



Operator's Manual VirtualProbe Software



VirtualProbe Software Operator's Manual

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Virtual Probe Overview

The Teledyne LeCroy **Virtual Probe**software option lets you view waveforms as they would appear in circuit locations other than the probing point, and in circuit configurations different from the configuration actually used for the measurement. By using Virtual Probe, you can understand the characteristics of signals where a physical probe cannot be placed, such as inside of a package or at the end of an interconnect that doesn't physically exist. You can choose to remove effects caused by elements such as fixtures that will not be present when the device under test is used its final configuration, or add the effects of a device that is to be included but for which only an S-parameter model exists.

VirtualProbe can be used in conjunction with the SDAIII-CompleteLinQ family of serial data analysis tools, or operated independently. It is compatible with SDAIII-CompleteLinQ multi-lane capabilities, integrating seamlessly into the SDAIII-CompleteLinQ framework flow diagram. When the oscilloscope is also out-fitted with the Noise and Crosstalk measurement package (offered with SDAIII-CrossLinQ or SDAIII-CompleteLinQ), you can model the crosstalk across multiple lanes. Configuring and compiling the circuit model is fast, and the software rapidly calculates the output waveforms.



Virtual Probe Process

The basic process for using Virtual Probe is:

- Create a model of the circuit to be analyzed using a simple user interface.
- For each block of the model, indicate whether or not the virtual probe output should include or remove the effects of that block.
- For measurements taken with a differential probe, indicate the probe used to make the measurement, so that the probe loading effects can be removed.
- Identify the position of the probe used to take the measurement.

- Identify the position of a "virtual probe" that outputs the waveform that would be seen at the selected position .
- When used in conjunction with SDAIII-CompleteLinQ serial data analysis packages, use the VirtualProbe output as the source waveforms for equalization, eye, jitter, and noise measurements.

Choose Your Mode of Operation

VirtualProbe appears in the Analysis menu of the scope application. When used independent of SDAIII-CompleteLinQ, choosing Analysis > VirtualProbe opens the VirtualProbe setup dialog, where you'll see four, independent setups.

When used from within the SDAIII-CompleteLinQ framework (EyeDoctor II required), choosing Analysis > VirtualProbe opens a VirtualProbe dialog within the SDAIII-CompleteLinQ De-embed/Emulate dialog.

VirtualProbe, EyeDoctor-VP and EyeDoctor II

VirtualProbe is the next step in the evolution of Teledyne LeCroy's virtual probing capability that was introduced in the EyeDoctor-VP package and was later included with the de-embed/emulate models in EyeDoctor II. The core functionality of VirtualProbe is in part described in the EyeDoctor II section of this Help system. EyeDoctor I required separate software for creating a system description file. EyeDoctor II included three choices for de-embedding and emulating 2 blocks (1 fixture and 1 channel). The current VirtualProbe extends the EyeDoctor II capabilities to model up-to-6 blocks.

Compatible Models

VirtualProbe is compatible with WavePro/SDA/DDA 7 Zi/Zi-A, WaveMaster/SDA/DDA 8 Zi/Zi-A, Lab-Master 9 Zi-A and 10 Zi series oscilloscopes.

Required Firmware

Your oscilloscope must be running firmware version **6.9.x.x** or higher to support the VirtualProbe option. Firmware upgrades are available from www.lecroy.com/support/downloads.

Modeling the Circuit

VirtualProbe Main Dialog

The VirtualProbe main dialog is used to select an active setup/lane and configure the "blocks" in the circuit represented by it. It also displays summary information on and under each block that allows you to quickly see how that block in the circuit is defined.



Before using this dialog to configure individual blocks, go to the VirtualProbe <u>Setup Dialog</u> to configure the overall setup/lane.

NOTE: When used independently, you choose from among four setups (called SetupA, SetupB, etc.) to configure. When used with SDAIII-CompleteLinQ, you select a Lane (e.g., Lane1) to configure.

Independent Use

The VirtualProbe dialog takes on a slightly different appearance depending on whether it is being used from within the SDAIII-CompleteLinQ framework or independently. These controls appear when VirtualProbe is used independent of SDAIII-CompleteLinQ.

SetupA...SetupD buttons - Touch to select a setup. A Setup tab and individual block tabs for the currently selected setup will be displayed (e.g. when SetupA is selected, tabs for SetupA, blocks A1, A2, etc. are displayed)

Setup Status LED - An LED next to each setup button displays the current status of the setup.

- Red: Error in setup. Check the setup for any inconsistency in the Num Ports, Input Type, or the block setup for undefined files or touchstone files with incorrect port count.
- Yellow: Apply needed; touch the Apply button when you are finished making changes to the setup
- Green: Compilation successful.
- Dimmed: The output of the setup is unused.

View Output (one per setup) - Touch to display virtually probed waveform at the position specified by the VProbe checkbox. The waveform name is VPOutX, where "X" is A, B, C or D, corresponding to the setup chosen

SDAIII-CompleteLinQ Use

These controls appear when VirtualProbe is used in conjunction with SDAIII-CompleteLinQ.

Lane1...Lane4 buttons - Touch to select a lane to setup. A VP Setup tab will be displayed that contains the setup for the selected lane.

Show Chann Out checkbox - Touch to display the virtually probed waveform at the position specified by the VProbe checkbox. The waveform name is "Ch."

Status LED - An LED next to the Apply button indicates the status of the VirtualProbe setup for the selected lane.

Setup Status LED - An LED next to each setup button displays the current status of the setup.

- Red: Error in setup. Check the setup for any inconsistency in the Num Ports, Input Type, or the block setup for undefined files or touchstone files with incorrect port count.
- Yellow: Apply needed; touch the Apply button when you are finished making changes to the setup
- Green: Compilation successful.
- Dimmed: The output of the setup is unused.

Common

These controls appear in all instances of VirtualProbe.

Apply button - Touch to build the system description for the circuit, and to compile it. When the Crosstalk package is present. When the Xtalk box is available, touching Apply compiles all setups or lanes together; without, only the selected lane is compiled. While compiling, the message "Compiling" is displayed in the lower-right corner of the application. The result of the compilation is displayed in the adjacent box. Success is indicated as "Compilation Succeeded".

Block Definition buttons (e.g. A1...A6) - Touch to open the dialog for configuring the selected block. The first and last blocks are dedicated as transmitter (data source) and receiver blocks (data sink). All blocks in between may be configured as circuit elements that connect the transmitter to the receiver. The button will show the action being taken by the block.

XTalk button - Touch to open the dialog for configuring the Xtalk block. This block is used to model cross-talk between the lanes. See __ for configuration details.

Meas checkboxes - These checkboxes are visible when the Input Type in the Setup dialog is set to "Probe." Check the Meas checkbox that corresponds to the position of the differential probe where the measurement is being taken. (When the Input Type is set to "Channel," the measurement position is assumed to be at the receiver, meaning that the oscilloscope is acting as the receiver for the channel. If you change the location of the probe by checking a different Meas checkbox, touch Apply to re-compile the model.

VProbe checkboxes - Check the VProbe checkbox corresponding to the position where you would like to locate the virtual probe. If you change the location of the "probe" by checking a different VProbe checkbox, touch Apply to re-compile the model.

Setup Dialog

The Virtual Probe Setup dialog configures the overall settings for the circuit represented by the selected setup or lane.

SDA	Signal	Virtual Probe	VP Setup	VP XTalk	VP Zoom	Clock	Eye	Jitter	Noise	Crosstalk		
Lane Lane Lane	e1 e2 e3 e4	Source S Num Ports	Setup Input Type Probe	Pro	Remove Pro	obe Loadi)xx05-SI	ing		Meas Auto BV Limi ilter Orde	v Max t 12.00 r BW 20.000	er Boost dB / Limit D000 GHz	
RefLa	ane	Apply	ок									

Source Setup

The settings in the Source Setup section of the dialog define the overall topology of the circuit and how it connects to the oscilloscope taking the measurement.

Num Ports field - Enter 2 or 4 to define whether the circuit is connecting a single-ended or differential lane between the transmitter and receiver. When choosing 2, for a single-ended lane, each block in the circuit is a 2-port network, with one input and one output. When choosing 4, for a differential lane, each block is a 4-port network, with two inputs (+ and -) and two outputs. The selection for Num Ports needs to be consistent with the data source setup. Note that when using Virtual Probe from within the SDAIII-CompleteLinQ framework, the data sources are configured in the Signal Input dialog for the selected lane.

Input Type field - When using a differential probe, select "Probe". When using cabled oscilloscope inputs, select "Channel". When using Channel, the measurement point is assumed to be at the receiver.

Remove Probe Loading checkbox - Check to use the probe loading model for the selected probe to deembed the probe from the measurement. This checkbox is enabled when Input Type = Probe.

Probe Model selector - Select the model of the differential probe to used for the measurement. This selector is enabled when Input Type = Probe.

INDEPENDENT USE

These controls appear in the Source Setup section when VirtualProbe is used independent of SDAIII-CompleteLinQ:

Data Source + : Select a source waveform. When using a differential probe, this will be the oscilloscope channel that the probe is connected to. When using Input Type = Channel, Num Ports = 4, this is the oscilloscope channel receiving the (+) side of the differential pair. When using "Channel" and NumPorts = 2, then there is only one data source; Data Source + is used in this scenario. Note that when using Virtual Probe from within the SDAIII-CompleteLinQ framework, the data sources are configured in the Signal Input dialog for the selected lane.

Data Source - : When Num Ports = 4 AND Input Type = Channel (i.e. the circuit is transmitting a differential pair being received by two oscilloscope channels), then Data Source - becomes active. Choose the source waveform for the (-) side of the differential pair.

Users may configure any waveforms for the data sources, and not just Cx waveforms.

NOTE: there is no need to configure a math function to be the difference between two inputs when using VirtualProbe.

SDAIII-COMPLETELINQ USE

When using VirtualProbe from within the SDAIII-CompleteLinQ framework, the data source for the active lane is configured on the SDAIII-CompleteLinQ Signal dialog.

Measurement Filter Section

The measurement filter section of the Setup dialog configures elements that determine the bandwidth limit of the filter and the maximum gain.

Auto BW Limit checkbox - Check to automatically determine the best setting for BW limit. The algorithm uses the Max Boost value to determine the BW value to use.

Max Boost field - Select a value for limiting the maximum boost to apply when de-embedding a block. A vale that is too high can boost noise and lead to undesirable results.

Filter Order field - The filter utilized for handling the measurement bandwidth is generally a high order filter. It is implemented as a filter that has a magnitude response given by a Butterworth filter of a given order. The phase response is always linear. The default value is 20, which is a very high order filter, but for sharper cutoff, higher orders can be used. A filter rolls off at 20 dB/decade (or 6 dB/octave) more for every increase in filter order.

BW Limit field -Set a value to limit the bandwidth of the filter.

Applying the Setting

After configuring the general circuit and individual blocks, return to either the Setup or VirtualProbe dialog and touch the Apply button to apply the settings.

Apply button - Touch to build the system description for the circuit and to compile it. When the Xtalk box is available, touching Apply compiles all setups or lanes together; without, only the selected lane is compiled. While compiling, the message "Compiling" is displayed in the lower-right corner of the application. The result of the compilation is displayed in the adjacent box. Success is indicated as "OK." If the oscilloscope still needs an input waveform in order to build the filter, you will see a message to that effect.

Setup Status LED - An LED next to each setup button displays the current status of the setup:

- Red: Error in setup. Check the setup for any inconsistency in the Num Ports, Input Type, or the block setup for undefined files or touchstone files with incorrect port count.
- Yellow: Apply needed; touch the Apply button when you are finished making changes to the setup
- Green: Compilation successful.
- Dimmed: The output of the setup is unused.

Block Setup Dialog

The Block Setup dialog is displayed when you touch a Block definition button. It is used to configure the corresponding block in the circuit.

Block Action Checkboxes

When a block is configured for something other than "Ideal Thru," the left-side of the dialog includes a set of checkboxes that determine how the circuit element defined by the block is handled. There are effectively three actions defined by these checkboxes:



Remove effects caused by block checkbox - check this when you want the electrical behavior of the circuit element to be removed from the signal. This is usually referred to as "De-embedding". Use this setting when wanting to remove the effects of fixtures or interconnects that would otherwise not be in the path between the transmitter and receiver.

Include effects caused by block checkbox - When not seeking to remove the effects caused by a block, check "Include effects caused by block." Checking this box enables two more selections that will determine the block action:

Block is present at time of measurement checkbox - check this when the element was in the circuit when the measurement was taken, and you wish to include its effects in the output of the virtual probe. That is, you are not seeking to either de-embed or emulate: the block is a real circuit element, and its effects are to be included in the VirtualProbe output.

Block is NOT present at time of measurement checkbox - check this when wanting to include the effects of a "virtual channel." This is often referred to as "emulating a channel," where the S-parameters of a channel are used to build a transfer function that models the reflections and loss characterized by the S-parameters. A typical use-case for this selection is when you wish to understand how a signal would look if the path between the transmitter and receiver were to be extended by an interconnect that does physically exist, and for which you only have an S-parameter model.

Block Type Selector

Ideal Thru - This is the default state. Use this setting when the block is unused or as a placeholder between other blocks.

Ideal Termination - This choice is only present for the outermost blocks, which correspond to the transmitter and receiver, and sets the termination to 50 ohm. **Transmission Line** - Select to use a lossless transmission line modeled by its delay and characteristic impedance.

Touchstone File - Select to use S-parameters to represent the block. The Touchstone file should follow the Touchstone 1 format, and should also meet requirements described in <u>Touchstone File Format</u>. When you select Touchstone File, the additional settings described below are enabled.

Touchstone File Block Type

If you choose to define a block by importing a Touchstone file of S-parameters, these additional controls will appear:

NumFiles - This selector is visible when the setup/lane is configure for 4 ports. See <u>Setup Dialog</u> for port setup information. Choose "1" to use a 4-port touchstone file, or "2" to use two 2-port touchstone files. Using two 2-port files is typically done when looking to describe the block using two transmission lines (such as cables) between which there is no meaningful crosstalk, such that using two 2-port S-parameters files is an accurate model for the block.

Format - This selector is visible when the setup/lane is configure for 4 ports. (See <u>Setup Dialog</u> for port setup information). In the unusually circumstance in which the S-parameters where saved in a mixed-mode format, select "Mixed mode".

NOTE: The Touchstone 1 format is not designed for mixed-mode S-parameters, and using Touchstone 1.0 to store mixed-mode S-parameters is NOT recommended. While it is certainly important to understand mixed-mode characteristics of differential interconnects, Teledyne LeCroy highly recommends saving your S-parameters in single-ended format in order to prevent any future confusion.

Touchstone File Port Mapping - The diagram in this section of the dialog will adapt to the settings for NumPorts, NumFiles, and Format. Configure the port number selectors in the diagram to correctly map the port numbers in the S-parameters file(s) to the input and output ports of the block.

NOTE: if the VirtualProbe output is extremely distorted, then it is possible that the ports were not assigned correctly.



Mapping for four-port network specified in one file.

Block Type: To	uchstone File NumFiles: 2		Touchstone File Port Mapping
SParam File 1:	D:\Applications\VirtualProbe\probe-port1.s2p	Browse View	$\stackrel{1}{\longrightarrow} \operatorname{File1} \stackrel{2}{\longrightarrow} \stackrel{2}{\longrightarrow}$
	ок		
SParam File 2:	D:\Applications\VirtualProbe\probe-port3.s2p	Browse View	\rightarrow File2 \rightarrow \leftarrow
	ок		

Mapping for four-port network specified in two files.

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Block Type:	Touchstone File		Touchstone File Port Mapping
SParam File	D:Applications/VirtualProbe/probe-port4.s2p	Browse View	$^{1} \rightarrow \text{File} \rightarrow ^{2}$
	ок		

Mapping for two-port network specified in two files.

VirtualProbe (XTalk) Crosstalk Block

When the Crosstalk package is present on the oscilloscope, the main VirtualProbe dialog will include the XTalk block. The block is used to define the S-parameter Touchstone file and port assignments. By using the XTalk block—and in doing so, including a model of the crosstalk between lanes—you can create a more accurate model of the circuit and obtain better VirtualProbe results.

The initial implentation of the XTalk block includes the following requirements. If the requirements aren't met, then warning triangles are shown in the dialog, along with a message in the VirtualProbe Status indicator.

- The VP Setup should be NumPorts=4, InputType=Channel
- The Signal Input configuration should match the above requirement, meaning that two data sources should be provided.

XTalk Dialog Elements

The XTalk dialog includes configuration elements in common with other block types.

BLOCK ACTION

When a block is configured for something other than "Ideal Thru," the left-side of the dialog includes a set of checkboxes that determine how the circuit element defined by the block is handled. There are effectively three actions defined by these checkboxes:

Remove effects caused by block checkbox - check this when you want the electrical behavior of the circuit element to be removed from the signal. This is usually referred to as "De-embedding". Use this setting when wanting to remove the effects of fixtures or interconnects that would otherwise not be in the path between the transmitter and receiver.

Include effects caused by block checkbox - When not seeking to remove the effects caused by a block, check "Include effects caused by block." Checking this box enables two more selections that will determine the block action:

Block is present at time of measurement checkbox - check this when the element was in the circuit when the measurement was taken, and you wish to include its effects in the output of the virtual probe. That is, you are not seeking to either de-embed or emulate: the block is a real circuit element, and its effects are to be included in the VirtualProbe output.

Block is NOT present at time of measurement checkbox - check this when wanting to include the effects of a "virtual channel." This is often referred to as "emulating a channel," where the S-parameters of a channel are used to build a transfer function that models the reflections and loss characterized by the S-parameters. A typical use-case for this selection

is when you wish to understand how a signal would look if the path between the transmitter and receiver were to be extended by an interconnect that does physically exist, and for which you only have an S-parameter model.

CONFIGURATION

The Config selector allows the user to from several topologies for the XTalk block:

1xS8P - Select to use a single 8-port S-parameter model

1xS12P - Select to use a single 12-port S-parameter model

2xS8P - Select to use two 8-port S-parameter models.

The dialog will adapt based on the config selected, showing a network(s) with the number of ports corresponding to the selection. For example, selecting 1xS12P shows a 12-port network; selecting 2xS8P shows two 8-port networks (16 ports total).



PORTS ASSIGNMENTS

On the left side of the Touchstone File Port Mapping section, select the S-parameter port number that maps to the signal flow for each lane. Lane numbers go from top to bottom, and, since each lane is differential in the XTalk model, each lane should map to a (+) and (-) port. On the right side, select the ports that correspond as THRUs for the input ports.

APPLY SETTINGS

After completing XTalk configuration, switch to the VirtualProbe or any VP Setup dialog and click Apply. The system description is compiled. When XTalk is active, there is only one system description to compile, which includes all lanes.

Warnings and Error Messages

If all lanes are not setup as 4 port, Channel in the VP Setup dialogs for each lane, then a message will be displayed. For example:



Warning triangles may also be displayed in the XTalk dialog when an error situation exist. Touch the triangle to call up a dialog that explains the error.

Touchstone File Format

Touchstone is a file format used for specifying S-parameters. It is a standard that is commonly adopted by vector network analyzers (VNAs), time-domain network analyzers (TDNA) and EDA tools such as micro-wave simulators.

Specification

VirtualProbe requires that Touchstone files meet the following specification:

- The extension must be in the form **.s[N]p** where [N] corresponds to the number of ports in the device. For example, a two port S-parameter file has an extension ".s2p".
- Lines cannot be longer than 2000 characters.
- Lines beginning with ! are comment lines. Comments must be at the front of the file. No comments are allowed once the frequencies and S-parameter values start.
- There should be at least one line that begins with '#'. This line is a line that contains tokens that help interpret the S-parameters. Valid tokens are:
 - Hz frequencies are in Hz.
 - MHz frequencies are in MHz.
 - **GHz** frequencies are in GHz.
 - MA S-parameters are in magnitude/angle form where the magnitudes are true magnitudes and the angle is in degrees.
 - **RI** S-parameters are in real/imaginary form.
 - **DB** S-parameters are in magnitude/angle form where the magnitude is in decibels and the angle is in degrees.
- If the above tokens are not found, the frequencies are assumed to be in MHz, and the S-parameters are assumed to be in magnitude/angle form.
- The S-parameters for each frequency are assumed to be listed as:

[frequency] (S11) (S12) ... (S1[N])(S21) (S22) ... (S2[N]) ... (S[N]1) (S[N]2) ... (S[N][N])

where N is the number of ports dictated by the file extension, except for two-port S-parameters which are assumed to be listed as [frequency] (S11) (S21) (S12) (S22) according to the standard.

• All S-parameters are assumed to be 50 Ohm. In S-parameter files, on the line beginning with '#', usually there is a token pair: R [Z0] where [Z0] is the characteristic impedance. We assume Z0 is 50 and ignore these tokens.

• All frequencies are assumed to go from the first frequency listed to the last frequency listed with constant frequency spacing.

S-parameter File Interpretation and Usage

S-parameters provided to the virtual probe will tend to have various frequency scales, differing in both resolution (frequency spacing) and range (start frequency and end frequency). The VirtualProbe component will resample all S-parameter sets onto a new frequency scale dictated by the system sample rate (half the sample rate will be the last frequency) and the time length (see Time Length) – where the time length dictates the new frequency resolution. In performing this resampling, it is important to understand that the resolution may be higher or lower than the original resolution and that the frequency range may require extrapolation of points. When the frequency range is higher than that provided in the S-parameter data (i.e. the S-parameters are not provided to half the system sample rate), then the S-parameter data will be set to zero at these extra required data points. Furthermore, most S-parameter data does not go to DC, because VNAs don't measure data to DC, and therefore the DC response is also extrapolated by setting the low frequency points equal to the first frequency provided in the S-parameter data.

What this means is that it is helpful to follow some simple rules that will maximize the effectiveness of the virtual probe.

- Take S-parameter data as low in frequency as the VNA allows to minimize DC extrapolation errors.
- Take S-parameter data up to one half of the system sample rate. In other words, if you are going to supply waveforms to the virtual probe at 40 GS/s, it is good to provide data up to 20 GHz. Otherwise, if the frequency content of the signal provided to the system is much lower, then it is unnecessary to sample at a high sample rate anyway.
- Take S-parameter data with sufficient frequency resolution. The resolution that needs to be provided depends on the electrical lengths of the circuit elements involved. In other words, if you have a cable that is 5 ns long, and there are reflections going on in the system, then taking data at maybe one tenth the minimum frequency resolution of 1/5 ns = 200 MHz (like 20 MHz) is a good idea. Said differently, in a more practical manner, if there are lots of bumps and wiggles in the Sparameters that are narrow in frequency, then you will need to measure S-parameter data with an appropriate frequency resolution to capture these bumps and wiggles. Usually the narrowness of the bumps and wiggles becomes smaller when the electrical lengths of circuit elements becomes longer.



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