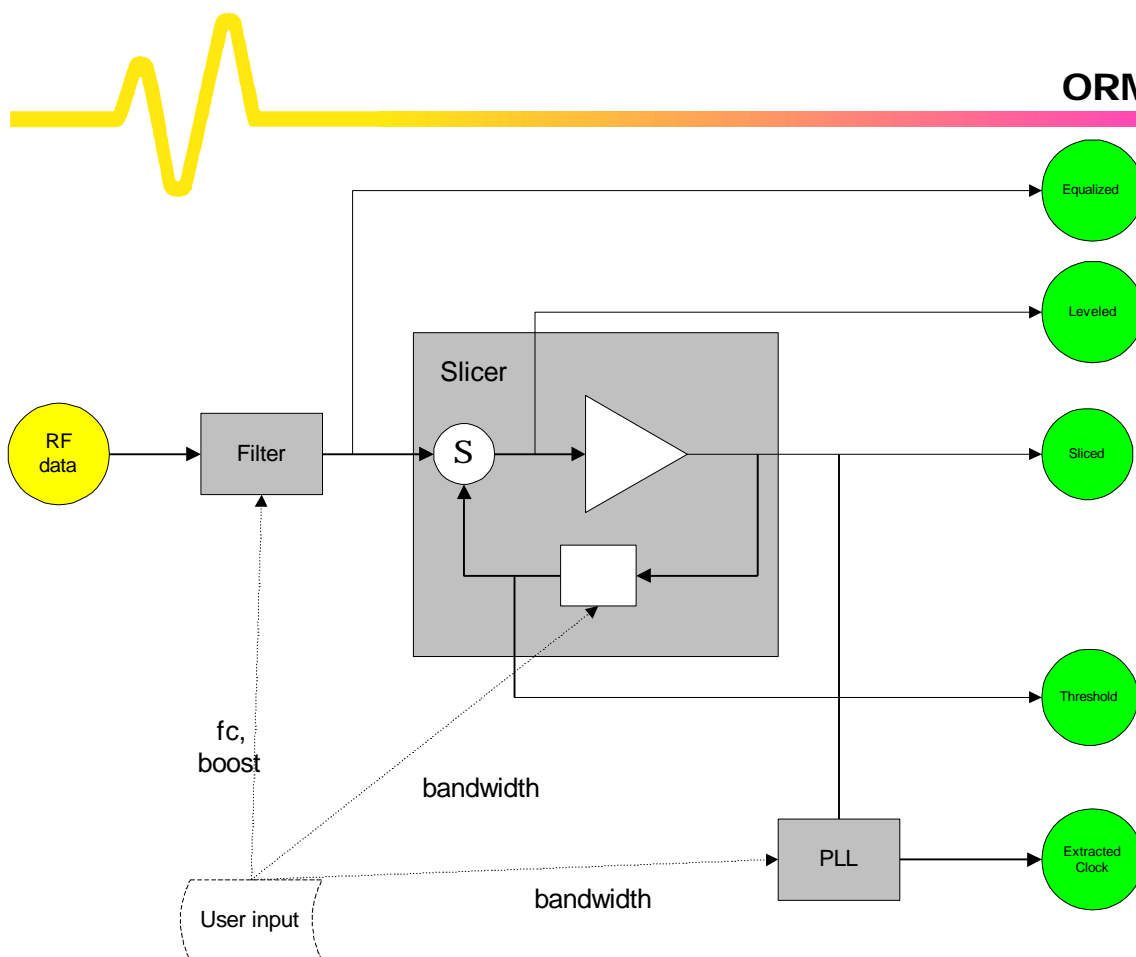
In many applications, it is important to make measurements directly from the RF signal, independent of a specific DVD chip. The OR Data processing function provided in the Advanced ORM package can emulate the filter, slicer, and/or phase-locked loop (PLL) of a typical optical recording drive. A schematic of this function is shown in the following diagram. You can view the equalized data, leveled data, threshold, sliced data, or the extracted clock.

You can control the cutoff frequency and boost of the equalizing filter, the closed loop bandwidth of the slicer, and the bandwidth of the PLL. Alternatively, you can input the equalized signal and still look at the slicer or PLL output of the function.

Additionally, some of the advanced optical drives have a header and data section. A Gate signal differentiates the header and data sections. The OR Data function lets you input a gate signal, and allows you to choose when to analyze the data (gate high or low), so that either the header or the data area can be analyzed.

DVD RAM

For noisy signals if less than three width peaks are found, the PLL start frequency is set so that T is the nearest value to the expected bit rate for which the first width peak is an integer multiple of T . Also, the PLL start phase is derived from the first two edges instead of the first one.



Where:

- Equalized – applies a low pass filter with boost to the input data. This should not be used if the input data is already equalized (filtered).
- Leveled – Applies the filter (if the input data is raw RF) and then subtracts the sliced threshold from it.
- Sliced – This is the output of the slicer. It is similar to Leveled except the amplitude of each pulse is normalized to “1” and “0.”
- Threshold – this waveform comprises the low frequency components of the original signal.
- Extracted CLK – the sliced data is passed through a PLL and the recovered clock signal is produced.

FILTERING

A low-pass filter that removes high-frequency noise and provides equalization is needed for the newer optical recording systems (e.g., DVD). In the DVD read-only and recordable specifications are given the frequency characteristics of the low pass filter (LPF) and equalizer (EQ) as a graph. The combination of these must meet within 1 dB below 7 MHz, and it is recommended to meet it up to 10 MHz. Also, group delay variation for frequencies ≤ 6.5 MHz must be ± 3 ns, and gain at 5.0 MHz minus gain at 0 Hz must be 3.2 ± 0.3 dB. For the LPF, it gives an example implementation to achieve these characteristics as a 6th order Bessel filter with a cutoff frequency f_c (-3 dB) = 8.2 MHz, and an example for the EQ is a three-tap transversal filter.

The OR Data function implements the 6th order Bessel filter as a FIR filter to provide the low-pass filter capability. The number of coefficients of the FIR depends on the ratio between the cutoff frequency f_c and the sample rate f_s . For a 1x DVD with an f_c of 8.2 MHz, sampled at 500 MS/s, approximately 220 taps are required. Sampling at 1 GS/s is about twice that. Ideally, the sampling rate should be 10 to 20 times the clock rate. For a 1x DVD with a clock period of 37 ns, the sample rate should be 500 MS/s.

The three-tap equalization filter (EQ) is applied to the data after it has been low-pass filtered. The three samples input to the EQ are not adjacent; they are at 0 and $\pm 2T$, where T is a $1/\text{channel bit rate}$.

Because the spacing in DSO samples depends on data rate and sample rate, T is likely to be a non-integer number of samples. In this case, interpolation is used to find the values at $-2T$ and $+2T$.

SLICER

The Slicer is a 1st order integrating slicer with a programmable closed loop bandwidth (e.g., 5 kHz for 1x DVD as specified in DVD-R Annex G and DVD Annex H). Besides producing the sliced data, the slicer can output the difference of the input signal and the slicer threshold level. The slicer threshold will be determined by an exponential average of data samples computed as:

$$\text{New thresh} = (n - 1)/n * \text{old thresh} + 1/n * \text{new data}$$

Where n is chosen to meet the bandwidth requirement at the current sample rate.

**CLOCK RECOVERY**

The Clock recovery function emulates a PLL with an open-loop transfer function, as specified in DVD-R Annex G and DVD Annex H (12 dB per octave at low frequencies, would intercept 0 dB gain at 6 kHz except it breaks to 6 dB per octave, the 6 dB/octave line intercepts 0 dB gain at 9 kHz). The emulation of the VCO directly implements the edge comparators, charge pump, loop filter, and VCO.

A detailed description of the PLL calculation and its limitations is given in Appendix A.

OR Data Configuration Menu

Press the MATH TOOLS front panel button or the **MATH SETUP** soft button to access the “ZOOM+MATH” menus (see the MATH SETUP chapter of the scope *Operator's Manual*). These menus allow you to redefine each of the four traces (A, B, C, and D) and to access their “SETUP” menus. Pressing the button that corresponds to one of the traces allows that trace (here Trace A) to be set up.

SETUP OF A

This allows the selected trace (here Trace A) to be set up.

SETUP OF A

use Math?
No Yes

Math Type
Functions
Histogram
O.R. Data
Resample
Trend

Produce
RF (input)
Equalized
Leveled
Threshold
Sliced

MORE O.R. SETUP

of

A	2	3	4	B	C	D
M1	M2	M3	M4			

use Math?

Use this to enable math on the trace. Traces can be set to use math or as zooms of other traces. Because OR Data is a math function, “use Math?” should be set to “Yes.”

Math Type

Use this to select “O.R. Data.”

MORE O.R. SETUP

Use this to access more OR Data setup options and the final OR dedicated menu (see next page).

**OPTICAL RECORDING SETUP**

OPTICAL REC

Input

☒ RF Equalized

Set

☒ LP Fc
Boost
Slicer BW
PLL BW
Gate

LP Fc

10 k Hz

Input

This allows you to specify whether the input is connected to raw or already equalized RF data.

Set

This allows you to control "circuit" parameters.

Parameter	Description	Possible Values
LP fc	Cutoff frequency for the Equalizer (low-pass filter)	10 kHz to 800 MHz
Boost	Boost for the Equalizer	0 to 20 dB
Slicer BW	Controls the bandwidth of the Slicer	1 to 200 kHz
PLL BW	Controls the bandwidth of the PLL (used for clock recovery only)	1 to 200 kHz
Gate	Optionally, you can specify a channel that will be used to gate the input signal. When specified, you must also specify the polarity of the gate (i.e., process when low or high).	None, C1, ... C4, M1, M4, other traces High or Low

#

Using ORM Remotely

This chapter lists the commands for performing remote programming of the Optical Recording Measurement package. Refer to your *Remote Control Manual* for a complete description of the oscilloscope's remote control capabilities.

CURSOR

CURSOR_MEASURE, CRMS Command/Query

DESCRIPTION

The CURSOR_MEASURE command specifies the type of cursor or parameter measurement to be displayed and is the main command for displaying parameters and pass/fail.

The CURSOR_MEASURE? query indicates which cursors or parameter measurements are currently displayed.

Notation	
ABS	absolute reading of relative cursors
CUST	custom parameters
FAIL	pass/fail: fail
HABS	horizontal absolute cursors
HPAR	standard time parameters
HREL	horizontal relative cursors
OFF	cursors and parameters off
PARAM	synonym for VPAR
PASS	pass/fail: pass
SHOW	custom parameters (old form)
STAT	parameter statistics
VABS	vertical absolute cursors

Notation	
VPAR	standard voltage parameters
VREL	vertical relative cursors

Note: The PARAM mode is turned OFF when the XY mode is ON.

COMMAND SYNTAX

CuRsor_MeaSure <mode>[,<submode>]

<mode> := {CUST, FAIL, HABS, HPAR, HREL, OFF, PARAM, PASS, SHOW, VABS, VPAR, VREL}

<submode> := {STAT, ABS}

Note 1: The keyword STAT is optional with modes CUST, HPAR, and VPAR. If present, STAT turns parameter statistics on. Absence of STAT turns parameter statistics off.

Note 2: The keyword ABS is optional with mode HREL. If it is present, ABS chooses absolute amplitude reading of relative cursors. Absence of ABS selects relative amplitude reading of relative cursors.

QUERY SYNTAX

CuRsor_MeaSure?

RESPONSE FORMAT

CuRsor_MeaSure <mode>

EXAMPLE (GPIB)

The following command switches on the vertical relative cursors:

```
CMD$="CRMS VREL": CALL IBWRT(SCOPE%,CMD$)
```

The following command determines which cursor is currently turned on:

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

Example of response message:

```
CRMS OFF
```

Remote Control Commands

RELATED COMMANDS **CURSOR_SET**, **PARAMETER_STATISTICS**,
PARAMETER_VALUE, **PASS_FAIL_CLEAR**,
PASS_FAIL_CONDITION, **PASS_FAIL_DELETE**,
PASS_FAIL_MASK

ADDITIONAL INFORMATION To turn off the cursors, parameter measurements or Pass/Fail tests, use:

CURSOR_MEASURE OFF

To turn on a cursor display, use one of the following four forms:

CURSOR_MEASURE HABS

CURSOR_MEASURE HREL

CURSOR_MEASURE VABS

CURSOR_MEASURE VREL

To turn on parameter measurements without statistics, use one of the following three forms:

CURSOR_MEASURE CUST

CURSOR_MEASURE HPAR

CURSOR_MEASURE VPAR

To turn on parameter statistics, add the keyword **STAT** to the above three forms.

To turn on Pass or Fail tests on parameter or mask tests, use:

CURSOR_MEASURE PASS

CURSOR_MEASURE FAIL

Use the command:

PASS_FAIL_CONDITION

to select parameters in the Custom mode, and to modify the test conditions in the Pass/Fail mode.

**CURSOR****CURSOR_SET, CRST**
Command/Query**DESCRIPTION**

The CURSOR_SET command allows you to position any one of the eight independent cursors at a given screen location. The positions of the cursors can be modified or queried even if the required cursor is not currently displayed on the screen.

When setting a cursor position, you must specify a trace, relative to which the cursor will be positioned.

The CURSOR_SET? query indicates the current position of the cursor(s). The values returned depend on the grid type selected.

Note: If the parameter display (or the pass/fail display or extended parameters display) is turned on, the parameters of the specified trace will be shown, unless the newly chosen trace is not displayed or has been acquired in sequence mode. These conditions will produce an environment error. If you change only the trace without repositioning the cursors, the CURSOR_SET command may be given with no argument (for example, TB:CRST).

Notation			
HABS	horizontal absolute	PREF	parameter reference
HDIF	horizontal difference	VABS	vertical absolute
HREF	horizontal reference	VDIF	vertical difference
PDIF	parameter difference	VREF	vertical reference

COMMAND SYNTAX

<trace> : CuRsor_SeT <cursor>,<position>[,<cursor>,<position>,<cursor>,<position>]

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

<cursor> : = {HABS, VABS, HREF, HDIF, VREF, VDIF, PREF, PDIF}

<position> : = 0 to 10 DIV (horizontal)

Remote Control Commands

<position> : = -29.5 to 29.5 DIV (vertical)

Note 1: The suffix DIV is optional.

Note 2: Parameters are grouped in pairs. The first parameter specifies the cursor to be modified, and the second one gives its new value. Parameters may be grouped in any order, and may be restricted to those items to be changed.

QUERY SYNTAX

<trace> : CuRsor_SeT? [<cursor>,...<cursor>]

<cursor> : = {HABS, VABS, HREF, HDIF, VREF, VDIF, PREF, PDIF, ALL}

RESPONSE FORMAT

<trace> : CuRsor_SeT <cursor>,<position>[,<cursor>,<position>,...<cursor>,<position>]

If <cursor> is not specified, ALL will be assumed. If the position of a cursor cannot be determined in a particular situation, its position will be indicated as UNDEF.

AVAILABILITY

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

EXAMPLE (GPIB)

The following command positions the VREF and VDIF cursors at +3 DIV and -7 DIV respectively, using Trace A as a reference:

```
CMD$="TA:CRST VREF,3DIV,VDIF,-7DIV":  
CALL IBWRT(SCOPE%,CMD$)
```

RELATED COMMANDS

CURSOR_MEASURE, CURSOR_VALUE,
PARAMETER_VALUE, PER_CURSOR_SET,
XY_CURSOR_SET



CURSOR

CURSOR_VALUE?, CRVA?
Query

DESCRIPTION

The CURSOR_VALUE? query returns the values measured by the specified cursors for a given trace. (The PARAMETER_VALUE? query is used to obtain measured waveform parameter values.)

Notation			
HABS	horizontal absolute	VABS	vertical absolute
HREL	horizontal relative	VREL	vertical relative

QUERY SYNTAX

<trace> : CuRsor_VAlue? [<mode> ,...<mode>]
<trace> := {TA, TB, TC, TD, C1, C2, C3, C4}
<mode> := {HABS, HREL, VABS, VREL, ALL}

RESPONSE FORMAT

<trace> : CuRsor_VAlue HABS,<abs_hori>,<abs_vert>
<trace> : CuRsor_VAlue HREL,<delta_hori>,<delta_vert>,<absvert_ref>,<absvert_dif>
<trace> : CuRsor_VAlue VABS,<abs_vert>
<trace> : CuRsor_VAlue VREL,<delta_vert>
For horizontal cursors, both horizontal as well as vertical values are given. For vertical cursors only vertical values are given.
Note: If <mode> is not specified or equals ALL, all the measured cursor values for the specified trace are returned. If the value of a cursor cannot be determined in the current environment, the value UNDEF will be returned.

AVAILABILITY

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

EXAMPLE (GPIB)

The following query reads the measured absolute horizontal value of the cross-hair cursor (HABS) on Channel 2:
CMD\$="C2:CRVA? HABS": CALL IBWRT(SCOPE%,CMD\$):
CALL IBRD(SCOPE%,RSP\$): PRINT RSP\$
Response message:
C2:CRVA HABS,34.2E- 6 S, 244 E- 3 V

Remote Control Commands

RELATED COMMANDS

CURSOR_SET, PARAMETER_VALUE,
PER_CURSOR_VALUE, XY_CURSOR_VALUE

**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 oscilloscope and WPOX processing packages.

COMMAND SYNTAX

<function> : **DE**fine **EQ**N, '<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 can be restricted to the variables to be changed.

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

QUERY SYNTAX

<function> : **DE**fine?

RESPONSE FORMAT

<function> : **DE**fine **EQ**N, '<equation>' [, **MAXPTS**, <max_points>]
[, **SWEEPS**, <max_sweeps>][, **WEIGHT**, <weight>][, **BITS**, <bits>]

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

Remote Control Commands

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 <i>Note: The source waveform must be a time-domain signal, single segment.</i>	
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

Remote Control Commands

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 ORDATA Function

<OR_boost> := 0 to 10 dB

<OR_fc> := 10e3 to 800e6 Hz

<OR_gate> := {NONE, TA, TB, TC, TD, M1, M2, M3, M4, C1, C2, C3, C4}

<OR_gate_state> := {HIGH, LOW}

<OR_in> := {RF, EQUALIZED}

<OR_OP> := {NOOP, EQUALIZED, LEVELED, THRESHOLD, SLICED, EXTRACTED_CLOCK}

<OR_PLL_BW> := 1e3 to 200e3 Hz

<OR_SLICER_bw> := 1e3 to 200e3 Hz

AVAILABILITY

<sourceN> := {C3, C4} available only on 4-channel scopes.



<extended_source>:= {C3, C4} available only on 4-channel scopes

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

Remote Control Commands

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 sets up 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 sets up 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 sets up Trace C to construct the histogram of risetime measurements made on source Channel 1. The risetime measurement is defined on custom line 2. The histogram has a linear vertical scaling, and the risetime 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

Remote Control Commands

CURSOR

PARAMETER_CLR, PACL Command

DESCRIPTION

The PARAMETER_CLR command clears all the current parameters from the five-line list used in the Custom and Pass/Fail modes.

Note: This command has the same effect as the command PASS_FAIL_CONDITION, given without any arguments.

COMMAND SYNTAX

PArAmeter_CLeAr

RELATED COMMANDS

PARAMETER_DELETE, 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 following table.

<param>	definition	<qualifier> list
Parameters available on instruments equipped with ORM processing firmware		
BEES	beginning and ending edge shift	<subject n>, <data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
BES	beginning edge shift	<subject n>, <data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
BESS	beginning edge shift sigma	<subject n>, <data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
EES	ending edge shift	<subject n>, <data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>

Remote Control Commands

<param>	definition	<qualifier> list
		n>, <unit>

<param>	definition	<qualifier> list
EESS	ending edge shift sigma	<subject n>, <data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
DP2C	delta pit to clock	<data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
DP2CS	delta pit to clock sigma	<data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
EDGSH	edge shift	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
LPER	local period	<clock source>, <clock edge>, <clock threshold>, <hysteresis>
PAA	pit average amplitude	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PASYM	pit asymmetry	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PBASE	pit base	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PMAX	pit maximum	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PMIDL	pit middle level	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PMIN	pit minimum	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PMODA	pit modulation amplitude	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>



<param>	definition	<qualifier> list
PNUM	pit number	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PRES	pit resolution	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PTOP	pit top	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
T@PIT	time at pit	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
TIMJ	timing jitter	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>, <units>
PWID	pit width	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>, <units>
Histogram and Trend Parameters available on instruments equipped with ORM processing firmware		
AVG	average value	
FWHM	full width at half maximum	
FWXX	full width at xx% of max	<source>,<threshold>
HAMPL	histogram to minus histogram base	
HBASE	lower of two most probable histogram states	
HIGH	largest value	
HMEDI	median value	
HRMS	rms value	
HTOP	higher of two most probable histogram states	
LOW	lowest value	
MAXP	highest population in all histogram bins	

Remote Control Commands

<param>	definition	<qualifier> list
MODE	histogram bin with highest population	
PCTL	percentile	<source>,<threshold>
PKS	number of histogram peaks	
RANGE	range of histogram or trend	
SIGMA	standard deviation of histogram	
TOTP	total histogram population	
XAPK	x position at peak	<source>,<rank>

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

PParameter_CUstom? <line>

RESPONSE FORMAT

PParameter_Custom
 <line>,<parameter>,<qualifier>[,<qualifier>,...]

AVAILABILITY

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

EXAMPLE 1

BEES

Command Example

PACU 1,BEES,3,TA,POS,0,TB,POS,0,1,231NS,4,4,TIME



Query/Response Examples

PACU? 1 returns:
PACU 1,BEES,3,TA,POS,0E-6,TB,POS,0E-3,1
DIV,231E-9 S,4,4,TIME
PAVA?CUST1 returns:
TA:PAVA CUST1,-14.9E-9 S,OK

EXAMPLE 2

EES

Command Example

PACU 2,EES,3,TA,POS,0,TB,POS,0,1,231NS,3,11,%

Query/Response Examples

PACU? 2 returns:
PACU 2,EES,3,TA,POS,0E-6,TB,POS,0E-3,1 DIV,
231E-9 S,3,11,PCT
PAVA? CUST2 returns:
TA:PAVA CUST2,-14.639 PCT,OK

EXAMPLE 3

PTOP

Command Example

PACU 3,PTOP,TA,0,1,231NS,3,11

Query/Response Examples

PACU? 3 returns:
PACU 3,PTOP,TA,0E-6,1 DIV,231E-9 S,3,11
PAVA? CUST3 returns:
TA:PAVA CUST3,28.8E-3 V,OK

RELATED COMMANDS

PARAMETER_DELETE, PARAMETER_VALUE,
PASS_FAIL_CONDITION

Remote Control Commands

CURSOR

PARAMETER_DELETE, PADL
Command

DESCRIPTION

The PARAMETER_DELETE command deletes a parameter at a specified line from the list of parameters used in the Custom and Pass/Fail modes.

Notation		
1	line 1	of Custom or Pass/Fail display
2	line 2	of Custom or Pass/Fail display
3	line 3	of Custom or Pass/Fail display
4	line 4	of Custom or Pass/Fail display
5	line 5	of Custom or Pass/Fail display

COMMAND SYNTAX

PARAMETER_Delete <line>

<line> : = {1, 2, 3, 4, 5}

Note: This command has the same effect as the command PASS_FAIL_CONDITION <line>, given without any further arguments.

EXAMPLE (GPIB)

The following instruction deletes the third test condition in the list:

```
CMD$="PADL 3": CALL IBWRT(SCOPE%,CMD$)
```

RELATED COMMANDS

PARAMETER_CLR, PARAMETER_VALUE,
PASS_FAIL_CONDITION

**CURSOR****PARAMETER_LIST, PALI****Command/Query****DESCRIPTION**

The **PARAMETER_LIST** command controls the ORM parameters that have 'list by nT' calculation modes. *Only ORM package parameters shown here.*

COMMAND SYNTAX

PARAMETER_LIST <parameter>, <qualifier>, [<qualifier>,...]

<parameter> := {a parameter from the table below }

<qualifier> := Measurement qualifier(s) specific to each <param>. See the following table.

<param>	definition	<qualifier> list
Parameter Names (available on instruments equipped with ORM processing firmware)		
BES	Beginning edge shift	<subject n>,<data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>,
BESS	Beginning edge shift sigma	<subject n>,<data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
DP2C	delta pit to clock	<data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
DP2CS	delta pit to clock sigma	<data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
EDGSH	edge shift	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
EES	Ending edge shift	<subject n>,<data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>

Remote Control Commands

<param>	definition	<qualifier> list
EESS	Ending edge shift sigma	<subject n>, <data source>, <data polarity>, <data threshold>, <clock source>, <clock edge>, <clock threshold>, <hysteresis>, <period>, <low n>, <high n>, <unit>
PAA	pit average amplitude	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PBASE	pit base	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PMAX	pit maximum	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PMIDL	pit middle level	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PMIN	pit minimum	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PNUM	pit number	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PTOP	pit top	<data source>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>
PWID	pit width	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>, <units>
TIMJ	timing jitter	<data source>, <data polarity>, <data threshold>, <hysteresis>, <period>, <low n>, <high n>, <units>

<data source>:= {C1, C2, C3, C4, TA, TB, TC, TD}

<clock source>:= {C1, C2, C3, C4, TA, TB, TC, TD}

<data polarity>:= {POS, NEG, ALL}

<clock edge>:= {POS, NEG, NEAR}

<data threshold>:= Level in <data source> in the units of the waveform.

<clock threshold>:= Level in <clock source> in the units of the waveform.

<hysteresis>:= {0.5, 1, 2, 5} divisions

<period>:= 1e-9 to 0.001 seconds

<low n>:= 1-25

<high n>:= 1-25

<units>:= {PCT, TIME}

<subject n>:= 1-25



QUERY SYNTAX	PParameter_Llist?
RESPONSE FORMAT	PParameter_List <parameter>, <qualifier>, [<qualifier>,...]
AVAILABILITY	<sourceN>:= {C3, C4} only on four-channel oscilloscopes.
EXAMPLES	DP2C
Command Example	PALI DP2C, C1, ALL, 20E-3, C2, NEAR, 0E-3, 0.5, 231.5E-9, 3, 11, TIME
Query/Response Examples	PALI? returns: PALI DP2C,C1,ALL,0E-3,C2,NEAR,0E-3,0.5 DIV,231.5E-9 S,3,11,TIME PALV? returns: PALV DP2C,1.45E-9 S,9.84E-9 S,-8.88E-9 S,2.34E-9 S,-1E-9 S,15.2E-9 S,-16.02E-9 S,7.69E-9 S,-1.9E-9 S
Command Example	PWID PALI PWID, C1, POS, 25E 3, 1, 231.5E-9, 3, 11, PCT
Query/Response Examples	PALI? returns: PALI PWID,C1,POS,0E-3,1 DIV,231.5E-9 S,3,11,PCT PALV? returns: PALV PWID,289.402 PCT,393.383 PCT,497.709 PCT,603.318 PCT,698.435 PCT,804.229 PCT,905.015 PCT,1.003959E+3 PCT,1.110306E+3 PCT
RELATED COMMANDS	PARAMETER_DELETE, PARAMETER_VALUE, PARAMETER_LIST_VALUES, PARAMETER_CUSTOM, PASS_FAIL_CONDITION

Remote Control Commands

CURSOR

PARAMETER_LIST_SET_NT, PALSNT Command/Query

DESCRIPTION

The PARAMETER_LIST_SET_NT command is used to set or query the subject nT of the AORM list parameter. It is only available with the AORM package. The command provides a way to change the subject nT without resetting statistics.

In order to remotely collect a table of edge shift data for a set of pit/space pairs over a range of pit sizes, it is necessary to issue a series of **PALV?** queries for a sequence of nT subject values. If the **PALI** command is used to change the nT subject value, statistics are reset. Not only is it impossible this way to collect accumulated data, but also each line of the table comes from a different acquisition.

The PALSNT command solves the problem by setting only the subject nT value for the list parameter and doesn't reset the accumulated data.

The only parameters for which this command is useful are BES, BESS, EES and EESS.

Note: It is possible for a trigger to occur during the collection of the table data. When accumulation is on, additional data shouldn't affect the values in the table if the number of sweeps is large. If it is important that the data read out by multiple queries be totally consistent, stop the trigger before issuing the queries.

Note: Measuring edge shifts in percent will cause data variation if the period is being determined from the data, and fluctuates.

Note: This command will not work when the ORM table is being displayed.

COMMAND SYNTAX

Parameter_List_Set_NT <subject nT value>

<subject nT value> = The value to set the subject nT, from 0 to 25.

QUERY SYNTAX

Parameter_List_Set_NT?



RESPONSE FORMAT

PALSNT <subject nT>

EXAMPLE (GPIB)

The following sequence of commands obtains the values for a 3x3 array of beginning edge shifts:

PALI BES,4,C1,POS,0E-3,C1,POS,0E-3,1 DIV,1E-9 S,3,5,TIME
Wait for the desired number of sweeps and then send:

```
PALSNT 3
PALV?
PALSNT 4
PALV?
PALSNT 5
PALV?
```

The output will appear as:

```
PALV BES,0.1E-9,-0.8E-9,-0.4E-9
PALV BES,-0.3E-9,-0.2E-9,0.9E-9
PALV BES,-1.1E-9,0.6E-9,1.3E-9
```

Remote Control Commands

CURSOR

PARAMETER_LIST_VALUES?, PALV? Query

DESCRIPTION	The PARAMETER_LIST_VALUES query returns the current value(s) of the ORM measurement parameter(s) configured for 'List by nT' mode. <i>Only ORM parameters are shown here.</i>
QUERY SYNTAX	PARAMETER_List_Values? <parameter> := See table of list parameter names under PALI command.
RESPONSE FORMAT	PARAMETER_List_Values <parameter>,<v value>, [...,<v value>] <v value> := A decimal numeric v alue The number of v alues depends on the configuration, specifically the low n and high n specified. The number of v alues returned is: $high_n - low_n + 1$ $high_n \geq low_n$ The first v alue returned corresponds to the measurement calculated for the low n index, and the last v alue returned corresponds to the measurement calculated for the high n index.
EXAMPLE (GPIB)	The following query reads the pit middle lev els (pmidl) parameter of channel 1 configured for 'list by nT' calculation mode previously using the PALI command. The parameter was configured for low_n = 3 and high_n = 11, so 9 v alues are returned: CMD\$="PALV?": CALL IBWRT(SCOPE%,CMD\$): CALL IBRD (SCOPE%,RD\$): PRINT RD\$ Response message: PALV PMIDL,1.9E-3 V,2.3E-3 V,1.8E-3 V,1.3E-3 V,1E-3 V,0.6E-3 V,0.9E-3 V,0.8E-3 V,0.7E-3 V
RELATED COMMANDS	CURSOR_MEASURE, CURSOR_SET, PARAMETER_LIST, PARAMETER_STATISTICS



CURSOR

PARAMETER_STATISTICS?, PAST?
Query

DESCRIPTION

The PARAMETER_STATISTICS? query returns the current values of statistics for the specified pulse parameter mode and the result type for all five lines of the pulse parameters display.

Notation	
AVG	average
CUST	custom parameters
HIGH	highest value
HPAR	horizontal standard parameters
LOW	lowest value
PARAM	parameter definition for each line
NUM_ACQ	number of contributing acquisitions
NUM_VALUES	number of measurements taken for parameter
SIGMA	sigma (standard deviation)
SWEEPS	number of sweeps accumulated for each line
VPAR	vertical standard parameters

QUERY SYNTAX

Parameter_Statistics? <mode> , <result>

<mode> := {CUST, HPAR, VPAR}

<result> := {AVG, LOW, HIGH, NUM_ACQ, NUM_VALUES, SIGMA, SWEEPS, PARAM}

Note: If keyword PARAM is specified, the query returns the list of the five pairs <parameter_name>, <source>.

EXAMPLE (GPIB)

The following query reads the average values of the five standard vertical parameters:

```
CMD$="PAST? VPAR, AVG": CALL IBWRT(SCOPE%,CMD$):  
CALL IBRD(SCOPE%,RD$): PRINT RD%
```

RESPONSE FORMAT

PAST VPAR, AVG, 13V, 26V, 47V, 1V, 0V

RELATED COMMANDS

PARAMETER_VALUE

Remote Control Commands

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.

Remote Control Commands

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

#

Notes on OR Data Math Function

The ORDATA math function can accept as input either unequalized or already equalized data, and produce:

- RF (input): just a copy of the input waveform.
- Equalized: If the Input data is RF (not already equalized), as set on the "MORE O.R. SETUP" menu, it applies equalization using the "LP fc" and "Boost" settings from the "MORE O.R. SETUP" menu. The result is low-pass filtered such that -3dB frequency, without boost, is "LP fc," and has high frequency boost applied such that the specified boost is reached at about 61% of "LP fc." The default values for LP fc (8.2 MHz) and boost (3.2 dB) are the correct settings for 1x DVD and DVD-R.
- Leveled: If the input is not equalized, equalization is applied as described above. Then, the equalized data is fed to a 1st order integrating low-pass filter whose bandwidth is set by "Slicer BW" on the "MORE O.R. SETUP" menu. The default for "Slicer BW" (5.0 kHz) is correct for 1x DVD and DVD-R. The output of this filter is subtracted from the waveform to move the correct slice level to zero. "Leveled" output may be used for pit width measurements, etc. The correct level for the parameter threshold is always zero volts when it is used on Leveled data.
- Threshold: This is similar to Leveled, but when "Threshold" is selected the output of the function is the slicer threshold, instead of the equalized waveform minus the slicer threshold.
- Sliced: The leveled data is passed through a (software) high gain comparator. The result appears to be a noise-free waveform where all peaks are the same height. Each edge has two samples that are not at the railed levels, and are positioned such that linear interpolation between these points will give exactly the same zero level cross time as linear interpolation between points on the equalized waveform. The Sliced output, therefore, may also be used for pit width measurements, etc.
- Extract Clk: The Sliced data is sent through a PLL emulation, and the output is the PLL's VCO output. This uses the "PLL BW" setting on the "MORE O.R. SETUP" menu. The default PLL Bandwidth (9 kHz) is the correct setting for 1x DVD and DVD-R. The VCO's starting frequency and phase are preset to attempt to start the PLL in a "locked" condition on each sweep.



OR DATA Math Function

This appendix contains more information about each of these operations, including known limits on their operations. Extracting the clock from the data has the most dependencies; if you plan to use that function, please see the appropriate following section.

RF (input)

It is worth noting that the O.R. DATA function does not use the setting on the "for Math use max points" menu field or the value following MAXPTS in the DEFINE remote command. The copy has all the points of the input waveform.

Equalized

Equalization can be applied if three conditions are met:

- We can make the low-pass filter.
- We can apply boost.
- The waveform is large enough to still have valid points after the filtering.

A warning message is displayed if any of these conditions is not met. If one of the following warning messages appears, the waveform is NOT equalized:

- "LP fc low & sample rate too high, can't LP filter" — The number of coefficients needed for the finite impulse response (FIR) low-pass filter exceeded the maximum number supported. The maximum is adequate for 1x DVD at 16 GS/s, which means the maximum ratio of sample rate to LP fc is $16e9/8.2e6 = 1951.22$. This is far above the maximum it is reasonable to use. See the note on computation time under "operational notes."
- "Acquisition too small to apply EQ filters" — The valid region of the waveform is reduced by "EQ spacing" (see following explanation) on each side. This error message means that the result would then have no valid points.
- "LP fc low & sample rate too high, can't EQ filter" — This message is shown if current EQ spacing is greater than 8191 samples, an implementation restriction. The EQ spacing is set to correspond to 2T, assuming that the LP fc is correctly set; it is calculated from LP fc as follows:

$$\text{EQ spacing in samples} = 2.0 / (\text{fc} * 26.16 / 8.2) * \text{sample interval}$$

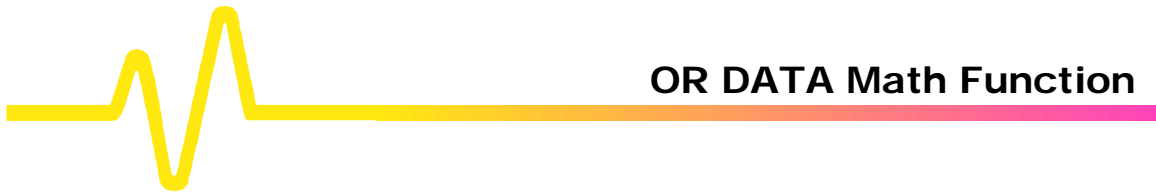
Operational notes

1. Even if the input data is already equalized, it is often helpful to tell the O.R. DATA function that it is not, but set the boost to zero. This greatly reduces noise. White noise has power per Hz of bandwidth, and reducing the scope's 1 GHz bandwidth to around 8.2 MHz gets rid of 99% of white noise.
2. Applying high-frequency boost makes short pulses larger and has less effect on longer pulses. The correct boost should not greatly increase the signal's overall amplitude.
3. The output of the Equalization is not delayed, as it would be by an analog filter. We compensate for the known delay through the digital filter and replace each input point with the corresponding equalized point.
4. The FIR LP filter plus 3.2 dB boost from the three-tap EQ filter produces the transfer function shown in Figure 1 when the FIR fc is set to 8.2 MHz. The highest peak is 20 log (dB) magnitude. The bowed trace below it is the real component of the TF. The flat line at zero is the imaginary component of the TF. It is zero indicating that there is no delay at all from input to output.
5. The computation time for the low-pass filter is generally longer than the time required for the sum of the rest of the computations done by the OR DATA math function. This is because the low-pass filter is a finite impulse response filter (emulating the shape of a 6th order Bessel filter). It can require hundreds of multiplies-and-adds per sample in the waveform. The higher the sample rate relative to the bit time, T, the longer the FIR is. It is adequate to sample at least 10 to about 20 times in the channel bit time, T. For 1x DVD, T is 26.16 MHz. Twenty times that is 523 MHz, so 500 MS/s is a good sample rate.

The OR DATA math function supports the "progress bar" capability. The progress bar shows the progress of applying the LP FIR filter only. To enable the progress bar, either send the command "PMSG LR_CORNER" (other choices are CENTER and STD) or put that command in file "autoexec.dso" on a floppy so the DSO will execute it at boot-up.

Here are some measured times to produce equalized data for a 1 ms acquisition of 1x DVD data. The LP fc is set to 8.2 MHz and the boost is set to 3.2dB, the default values. These times were measured on a LeCroy DDA120.

Sample Rate	Number of samples	Time to make Equalized
-------------	-------------------	------------------------



OR DATA Math Function

acquired		trace
250MS/s	250,000	1 second
500MS/s	500,000	3 seconds
1GS/s	1,000,000	10 seconds
2GS/s	2,000,000	36 seconds

This shows that as the sample rate is doubled (which doubles the number of samples), the time required nearly quadruples because the number of multiplies-and-adds to filter each point also doubles.

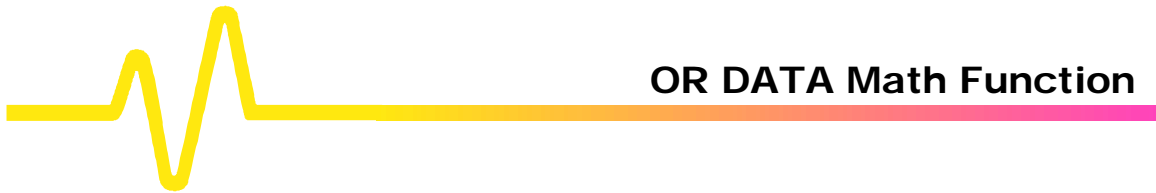
6. The three-tap EQ filter uses as input the point to be replaced and the points 2T away on each side. Since 2T may not correspond to an integer number of scope samples, linear interpolation between scope samples is used to get the values at exactly 2T away on each side.



Figure 1: Simulation result showing transfer function of the digital low-pass filter and 3-tap EQ (boost) filter, set to 8.2 MHz LP fc and 3.2 dB boost.

Leveled

There are no additional conditions to produce leveled data. The threshold is calculated and subtracted even if the equalization could not be applied for the reasons described above.



OR DATA Math Function

Threshold

There are no additional conditions to produce the slicer threshold. The threshold is calculated even if the equalization could not be applied for the reasons described above.

Sliced

The slicer uses a fixed hysteresis around zero, which corresponds to half a division (+ and - 1/4 division) when not vertically zoomed. (Remember that the slicer works on Leveled data, so zero is the correct threshold; the dynamically computed threshold has already been subtracted.) This means a peak must cross zero and exceed it by a quarter of a division or it will be ignored, as if it were noise after the previous crossing. A signal that is four divisions high (half of full scale) should have no problem meeting this requirement, as shown in Figure 2.

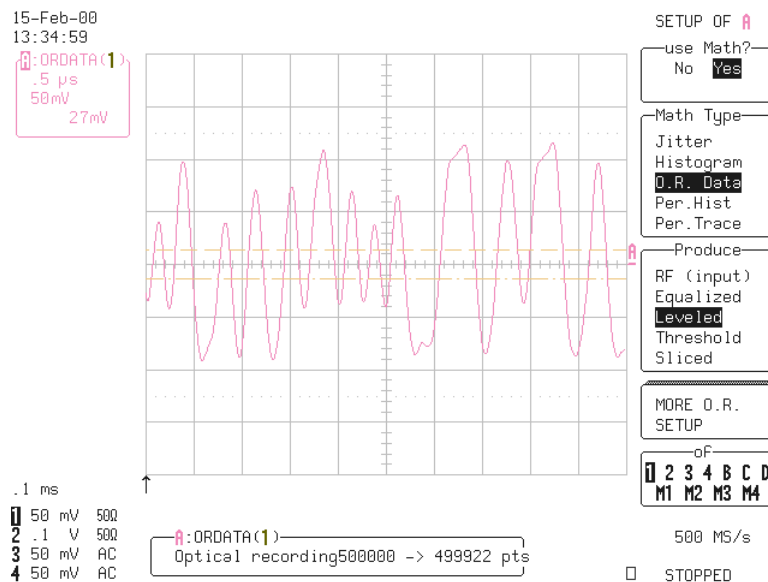


Figure 2: Leveled DVD data, with cursors showing the approximate hysteresis requirements for Sliced data.

The slicer produces waveforms that are exactly five divisions high. Each edge has two samples that are between the high and low levels and are positioned 2.5 divisions apart such that the zero cross time of the sliced output edge is the same as the zero cross time of the leveled data.

Extract Clk

It is usually not possible to get data and clock signals correctly aligned from an optical drive to visualize how the data edges align with the clock; in some cases, the clock may not be available at all. This function produces a clock waveform from the data by passing it through a software PLL. This output may be overlapped on the display with Leveled or Sliced output on another trace; and it can be used for measurements of the clock frequency. If the JTA option is present, a JitterTrack of Frequency of the extracted clock may give interesting insight into timing variation in the input signal.

The only user-set parameter for clock extraction is the "PLL BW" setting on the "MORE O.R. SETUP" menu. The PLL Bandwidth is the unity gain intercept of the open loop transfer function of the PLL. The closed loop -3 dB frequency is approximately 1.274 times that. The loop filter meets the specification shown in Annex H of the DVD Physical specifications (or Annex G of the DVD-R Physical specifications). For 1x DVD the PLL BW should be set to 9 kHz. In that case the software PLL has this closed loop response:

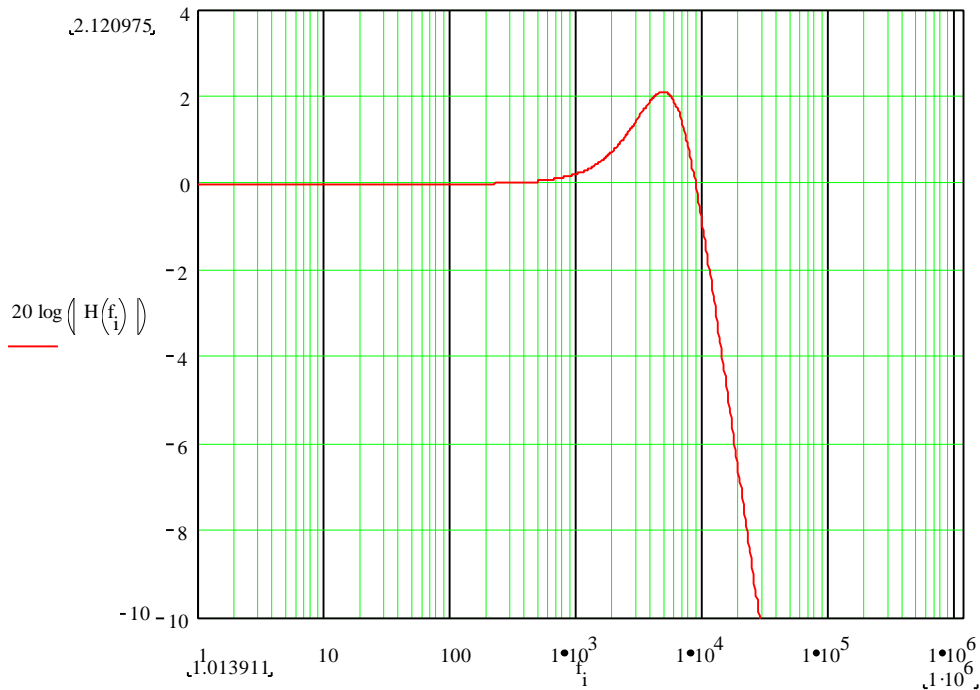


Figure 3: PLL closed-loop transfer function when "PLL BW" is set to 9 kHz.

The bandwidth of any PLL is a trade-off between jitter (phase noise) and desirable properties like a wide locking range and fast tracking. The "lock range" is the maximum frequency step for which the PLL can acquire lock without slipping a cycle. If we set up the VCO to start at other than the correct frequency (which corresponds to a frequency step), the PLL must change frequency to match the data. With PLL BW set to 9 kHz, the lock range is only about 25 kHz, slightly less than 0.1% of the expected clock frequency. The pull-in range is much broader but the pull-in time can be quite long. If we start the VCO just 0.4% away from the correct frequency, it would take hundreds of microseconds for the PLL to lock.

Since the acquired data may be a millisecond or less in duration, extracting the clock depends critically on the scope's ability to determine T (1/clock frequency) from the data and on starting the PLL's VCO at that frequency and at about the right phase. When it can do that, the VCO starts up locked and does not have to settle noticeably. If it cannot find the frequency, the

warning message: "ORDATA VCO start freq is 3.19*LP fc, didn't find it" will be displayed. As the message says, if the scope cannot find the frequency, it starts the VCO at $3.19024 * LP\ fc$. That ratio is 26.16/8.2 (to six significant digits). That is correct for DVD according to the specification, however it may not be within 0.1% for a real drive. In our experience, drives read a couple of percent fast.

To make the clock extraction successful, the scope must be successful in finding the starting frequency from the data. Here are some things you should do to make this successful:

1. Capture as clean a signal as possible. Remember that a passive probe is 10 MO resistive only at low frequencies and, therefore, may significantly load a high-speed signal. A passive probe's response will roll off well below the scope's DC 50 O bandwidth. Consider using a differential probe such as the AP033 or AP034, or an FET probe such as the AP020. Remember to attach the ground lead.
2. Equalize properly. If the signal you are probing is already equalized but not very clean, you can tell OR DATA that it is RF anyway and set the boost to zero. That way the data will be low-pass filtered, which greatly reduces noise. If you don't equalize when you need to, or if you apply boost to an already equalized signal, the scope will probably not be able to determine the starting VCO frequency from the data, you will see the warning described above, and the extracted clock may not be good.
3. Sample at about 20 times the expected clock frequency. If you sample closer to 10 times the clock or below that, the extraction algorithm may not be able to correctly separate the peaks in the width distribution to determine the frequency at which to start the PLL. If you sample much more than 20 times the clock, the widths (in samples) may be too spread out from detectable peaks in the distribution. (See the following explanation "How the Starting VCO Frequency is Determined" for more details.) Example: CD data has $T = 231\text{ ns}$, about 4.33 MHz. We can extract the clock from CD data at 100 MS/s (23x) and 200MS/s (46x) or 250 MS/s (58x). At 50 MS/s (11.5x) and at 500 MS/s (115x), it sometimes does not find the right starting frequency. Another example: DVD has $T = 1/26.16\text{ MHz}$, about 38.2 ns. We can extract the clock from DVD data at 500 MS/s (19x), 1 GS/s (38x), and 2 GS/s (76x). At 250 MS/s (9.5x) and at 4 GS/s (153x), it sometimes does not find the right starting frequency.

Following are some interesting pictures to show what can be handled:

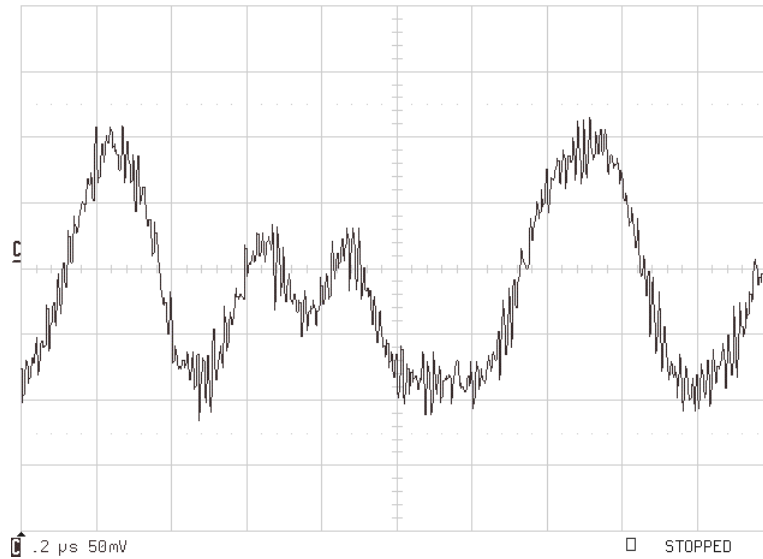


Figure 4: A small section of a 1 ms long noisy DVD waveform. Acquired with an ungrounded AP020 probe at 500 MS/s.

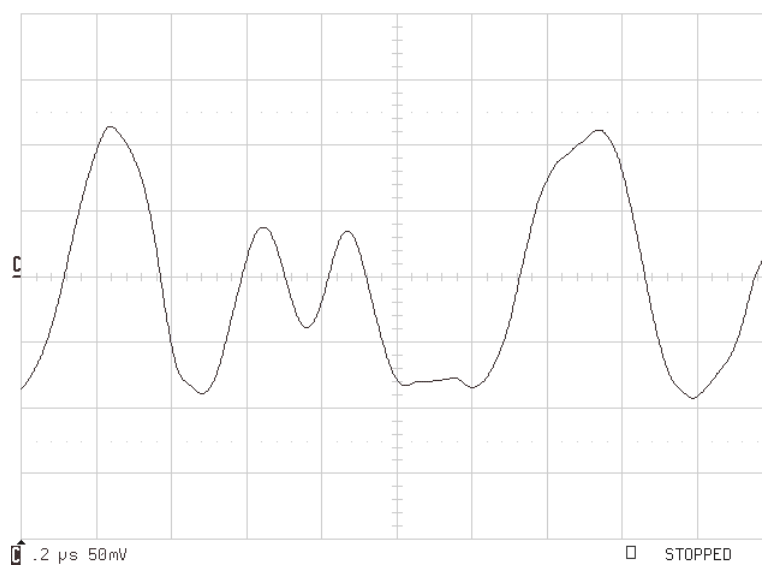


Figure 5: Same piece of the same signal, equalized and leveled. TC is set to O.R. DATA, Produce Leveled.

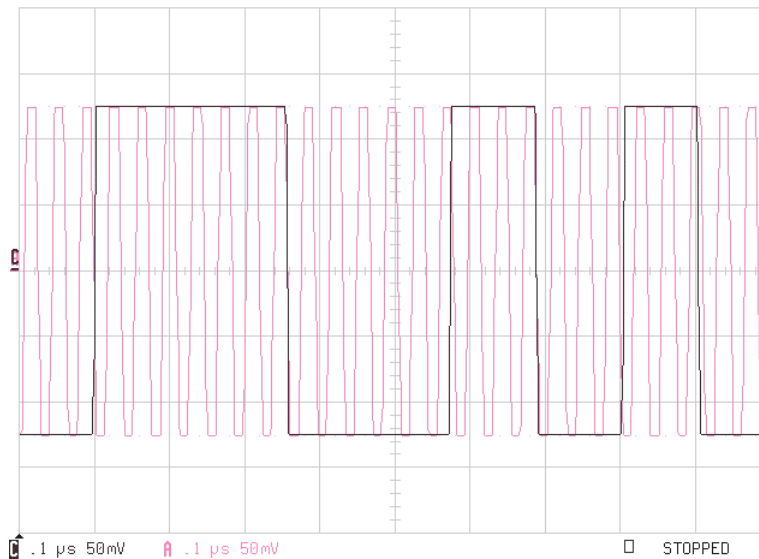


Figure 6: C is now "Sliced," A is "Extract Clk" of channel 1, showing the same data as the left side of Figure 5. Note that the edges of the 3T pulses are somewhat shifted, those of the longer pulse are better.

As you look at Figure 6, we should mention that the extracted clock output is also exactly five divisions high (without vertical zoom), and its edges are linear from $-0.1 * T$ and from $+0.4$ to $+0.6 * T$. Therefore, if there are 20 samples per T , each edge of the extracted clock signal has four samples between the top and base. These samples are placed proportional to phase, so that the edge crosses 0 at exactly 0 and 180 degrees VCO phase.

The phase steering target for the VCO is, roughly speaking, that the data transitions should happen on the falling edge of the VCO output. To be more precise, we steer such that the VCO phase will be 180 degrees at the sample where a zero crossing in the data is detected. Because the software VCO works on a sample-by-sample basis, there is, on average, a half sample delay from the VCO falling edge's zero cross to the data zero cross. At 20 samples per T , this half sample error is 2.5% of T , not noticeable without zooming in. At 10 samples per T , it is 5% of T . The following small figure shows part of a zoom on a rising data edge and a falling clock edge sampled at 500 MS/s (2 ns per sample). The horizontal scale is 2 ns per division. The samples are bold. Note that the data crosses zero at 1 ns after the falling edge of the VCO output crosses zero. This is the expected result.



The signal used for this picture is a 4.36 MHz square wave, which has a transition every $3T$ when $1/T = 26.16$ MHz. During the first 50 μ s or so the phase settles in from initial startup, after that all the zero crossings are half a sample apart, as shown in this picture.

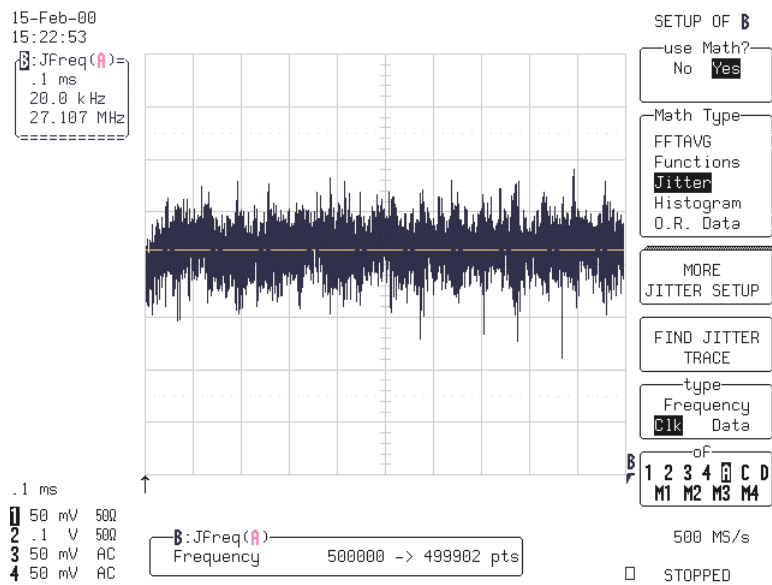


Figure 7: JitterTrack of Frequency (requires JTA option) of the extracted clock. The startup frequency was correct to within a few kHz, and the PLL did not slip. It is possible that the starting frequency was precise but the starting phase was not; the effect would be the same. JitterTrack shows frequency as a function of time. The vertical scale is 20 kHz per division; the cursor is positioned at 27.107 MHz. The horizontal scale is 0.1 ms per division.



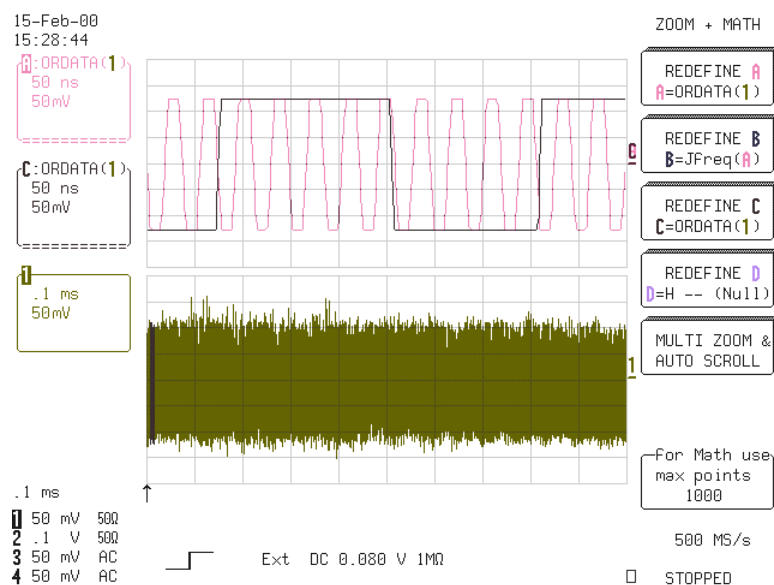


Figure 8: C and A expansion from near the beginning of the input, at the highlighted position, showing that the alignment of the extracted clock to the sliced data is good.

How the Starting VCO Frequency and Phase are Determined

The PLL's VCO is started at a frequency of $1/T$. Due to the accuracy required, we determine T in two steps. The first step produces an estimate of T starting with very few assumptions. The second step starts with the estimate of T and refines it. The information used in both steps is the sample at which a transition (through zero) occurred in the sliced data, for up to the first 2000 edges. If the source waveform has less than 2000 edges, the accuracy of this procedure may be reduced.

If the source waveform has less than 50 edges, we will not even attempt to estimate T . The PLL will start at $3.19024 * LP\ fc$. Because of the low bandwidth of the PLL, it does not make much sense to try to extract the clock from a very short waveform; the PLL will not have time to react.

The first step calculates the width of the first (up to) 2000 pulses, sorts the widths, and finds the first three peaks in the distribution of widths. The distribution is "smoothed" by a five-bin wide boxcar filter to prevent small local events from misleading the peak detection. This is the primary reason why the signal must be over-sampled by greater than 10x. The distribution of widths is similar to a histogram of $pwid$ (pit width) on "leveled" output of the O.R. DATA function, using a



threshold of 0.0 mV and measuring All widths. The spacing between the peaks is approximately T , close enough to determine the lowest nT . We calculate our estimate of T from the means of the first three peaks, which are assumed to be lowest n , lowest $n + 1$, and lowest $n + 2$ (i.e., $3T$, $4T$, and $5T$). This estimate is generally good to better than 1%.

The second step uses the location of the first (up to 2000) transitions, in order. It uses the estimate of T to calculate n between each pair of same-polarity edges. If the estimate is within 1%, we have at least 50% margin. A 50% margin occurs if a pair of same-polarity edges is $25T$ apart. On a good waveform, the count is likely to be exact. On a noisy or distorted waveform, it may be that some peaks are miscounted, but as long as some are long and some are short, the final total will be nearly correct. Finally, T is computed as:

$$(\text{time at the last transition} - \text{time at the first transition}) / (\text{total } n \text{ between them})$$

If there are 2000 edges, an average of $4T$ apart, the separation between first and last edge is $8000T$. If our count of n is off by 1, that is a 0.0125% error. We can tolerate up to 7 counts error (0.0875%) before the PLL will not start locked. When the waveform is correctly equalized, this does not happen.

A highly asymmetric waveform will not have clean peaks in the distribution of its pulse widths, which also means that many of the pulses will be nearly $(n + 0.5)T$. On such a waveform, we may not be able to determine T . The possible reasons for failing to determine T (and therefore the VCO start frequency) are:

- 1) Less than 50 edges in the waveform.
- 2) Could not distinguish the first three peaks in the distribution of widths.

As mentioned above, you should sample at about 20x to 50x the clock frequency to make clock extraction work reliably.

An attempt is made to start the VCO not only at the correct frequency but also at the correct phase. The phase is pre-set such that the first edge in the waveform will occur on a falling edge of the VCO output. The first edge is just as likely to be out of place as any other edge in the waveform, of course. If the VCO starts significantly at the wrong phase it will either slow down or speed up for a short while until it gets to the right phase. A JitterTrack shows this clearly. On a 4x DVD waveform we captured, which just happens to have a significantly out-of-place first edge, the frequency is disturbed slightly for the first 15 μs or so; the frequency shift during this time is very small, on the order of 0.1%, as the phase adjusts.

#