



# **Instruction Manual**

VectorLinQ Vector Signal Analysis Software



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#### VectorLinQ Vector Signal Analysis Software Instruction Manual

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# **About This Manual**

This manual outlines the operation of the VectorLinQ<sup>™</sup> Vector Signal Analysis (VSA) software and provides several examples to highlight the various features. Full instructions for using your Teledyne LeCroy oscilloscope can be found at:

teledynelecroy.com/techlib/

The VSA software shown throughout this manual is based on a LabMaster using X-Stream<sup>™</sup> v. 7.8.x.x. Your user interface may look slightly different than that shown here, but the functionality described is the same.

# Introduction

VectorLinQ<sup>™</sup> Vector Signal Analysis (VSA) is a software package that allows you to completely characterize RF and IQ modulated signals. When installed and activated, VSA is fully integrated with the Teledyne LeCroy X-Stream<sup>™</sup> oscilloscope application.



VectorLinQ software at work on a 64-QAM signal

## **Supported Platforms**

The VSA software is available on the WavePro/SDA/DDA 7 Zi/Zi-A, WaveMaster/SDA/DDA 8 Zi/Zi-A/Zi-B, LabMaster 9 Zi-A and LabMaster 10 Zi/Zi-A oscilloscope platforms.

## **VSA User Model**

The VSA is capable of simultaneously analyzing up-to-eight real or complex valued signals. These signals are considered independent and can come from a variety of sources. Each signal passes through a set of configurable DSP nodes collectively called a *stream*. A range of DSP algorithms are available to process input signals according to your application needs.

The VSA is configured at three levels:

- Global settings applied to all currently active streams
- Per Stream signal settings and number of nodes in DSP stream
- Per DSP Node processes to be applied at each stage in the DSP stream

VSA inputs are shown in blue in the user model diagram below.

The output of each characterized stream may be visualized using a variety of graphs and measurements. Several DSP nodes also output additional data about optimization points found by the algorithm. These outputs are referred to as **output parameters** and may be viewed within the VSA software or utilized as inputs to other oscilloscope Math processes. The VSA outputs are shown in light green in the user model.



VSA user model diagram

# **Preparing for Optimal Measurements**

The following procedures will prepare the oscilloscope to yield the most accurate measurements. We highly recommend performing each of them before starting a VSA session.

## Warm Up

Power on all components and allow them to warm for at least 20 min. before starting a test session.

## **Deskew Channels**

All Teledyne LeCroy oscilloscopes have both automatic and user-initiated calibration functions to correct for skew between channels. You can also manually enter a Deskew value on the Channel setup dialog to compensate for propagation delays due to probes/cables. Consult your oscilloscope *Operator's Manual* for the available deskew procedures.

## **Adjust Signal Pre-Processing**

The Pre-Processing settings on the Channel setup dialog are used to configure the pre-acquisition processes that will affect the waveform, such as noise filtering and interpolation. Adjust these settings as needed to yield an input signal that is as close as possible to the conditions you wish to test.

In most cases, it is sufficient to retain the default Linear Interpolation pre-processing setting and adjust the interpolation more precisely in the VSA software, although you can apply Sinx/x interpolation if you wish. Consult your oscilloscope *Operator's Manual* for a description of the available pre-processing settings.



Channel Pre-processing settings

# **Using the VectorLinQ Software**

## Starting the VSA Software

Follow the instructions in your oscilloscope *Operator's Manual* for adding a license key to activate the VSA software.

After activation, VSA is fully integrated into the oscilloscope application. It can be started by choosing **Analysis->VSA** from the oscilloscope touch screen menu bar.



The VSA dialog appears at the bottom of the touch screen. Select **Enable VSA** to turn on the VSA application and begin configuring the input streams.

**IMPORTANT:** Before enabling VectorLinQ, *disable* SDAIII, PAM4, DDRDebug Toolkit, or OpticalLinQ by clearing the Enable checkboxes within these applications. The applications cannot run concurrently.

## **VSA Global Configuration**

The main VSA dialog is used to configure the:

- **Signal Class.** This selection defaults to Independent, which means that all streams are analyzed independent of each other.
- Number of processing Streams to be analyzed concurrently (eight maximum).

Tabs are added to the VSA dialog depending on the number of streams entered. Open each tab in turn to make per stream configuration settings.

VSA Stream 1 Stream 2		EVM	Q Factor	Q Factor	IQ Phase Error	BER	SNR	SNR
VSA	Stream 1	Stream 2	Graphs/Metrics	Settings				
🗹 En	able VSA							
Sig	nal Class	_						
Indep	endent							
s	Streams							
2								
TELEDY	NE LECRO	ŊΥ						

## **VSA Stream Configuration**

Each stream is configured individually, generally by following the "flow" of the dialog from left to right.

#### **Signal Modulation**

VSA	Stream 1	Graphs/Metrics	Settings							
Sig QAM Syr 6.250 Bits 6	gnal Type mbol Rate 10000 MBaud per Symbol	Template No. of Stag	e Jes	tage 1 MM	Sta	ge 2 🕂	<b>]</b> →  ]	Stage 3 Equalizer	-	Stage 4 +
TELED)		1								

Control	Action
Signal Type	Select the modulation scheme used. Choose Custom to apply a user- defined scheme rather than one of the standards.
Symbol Rate	Enter the baud rate of the input as nearly as possible.
Bits per Symbol	Enter the number of bits in one symbol.
Input 1/Input 2	Select the physical channel to which the input signal is connected. Input 2 will appear only if you've selected IQ. While input usually refers to channels (Cx), other sources such as Math functions (Fx) or Memories (Mx) are equally valid. The same input source(s) can be used in multiple streams, allowing different analyses on the same source to run in parallel.
Template	Custom/RF/IQ. See below for more details.
No of Stages	Enter number of stages (nodes) in the DSP processing stream. After selecting, a corresponding number of boxes appear in the workflow on the Stream # dialog.

#### **Templates**

VSA has implemented *templates* to ease setting up the DSP chain for typical scenarios. There are two preconfigured templates: *RF* and *IQ*. Once either of them is selected, the corresponding DSP chain is setup as shown in the following captures. The DSP configuration of each node is set to default, and you will need to change it as per your input signal.

VSA Stream 1 Graphs/Metrics Settings	Stream 1 - Settings Stream
Signal Type Input 1 (RF)	Templates
Page 1 A Stage 2 1 Stage 3 A Stage 4 A	Load
Symour care Filter Mixer Filter Carrier Estimator	Save
Bits per Symbol – RF –	Delete
3 Stape 6 33 Stape 6 424	
6 Equalizer Phase Estimator	
VSA Stream 1 Graphs/Metrics Settings	Stream 1 - Settings Stream
Signal Type Input 1 ()	Templates
Pisk Stage 1 Stage 2 A Stage 3 Stage 3	Load
Syntow Rate C1 DC Block Filter Equalizer	Save
Bits per Symbol - O	Delete
No. of Stages	

RF and IQ templates

The moment any chain or DSP node configuration is changed, the template switches to **Custom**. While not necessary for the VSA operation, the new custom template can also be saved to a file for later use. In the example below, DC block has been removed from the default chain, and the new template is saved as no\_dc\_block.xml. This can be loaded later by selecting the **Load** button from the Templates menu at the right of the dialog.

	Save			
		Open Explorer Here	+	
	¤ 📙 Hewlett-Packara <sup>^</sup> Name ¤ 🚺 LabNotebooks	Size Type	Modifi	
	¤ DVD RW Drive (F:) ¤ _ ፼ SD (I:)			
	🛚 🛹 MAUI (M:) 🛤 🛹 Local Disk (O:) 🔤			
				-
		m	4	
	File name :		ок	
	File of type : *xml	•	Cancel	
VSA Stream 1 Graphs/Metrics Settings	Current Path E:\LabNotebooks			Stream 1 - Settings Strea
Signal Type Input 1 (I) PSK C1 Stage 1 - Stage Symbol Rate C1 None Filter 62500000 MBaud Bts per Symbol - Custom -	Equalizer			Templates Load Save Delete
No. of stages				
TELEDYNE LECROY				
VSA Stream 1 Graphs/Metrics Settings				Stream 1 - Settings
Signal Type Input 1 (I)				Templates
PSK C1 Stage 1> Stage	e 2 A Stage 3			Load
6.2500000 MBaud Template Filter	Equalizer			Save
Bits per Symbol no_dc_block				Delete
3				
TELEDYNE LECROY				

Custom templates

#### Stream Summary

The **Stream # Summary** right-hand dialog displays the current configuration selections for all stages in the stream.

VSA Stream 1	Graphs/Metrics Set	ttings				Stream 1 - Settings	Stream 1 - Summary		Close
Signal Type OAM Symbol Rate 6 2500000 MBaud Bits per Symbol 6	Template - Custom No. of Stages 4	Stage 1 NW - Mixer	Slage 2 A	Stage 3	Stage 4 + 🙀 i Phase Estimator	Dits per Sec. Bits per Symbol No. of Symbols: No. of Bits. Symbol Rate	3.75000e+007 6 1.25000e+004 7.50000e+004 6.25000e+006 Baud	Samples per Baud: Time Resolution	1.00000e+001 1.60000e-008 s
TELEDYNE LECROY									26/11/15 8:44:01 AM

#### Stream Settings for Custom Modulation

If you choose Custom Signal Type, Custom Symbols controls will appear on **Stream # Settings** right-hand dialog for you to define the custom modulation scheme. Touch **Define Symbols**, then use the editor window to define the reference symbols.

Touch **Show Symbols** if you wish to see them along with the constellation.



#### **Retimer Settings**

The VSA is equipped with a versatile retimer that performs two important functions:

• Upsamples or downsamples the input signal

**NOTE:** This impacts the amount of data that is to be processed by DSP nodes. For example, if the signal was captured at 10 samples/symbol and the Retimer's samples/baud is increased to 20, there will be double the amount of data in the trace. More data results in longer processing time, but it allows more data to be accumulated in visualizations such as eye diagrams.

• Finds optimal sampling point (middle of each symbol) for best results

Control	Action
Interpolation Method	Choose either: Linear Sinc (Sin(x)/x)
Samples per Baud	Enter the target samples per baud, from 1 to 100. A lower number target samples than acquired samples will downsample the signal and vice versa.
Timing Estimation	Choose the algorithm for finding the symbol center:
	<b>Square</b> –squares the input samples and recovers the resulting spectral component at the symbol rate.
	<b>Std dev</b> – looks for the timing location that maximizes the standard deviation. In ideal systems, the standard deviation is minimum when transitioning between symbols and maximum when at the symbol center. However, some modulation formats, such as Offset-QPSK, do not behave this way.
	<b>EVM</b> – loops through all samples and all symbols, and sets the center at minimum EVM. This algorithm is computationally intensive.
	<b>Cross Points</b> – Similar to EVM but based on a period of samples/symbol estimates the eye crossing points and takes the center as the best sampling point. This algorithm is computationally intensive.
	<b>NOTE:</b> The retimer is internally called in many DSP nodes if it hasn't been called before, and symbol center is required for calculations. Once the retimer is called, it is not run again in subsequent DSP nodes unless a retimer node is specifically added by the user.

Retimer settings may also be configured on the Stream # Settings subdialog.

## Post Processor Settings

Control	Action
Fix Phase Ambiguity	Select to stop the constellation flipping from trace to trace.

## **DSP Node Configuration**

Once you have entered the number of stages in the processing stream, a **Stage # button** appears for each node on the Stream # left-hand dialog.

Touch the selection box beneath each button to choose the process run at that node. Then, touch the Stage # buttons to display the corresponding Stream # (Stage #)- <*process*> subdialog and configure the processor settings.

VSA Stream 1	Graphs/Metrics Set	tings				Stream 1 (Stage 1) - Mixer	Stream 1 - Settings	Stream 1 - Summary	Close
Signal Type	Input 1 (RF)	Commission of a				Mixer Type			
Custom	C2	Stage 1	Stage 2 🕂 🗕	Stage 3 🔣 🚽	Slage 4 📲	Manual			
Symbol Rate		Mixer	Filter	Equalizer	Phase Estimator	Carrier Frequency	à de la companya de la		
6.2500000 MBaud	Template		3 <del>0 - 3</del> 5		3	20.00000000 MHz			
Bits per Symbol	- Custom								
	No. of Stages								
		8							

The following processes are available at each node.

#### Mixer

The Mixer subdialog is used to select the optical level parameters of the signal under test.



Control	Action
Mixer Type	Manual – mixes the input RF signal with the specified carrier frequency
Carrier Frequency	Enter frequency to be used for mixing in Manual mode. Units are in Hz.

#### Filter

Choose the **Filter Type** from the list of standard filters (shown below), then specify the **Filter Bandwidth** and **Center Frequency** (required for all).

For Raised Cosine and Root Raised Cosine, also specify the Roll Off Factor.

For Bessel and Butterworth filters, also specify the **Order**.



#### DC Block

Applying DC Block at any stage removes the mean value from the signal. Real and Imaginary parts of the computed mean can be seen in the parameter's table via the respective checkboxes.



#### Retimer

This selection applies the Retimer definition on the Stream # Settings subdialog, unless you manually modify them on the Stream # (Stage #) – Retimer subdialog. The selections are linked and changing one will update the other. See <u>Retimer Settings</u>.

#### **Phase Estimator**

Two algorithms are provided for estimating the phase difference between local and remote oscillator. Select a **Phase Estimation Type** of either:

- Viterbi & Viterbi-commonly used for PSK type modulation formats
- Feed Forward (decision directed)-recommended for all other types of modulation formats

For both, enter the **Number of Symbols** that the algorithm uses in kernel iterations.

You can optionally Suppress DC (which internally calls the DC Block algorithm) by selecting the checkbox.

The estimated **Mean Phase Rotation** found by the estimator can be seen in the parameters table by checking the respective checkbox. The output tracking phase is a trace which is shown in the main Window alongside other visualizers ('**Show Tracking Phase**' checkbox).

Stream 1 (Stage 4) - Phase Estimator	Stream 1 - Summary		More	Close
Phase Estimation Type	Number of Symbo	ols		X
Feed Forward	10		)	
Suppress DC	Mean Phase Rotati	on	]	
Show Tracking Phase				

#### Equalizer

The equalizer is a Finite Impulse Response (FIR) Equalizer. The purpose of the equalizer is to correct frequency dependent distortion in the signal.



Control	Action
Gradient	This value controls the speed and accuracy of the adaptation. The value ranges from 1e-6 to 1. Smaller numbers will result in more processing time but better results in presence of noise, and vice versa for higher numbers. The default is a good compromise between the two, as seen over a range of signals.
Number of Symbols	Enter the length of the training set.
Number of Taps	Enter the number of taps in the equalizer kernel.
Suppress DC	Select to remove mean signal value before applying equalizer.
Force to T/2 Taps	If selected, sets the taps per baud (internal parameter) to 2. If left unselected, the taps per baud is equal to the number of symbols.

The equalizer process will automatically calculate its tap weights using the defined modulation formats and the input signal. The algorithm solutions for **Phase Response**, **Frequency Response**, and **Tap** can be viewed as output parameter traces by selecting them on the Stream # (Stage #) – Equalizer subdialog.

#### VectorLinQ Vector Signal Analysis Software



Equalizer Phase Response and Frequency Response traces

#### **Carrier Estimator**

This algorithm estimates and compensates for the residual frequency offset in the carrier that may be present in your signal. It is a useful process to apply if your carrier is unknown or fluctuating significantly. As a rule of thumb, the residual carrier frequency should be less than 10% of your baud rate for the algorithm to work effectively. For example, if the baud rate is 1GBaud, then the carrier estimator can correct up to 100MHz of residual carrier offset.

The estimated carrier **Frequency Offset** may be displayed as an output parameter trace by selecting it on the Stream # (Stage #) – Carrier Estimator subdialog.

Stream 1 (Stage 3) - Carrier Estimator	Stream 1 - Settings	More	Close
Frequency Offset			X

#### MATLAB

A custom MATLAB<sup>®</sup> function script can be inserted at any point in the DSP processing stream. Relevant stream data is made available in MATLAB space. Any computation performed on this can be made to feed the subsequent nodes.

Choose **Matlab** at the processing node, then touch the **Matlab Script button** that appears on the Stream # (Stage #) – Matlab subdialog.

Type or paste your script into the MATLAB Editor window, or else touch **Load From File** and select a MATLAB Script (.m) file to load. An example script with detailed comments is provided. You may use this as the basis of your own script.

**TIP:** We recommend storing scripts in the oscilloscope D:\Scripts folder for ease of loading. Any script saved from the editor will be saved at this location by default.

VSA     Stream 1     Graphs/Metrics     Settings     Stream 1 (Stage 3) - Matlab     Stream 1 (Sta		MATLAB Editor Edit Mattab Script Undo RedO Find 13 #stream.iBaudCenter Double - Best : * 14 #stream.arrcModFormat Char[16] - Module 15 #stream.I Double array - Real I 16 #stream.Q Double array - Imagin 17 18 #Example script. Delete and add your own code 19 #These will be displayed in a messagebox if showScreenO 20 stream.iBaudRate_bps 21 stream.iBatPerBaud 22 stream.I = stream.I*2; 23 stream.Q = stream.Q*3; 24 25 26 #At the end stream.I and stream.Q data will be passed of 27 win the DSC pipeline 28 * Close	
	VSA Stream 1 Graphs/Metrics Settings Signal Type C2 Stage 1 Stage 1 Stage Symbol Rate 62500000 MBaud Bits per Symbol Template -Custom -	ge 2 A Stage 3 V Stage 4 A	Stream 1 (Stage 3) - Matlab Stream 1 Matlab Script Reset Script

Touch **Reset Script** to clear the contents of the MATLAB Editor window.

You can view the output resulting from the MATLAB command prompt by selecting Show Output Window.

#### None

Selecting None as the DSP processing algorithm simply routes input to output. This selection is useful if you wish to bypass a processing stage without losing the configuration that is in place.

## Graphs

The VSA is equipped with a range of graphs for visualizing time and frequency domain results. These graphs can be accessed by opening the **Graphs/Metrics** left-hand dialog, which appears behind the Stream # configuration dialogs.

The graphs are divided into three categories for ease of use: **Traces**, **I-Q**, and **Eyes**. Touch the button to open the selection subdialogs for that category.

VSA Stream 1 Graphs/Metr	s Settings	Traces St	sectrum	Close
Graphs	Veasurements		Power	X
Traces UL	Parameters	<b>0</b>	Phase	
1-9	BER	Amplitus	se EVM%	
Eyes 🔀	Help 📎	Raw Inp	uts	

Graphs from all three categories can be displayed simultaneously.

File Ventical Timebase Tropper Dicplay Cersons Measure Math Analysis Lillilles I-ells	- 12	insper Setup	Processing II F Flashoan 1
	*	× × ×	* * * *
	×		<b>x</b> x x x
	×		- x - x - x
	×		
	×		- x - x - x
	×		-x -x -x
			* * * *
en ar al anno an an tha anna an an an an an deal bha an chuir ann ann ann an an an an an an an an an	×	× × ×	× × × ×
er de bereine en de alle er de			
2 Proved Crevel (Crevel) Creve			TimeDese 0 yo Toyper 200yean Step 500 kg 250 Nots Cage 4048
V/A Stream Oranhamites Settion	Traces Spectra	-	Con
Contra Mayerinda	Destan		X
Toon 🕕 Pastelin	0 Spectrum		
1-0	Total Brechu		
Def 💭 Hep 🤣	- Coloradora		

A small subset of VSA graphs providing visual interpretation of processed data

Most of the standard X-Stream oscilloscope display features can also be applied to VSA graphs:

• Traces and eye diagrams can be moved to different grids simply by dragging-and-dropping the descriptor box onto the destination grid.

**NOTE:** The X-Y grid, which shows IQ plots (constellation diagrams), is an exception; other plots cannot be moved to this grid.

- Traces can be labeled with custom annotations using the Label feature or LabNotebook™.
- Display Persistence functions can be applied to VSA graphs to further enhance the visualization with color and dimension that illustrate the frequency of samples.

See your oscilloscope *Operator's Manual* for more information about using persistence and other oscilloscope features on VSA data.

#### Traces

This set of graphs shows time domain behavior of the processed input signals. Each trace can be turned on or off individually by selecting from the Traces and Spectrum subdialogs.

Traces Spectrum	Close	Traces Spectrum	Close
	Power		X
Q	Phase Phase	Q Spectrum	
Amplitude	EVM%	Total Spectrum	
Raw Inputs			

The trace selection subdialogs

Dialog	Trace Selector	Shows
	I, Q	I and Q components of the trace after all DSP processing has been applied (i.e., mixer, filters, equalization, etc.).
	Amplitude	Amplitude of the trace after all DSP processing has been applied.
Traces	Raw Inputs	Output from the oscilloscope's front-end sampling system.
	Power	Power of the trace after all DSP processing has been applied.
	Phase	Phase of the electric field. Units are in degrees.
	EVM%	Error vector as a percentage.
Spectrum	l Spectrum Q Spectrum	Power spectrum of the I and Q components of the traces after the DSP has been applied.
	Total Spectrum	Total power spectrum of the processed trace.

See <u>Appendix A: VSA Measurement Definitions</u> for descriptions of the calculations that result in these traces.

#### I-Q

Touch the I-Q button to turn on/off IQ plots. Choose from:

- Trajectory-path taken by the trace to move from one symbol to another.
- Symbols symbols (shown in red) as found by the DSP.
- **Reference Symbols**—green crosses showing the location of where the symbols should ideally be located.

#### Eyes

These show the time domain trace data as eye diagrams. Touch the **Eyes button**, then select the eye diagrams to show from the Eyes subdialog.

VSA	Stream 1	Graphs/Metrics	Settings	Eyes			Close
Grap	19		leasurements		Power	Amplitude	X
	Traces	JT.	Parameters	٩	Phase	EVM%	
	1-0		BER				
	Eyes	XX	Help 🤌	Resample F	actor		

Eye Diagram	Shows
I, Q	Output electric field after all DSP processing has been applied (i.e., mixer, filters, equalization, etc.).
Power	Power of the trace after all DSP processing has been applied.
Phase	Phase of the electric field. Units are in degrees.
Amplitude	Amplitude of the trace after all DSP processing has been applied.
EVM%	Error vector as a percentage.

The **Resample Factor** controls how much data is to be displayed in the eyes per acquisition. A higher number results in brighter eyes but uses more processing time. The value ranges from 100 to 100k. The default of 1723 is a good compromise between eye visibility and processing speed.

**NOTE:** The eyes can be made persistent by turning on Persistence via the Display->Persistence Setup dialog.

#### **Settings Dialog**

The Settings dialog, which appears behind the Graphs/Measure dialog, allows you to control the scale of the visualizations displayed. With a factor of 1.0, all available space is used by the respective plot. With a factor of 2.0, half is used, and so on.

To rescale IQ plots, select a rescaling factor from Scale Factor - XY Plot.

To rescale traces and eye diagrams, select a rescaling factor from Scale Factor – Traces.

To divide the display into the maximum number of trace grids possible (given the space reserved for IQ plots), select **Use Max. Traces (10)**.



## Measurements

Measurements allow you to access key metrics of interest in tabular form. When turned on, VSA measurements appear in a table immediately above the VSA dialogs.

Touch the **Parameters button**, then select the parameters to display from the Parameters subdialogs.

#### Parameters

These parameters can be measured on VSA streams. See the <u>Appendix: VSA Measurement Definitions</u> for information about how measurements are calculated.

Measurement	Shows
EVM (%)	Magnitude of the error vector, which is the difference between the signal vector and the ideal reference vector, expressed as a percentage.
BER Estimate	An instantaneous estimation of the bit error rate calculated from the Q Factor. A less time consuming alternative to actual bit counting.
Q Factor (dB)	An alternate representation of the signal-to-noise ratio presented in dB.
Q Factor	An alternate representation of the signal-to-noise ratio presented as a percentage.
IQ Phase Imbalance	The IQ Phase is the angle between the in-phase and quadrature components of the signal. As the angle should be 90°; the degree of deviation from this number is displayed as the IQ Phase Imbalance.
SNR (dB)	Signal-to-Noise ratio, calculated as the reciprocal of EVM <sup>2</sup> , presented in dB.
SNR	Signal-to-Noise ratio shown as a percentage.
Phase Error	Phase difference between the signal vector and the ideal reference vector
IQ Phase Imb	Phase error of the constellation points with respect to the ideal phase relationship between the constellation points. Units are in degrees.
IQ Skew (UI)	Time difference between the in-phase and quadrature crossing points in the eye diagrams shown in units of <i>unit interval</i> .
IQ Skew (s)	Time difference between the in-phase and quadrature crossing points in the eye diagrams shown in seconds.
IQ Offset (dB)	Shift in center of the constellation with reference to the ideal center point, represented by the length of the center vector, presented in dB.
IQ Offset (%)	Shift in center of the constellation with reference to the ideal center point, represented by the length of the center vector, presented as a percentage.
IQ Offset Phase	The phase difference between I and Q traces. Units in radians.

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Measurement	Shows
IQ Imbalance (dB)	Ratio of the In-phase component versus the Quadrature component of the constellation points, presented in dB.
IQ Imbalance (%)	Ratio of the In-phase component versus the Quadrature component of the constellation points, presented as a percentage.
Magnitude Error	Difference in amplitude between the reference symbol and the signal vector.
I Offset % Q Offset %	Individual components of the IQ Offset calculation above.

#### **DSP** Parameters

Use the DSP Parameters dialog to quickly apply the same selection of parameters to a different stream and processing node. Just select the **Stream** and the **Stage** from the popup menus.



# **Applying Math and Measurements to VSA Data**

The VSA functions are completely integrated with the other oscilloscope functions, allowing you to apply extensive analysis features to VSA output data.

See your oscilloscope Operator's Manual for instructions on using Math and Measurement features.

## **Applying Math Functions**

Math functions can be operated on any of the VSA output parameters. When a function is configured and turned on, a new Math trace appears on the display showing the result of the operation applied to the VSA data.

Choose **Math >Math Setup** from the menu bar, then open a function tab (F*x*). Check **Trace On** to show the Math trace.

When selecting the function **Source**, open the **VSA** menu and choose from the VSA output parameters. You can narrow the selection by first selecting the Stream (**S1-S8**) whose output to use as the source.

Back on the Fx dialog, select the math **Operator** as usual.



## **Applying Measurements**

Any of the oscilloscope standard measurements can also be applied to any of the VSA's traces. These measurements are added to a new tabular display immediately below the waveform grids, above any VSA measurements you have enabled.

Choose **Measure > Measure Setup** from the menu bar. Be sure to check **Show Table** to display the measurement table, then open one of the parameter (Px) dialogs.

When selecting the parameter **Source**, open the **VSA** submenu and choose from the VSA output parameters. You can narrow the selection by first selecting the Stream (**S1-S8**) whose output to use as the source.

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Support <u>e</u> 0 Select Source Main Category Sub Category Source [LIN No All WRawl\_S1 WRawQ\_S1 IRawTr\_S1 QRawTr\_S1 ITr\_S1 SDA S1 1200 QTr S1 AmpITr S1 PowerTr S1 PhaseTr S1 EVMTr S1 VSA S3 ISp\_S1 TotalSp\_S1 Trajec\_S1 Symbols\_S1 QSp S1 **S**4 IEve S1 QEve S1 AmplEye\_S1 PowEye\_S1 RefSym\_S1 77 n 77 n 25.6 25.61 12.499 k# 12.499 kt VSA EVM IQ Skew 1.0922 % Stream 1 -5 mUI PhaEve S1 EVMEve S1 DSPOutpu DSPOutpu DSPOutpu Measure P1 P3 P4 **S**7 V On Туре measure on Q.F Summary Please note if the signal can not be waveforms to the max ampl(C1) math on \* ÷ parameters Actions for P1 Help Show on Markers Always On advanced web edit Histogra Trend Detailed

Back on the Px dialog, select the **Measure**(ment) as usual.

You may optionally show measurement statistics in addition to the acquired values, or plot measurements over time using histograms, tracks, and trends.

# **Examples**

Following are a small set of typical VSA use cases. The setup shown here can be used as is, or modified, for a variety of needs.

## RF 64-QAM

A four-stage DSP chain is configured as Mixer->Filter->Equalizer->Phase Estimator.

The first two stages are required to convert the signal frequency and remove unnecessary components. Equalizer and Phase Estimator improve signal quality, as shown in the capture.



## **RF 256-QAM**

The processing chain is the same as in the QAM64 example, but for a higher density modulation format.



## **Baseband 8-PSK**

This use case is an example of I and Q signal analysis.

In this processing chain, the Mixer is omitted in Stage 1, and the two-part signal is input directly to the Filter in Stage 2.



# **Custom Symbols 25-QAM** An example use of custom defined symbols.



## Maintenance

## Troubleshooting

If the VSA delivers unexpected results, please check the following:

• Proper channel is selected as Input1/Input2

TIP: Enable RAW traces and inspect whether the input is as you would expect.

- Stream parameters are correct (modulation format, symbol rate, and bits/symbol)
- Mixer frequency is correct
- Filter bandwidth is correct

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The Datasheet published on the product page contains the detailed product specifications. Oscilloscope System Recovery Tools and Procedures contains instructions for using the Acronis® True Image® Home recovery application included with the instrument.

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# **Appendix: VSA Measurement Definitions**

EVM

EVM (%) =  $100 \times \frac{rms|signal - reference|}{max|reference|}$ 

Equation 1 - Error vector magnitude calculation



Error vector magnitude, single sample point.

#### **Q** Factor

Q-Factor is an alternate representation of the signal to noise ratio that is commonly used since its relationship with the BER is more intuitive.

Q factor (%) = 
$$\sqrt{\frac{3 \log_2 L}{L^2 - 1} \frac{2}{(EVM\%/100)^2 \log_2 2^{bits\_per\_symbol}}}$$
Equation 2- Q-Factor calculation

Q factor<sub>dB</sub>= $20 \log_{10} (Q \text{ factor})$ Equation 3- Q-Factor in dB

Here L is the maximum number of levels in the signal (considering all dimensions). For example, in BPSK L = 2 where as 16QAM will have L = 4.

#### **BER Estimate**

The BER Estimate is calculated from the Q-factor through the relationship given by Equation 4. This provides an instantaneous estimation of the bit error rate to act as an alternative to actual BER counting, which can be time consuming.

$$\text{BERest} = \frac{1 - \frac{1}{L}}{\log_2 L} erfc\left(\frac{Q \ factor}{\sqrt{2}}\right)$$

Equation 4 - BER estimate calculation

Here *erfc* is the complimentary error function, which applies the assumption of Gaussian distribution of constellation points and L is the maximum number of levels in the signal (considering all dimensions). For example, in BPSK L = 2 where as 16QAM will have L = 4.

#### **IQ Phase Imbalance**

The IQ Phase Imbalance, also called Quad Error, is a measure of the angle between the in-phase and quadrature components of the signal. The angle between the in-phase and quadrature should be 90deg. Any deviation from 90 degree is displayed as an IQ Phase Imbalance. The quadrature error is an average measurement taken over all the constellation points as shown in Equation 5.

IQ Phase Imbalance = 
$$\frac{\angle A - \angle B + \angle C - \angle D}{4}$$





Figure 1: IQ Phase Imbalance for QPSK.

#### SNR

Signal-to-Noise ratio is the reciprocal of EVM<sup>2</sup>.

#### **Phase Error**

The Phase Error is the phase difference between the signal vector and the ideal reference vector. The numerical value displayed as Phase Error in the software is the RMS of all the symbols captured during that acquisition (Equation 6).

Phase Error = 
$$\theta_R - \theta_S$$
  
Phase Error<sub>RMS</sub> =  $\sqrt{\frac{1}{N} (Phase Error_1^2 + Phase Error_2^2 ... + Phase Error_N^2)}$   
Equation 6 – Phase Error calculation.

Phase Error

#### IQ Skew

The IQ skew is a measure of the time difference between the in-phase and quadrature crossing points in the eye diagrams, as shown in the figure below.

$$Skew_{IQ}(s) = t_I(s) - t_Q(s)$$

Equation 7- Skew timing calculation



Eye diagrams of QPSK signal skew

## IQ Offset

The IQ Offset is the shift in center of the constellation points from the ideal location and is represented by the length of the Center vector.



#### **IQ Imbalance**

The IQ imbalance is the ratio of the In-phase component versus the Quadrature component of the constellation points. The ratio is represented as a percentage, so 10% IQ imbalance would mean that the In-phase component is 10% larger than the Quadrature component.

$$Q_{\text{Imbalance}} \% = \left(\frac{|B|}{|A|} - 1\right) \times 100$$

Equation 8 - IQ Imbalance calculation



IQ Imbalance for QPSK

#### Magnitude Error

The magnitude error is the difference in amplitude between the reference symbol and the signal vector. The numerical value displayed as Magnitude Error in the software is the RMS of all the symbols captured during that acquisition (Equation 9).

Magnitude Error = |S| - |R|

Magnitude 
$$\operatorname{Error}_{RMS} = \sqrt{\frac{1}{N}} \left( Magnitude \operatorname{Error}_{1}^{2} + Magnitude \operatorname{Error}_{2}^{2} \dots + Magnitude \operatorname{Error}_{N}^{2} \right)$$

Equation 9 - Magnitude error calculation



Magnitude error calculation

## I/Q Offsets

These are individual components of IQ offset which is calculated as above.

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