Crosstalk Analysis Application

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User's Guide

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1 Crosstalk Analysis

NOTE   The crosstalk analysis feature is license enabled.

When signals have Aperiodic Bounded Uncorrelated Jitter (ABUJ), and you suspect it may be due to crosstalk from nearby signals or a power supply, crosstalk analysis can help you determine whether crosstalk is truly the cause. Crosstalk analysis can be performed on a total of four signals.

Crosstalk analysis analyzes the input signals, removes inter-symbol interference (ISI), finds the crosstalk effects, and shows you the victim signal with the crosstalk removed. You can then make measurements or perform real-time eye analysis on the signal with crosstalk removed to see how crosstalk is affecting your signal quality.

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There are two ways to set up crosstalk analysis:

- The Crosstalk Wizard is the recommended set up method because it guides you through the process in a simplified, step-by-step fashion. See "Using the Crosstalk Wizard" on page 43.

- If you are comfortable with the Crosstalk dialog box controls, you can use the manual set up method. See "Manually Setting Up Crosstalk Analysis" on page 54.

See Also   If you prefer to view a PDF version of this help, see *Crosstalk Analysis Application User's Guide.*

Crosstalk Analysis Overview

Increased data communication speeds, as well as increased circuit densities (in small devices), has led to high serial data rates on multiple lanes placed very close together. The combination of higher bit rates and tightly spaced circuit traces leads to an increased amount of crosstalk distortion between serial data signals. As a result, crosstalk is becoming a more important problem to diagnose and quantify.

Integrated-circuit power supplies are also increasingly susceptible to crosstalk at these higher serial data rates. Simultaneous Switching Noise (SSN) and ground bounce from serial data signals and switching power supplies can create perturbations on the supplies that distort the data lanes they drive, in the form of noise and jitter.

The need to troubleshoot and characterize crosstalk is not new. Legacy methods of measuring crosstalk in digital communications systems have relied on selectively disabling some channels while enabling others. This requires a system to operate in special test modes (which may not always be possible), and it means you measure crosstalk effects under abnormal conditions (see also "Challenges Solved by the Crosstalk Analysis Application" on page 9).

The Crosstalk Analysis application:

- Detects and quantifies crosstalk without requiring systems to operate in special test modes.

- Does not require crosstalk model or simulation files.

- Determines the relative "magnitude of error" that each aggressor imparts to the victim.

- Removes the crosstalk effects from the victim signal and gives you a crosstalk-removed waveform, so you can:

  - Visually compare the original waveform with the clean waveform side by side on the oscilloscope display.

  - Compare the "before" and "after" waveforms using other oscilloscope analysis tools such as real-time eye diagrams or jitter analysis. This approach gives you a direct way of quantifying the amount of improvement you can expect by mitigating the different sources of crosstalk.

- Supports the analysis of up to 4 simultaneously-acquired signals at a time.

- Supports the use model of probing various suspected aggressor signals around your running system individually while monitoring the victim signal until you identify the aggressor.

- Provides valuable insight into your design.

The Crosstalk Analysis application helps you determine the margins your design would recover by removing the crosstalk or whether a signal that fails a design specification would pass without the crosstalk. This approach can help you make important design decisions on whether it is worth the time and effort to improve the crosstalk effects and where to improve the board design.

How the Crosstalk Analysis Application Works
The Crosstalk Analysis application works by constructing optimal models of the crosstalk mechanisms between multiple measured signals. Whether you simultaneously acquire up to four signals of a running system or whether you analyze the victim and potential aggressor signals individually, how you configure the Crosstalk Analysis application determines how the optimal crosstalk models are calculated.

Once the crosstalk models are known, various victim signals can be displayed and analyzed, with and without the crosstalk from each aggressor. In this way, noise, jitter, and eye-diagram measurements can be made on the victim with and without crosstalk to quantify the amount that each aggressor contributes to each of these measurement values.

The crosstalk models also let you remove portions of the victim waveform for additional analysis. For example, leaving only the unknown crosstalk and noise, you can perform an FFT analysis to help identify the remaining crosstalk.

Figure 1   Keysight crosstalk analysis application for analyzing serial data, power supply and other sources of crosstalk effect to the victim signal. Up to 4 signals can be analyzed at once.

Challenges Solved by the Crosstalk Analysis Application

One (difficult) way to uncover the network model behavior and estimate its parameters is to selectively turn off the victim and/or potential aggressor signals. For example, you could visualize the crosstalk that signal 2 imparts on signal 1 by turning off signal 1 and turning on signal 2. The measured waveform of signal 1 would be pure crosstalk (and noise). Then, you could do the opposite by turning on signal 1 and turning off signal 2. The resulting measured waveform of signal 1 would represent a clean signal 1 without any crosstalk from signal 2. In order to quantify the relationships, you could do measurements on the different waveforms, such as peak-to-peak voltage measurements or eye diagrams.

While straightforward, there are a number of problems with this approach:

- First, it may not be possible or convenient to selectively enable or disable the different data signals.

- Second, the approach is tedious and time consuming. In a 4-lane system for example, there are 16 victim-aggressor pairs (if you include ISI), which leads to a large number of test setups and measurements, the results of which are seen separately and must be manually recorded.

- Third, because the measurements are not simultaneous, any constructive or deconstructive interference effects will be lost.

- Fourth, the approach simply will not work if the source of interference comes from outside the network, such as from a power supply that cannot be disabled (see "Power Supply Aggressor Crosstalk" on page 26 for more on power supplies).

The Crosstalk Analysis application solves these problems by estimating the full crosstalk network model from a single test setup, using a simultaneous acquisition of all data lanes. The model can be constructed by simply acquiring all transmission lines using the oscilloscope, and then enabling the application. After constructing the model, the application displays some scalar measurement results, such as the magnitude of the crosstalk for each victim-aggressor pair, and also displays a crosstalk-removed, or "clean" waveform. The crosstalk-removed waveform simulates what the waveform would look like if none of the specified aggressors were turned on (a "what if" scenario). The waveform is treated like any other waveform on the oscilloscope, and can therefore be used as an input to any other oscilloscope measurements or analysis applications. You could easily see, for example, the before and after eye diagrams, or compare the before and after jitter components using EZJIT Plus.

Network Models for Crosstalk Analysis

Regarding crosstalk on parallel transmission lines, there are a couple of other points worth mentioning:

- First, there are of course other sources of interference acting on a victim, such as inter-symbol interference (ISI), which is the result of finite channel bandwidth and reflections at terminal ends. You can think of ISI as the amount of "crosstalk" a signal adds to itself.

- Second, a pair of transmission lanes can crosstalk on each other, so that each of them are both a victim and an aggressor, at the same time.

- Third, there can be more than two lanes, so that each victim can have multiple aggressors.

In general, we can think of a collection of n-lanes as an n^2-port network. The input signal onto each lane experiences interference from itself, and from all other aggressors.

The crosstalk application constructs different types of crosstalk models from the measured waveforms depending on the victim and aggressor signal types. In the simplest case, when both victim and aggressor are serial data signals, the model is a linear n-port transfer function model.

The following figure shows a simple example of a 2-channel serial data system. Physically, the transmission system consists of two transmitters, two receivers and a 4-port linear network model connected between them. Probing the two serial data channels provides the input waveforms to the crosstalk application.
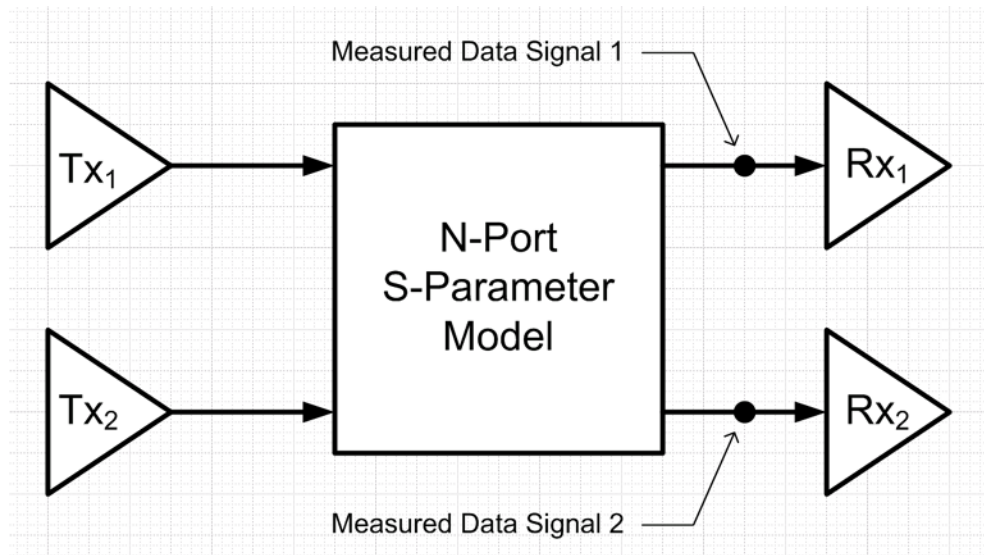
Figure 2   A 4-port network model for 2 parallel transmission lines. The black dots show possible probe locations at the far end.

The application begins analyzing the waveforms by extracting the serial clock and data pattern of each. It then uses the ideal data pattern as input to the 4-port linear crosstalk model shown in the following figure. It computes the best-fit transfer function model, which transforms the ideal waveforms into the actual measured waveforms. Within the model, h_{11} and h_{22} represent the signals' ISI while h_{21} and h_{12} represent the coupling or crosstalk between the two signals. This approach lets the crosstalk analysis application remove the effect of either the crosstalk, ISI, or both crosstalk and ISI from the measured waveforms.
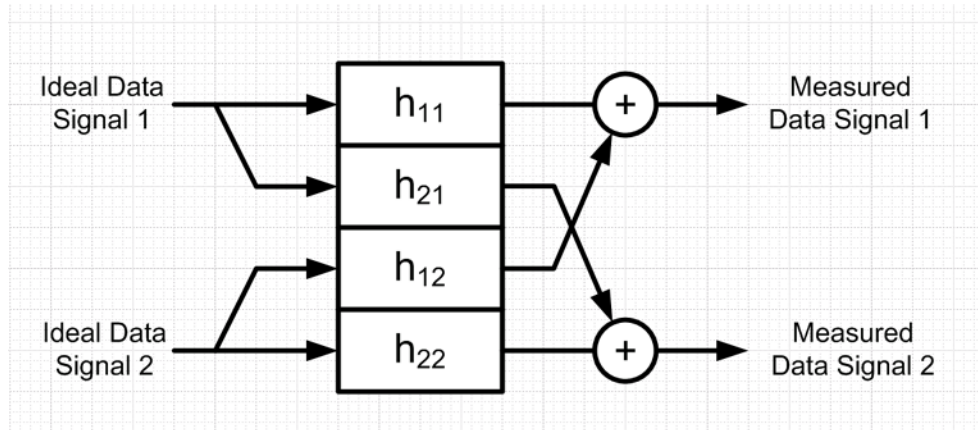
Figure 3   The crosstalk analysis application computes a 4-port linear crosstalk model, which transforms the ideal waveforms into the actual measured waveforms.

Transmission Line Crosstalk

Parallel transmission lines are prime candidates for crosstalk. The mutual inductance and capacitance between them allows energy to couple from one lane into another. The following figure shows an equivalent circuit with components L and C_c, which represent the lump inductance and capacitance of the normal transmission line model, as well as parasitic components M, which is the mutual inductance, and C_d, which is the parasitic capacitance between the two lanes.
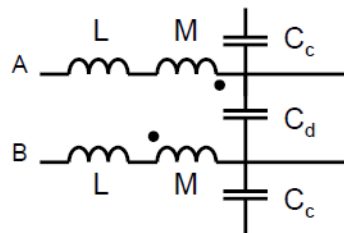
Figure 4   Mutual Inductance and Capacitance between 2 transmission lines. Source: "EE273 Lecture 5, Noise in Digital Systems", William Dally

A rising voltage, such as a step function, on lane A will create a voltage on lane B through capacitive coupling from C_d, and a current on lane B through the inductive coupling M. The following figure gives a representation of the resulting currents induced on the victim line. The voltage generated by capacitive coupling creates a current that travels in both directions (3), whereas the inductive coupling creates a current that travels in the reverse direction only (2). When added together, the two currents reinforce each other in the reverse direction, but cancel each other out (at

least to some extent) in the forward direction. The reverse traveling wave returns back to the transmitter end and is called "near-end" crosstalk (NEXT), while the forward traveling wave arrives at the receiver end and is called "far-end" crosstalk (FEXT). The magnitude and shape of these waveforms are quite different from each other.
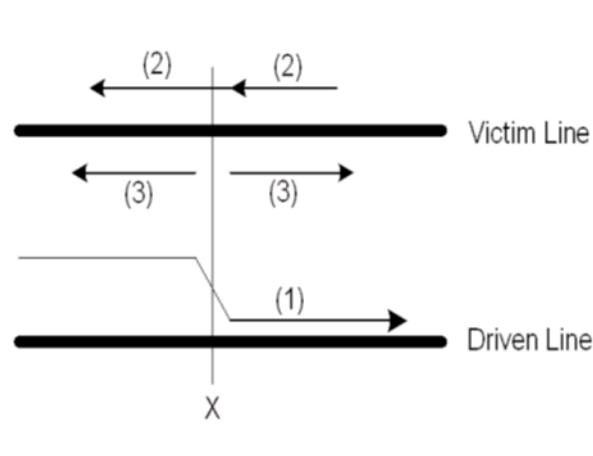
Figure 5   A step (1) on an aggressor line (bottom) couples onto the victim line (top). Capacitive coupling creates a current that travels in both directions (3), while inductive coupling creates a current that travels in the reverse direction (2). Source: "Signal Integrity Issues and Printed Circuit Board Design", Douglas Brooks , Prentice Hall, 2003

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- "Performing Transmission Line Crosstalk Analysis" on page 18

Far-End Crosstalk (FEXT)

At first glance, it may seem that the magnitude of FEXT would be much smaller than NEXT, because the capacitive and inductive currents (at least partially) cancel each other out. That may be the case (and in fact it is possible to completely cancel them using stripline), but because the forward traveling crosstalk travels at the same speed as the aggressor signal, the interference accumulates energy as the pulse travels down the line, so that the magnitude can grow. Another important characteristic of FEXT is that it is the result of a rising (or falling) edge on the aggressor. There are two consequences of this. First, faster rise times create larger amounts of crosstalk. And second, because the aggressor and victim waves are traveling synchronously, the interference remains localized in the vicinity of the aggressors rising edge. Thus, the FEXT crosstalk usually appears as a narrow spike whose width is equal to the rise time of the aggressor edge. See the following figure.
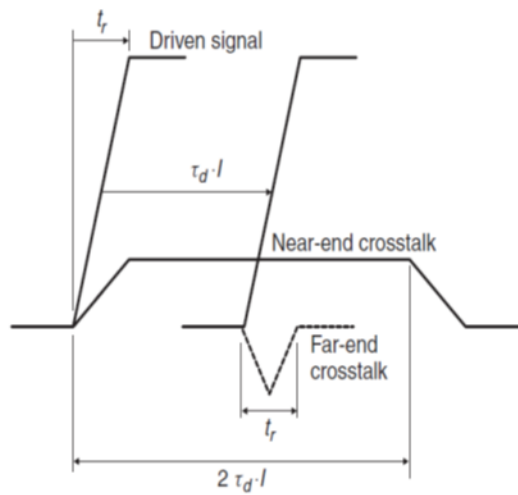
Figure 6   The two shapes of transmission line crosstalk. Far-end crosstalk appears as a tall, narrow pulse, with a width equal to the rise time of the aggressor (t_r). Source: Sam Palermo, Texas A&M University

Near-End Crosstalk (NEXT)

The behavior of NEXT is very different from FEXT. The reverse traveling wave is constantly moving away from the aggressor edge as soon as it is generated, so it is much more spread out. Interference begins immediately when the aggressor step leaves the transmitter, and continues being created until the step reaches the receiver. Crosstalk is being received at the near end during this whole time, which is equal to the propagation delay of the channel. But because the interference created at the far end still needs to travel back to the near end, the total length of the received pulse is equal to twice the propagation delay. The following figure illustrates the shape of the NEXT and FEXT waveforms generated by an aggressor step function (the FEXT can have positive or negative amplitude depending on whether capacitive or inductive coupling is dominant). NEXT tends to be a short, broad pulse, while FEXT tends to be a tall, narrow pulse.
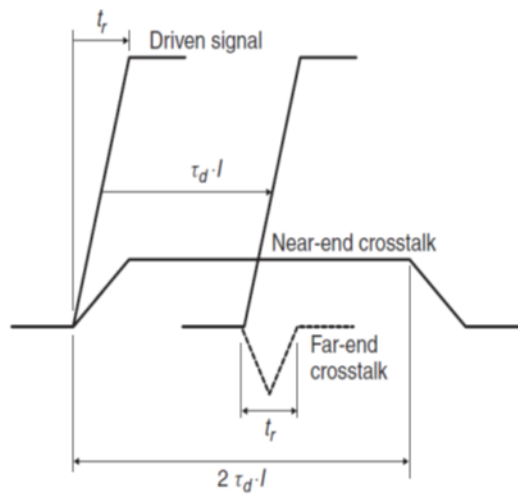
Figure 7   The two shapes of transmission line crosstalk. Near-end crosstalk appears as a short, wide pulse, with a width equal to twice the propagation delay along the line (t_d). Source: Sam Palermo, Texas A&M University

Transmission Line Crosstalk Test Setup

Probing for Transmission Line Crosstalk Analysis   The Crosstalk Analysis application allows signals to be probed anywhere, but for best results, here are some recommendations.

For serial data crosstalk, one victim:

- Victim: probe close to receiver. (This allows the tool to calculate what the receiver sees more accurately.)
- Aggressor: probe close to suspected transmitter. (This allows the tool to extract the aggressor's signature more accurately.)

For serial data crosstalk, multiple victims:

- Victim only: probe close to receiver. (This allows the tool to calculate what the receiver sees more accurately.)

- Victim and Aggressor: probe close to receiver. (This allows the tool to calculate what the receiver sees more accurately.)
- Aggressor only: probe close to suspected transmitter. (This allows the tool to extract the aggressor's signature more accurately.)

The simplest approach is to probe all the transmission lanes at the receiver end, as in this figure (see page 11), because this captures the actual waveforms that are delivered to the receiver. For perfectly terminated transmission lines, this probing scheme will capture primarily FEXT, because NEXT travels back towards the transmitter end. However, it is possible for a received waveform to contain elements of both FEXT and NEXT.

To specifically analyze NEXT, you can probe at the transmitter end. In the Crosstalk Analysis application, you do not need to specify a NEXT or FEXT measurement—the application will measure the crosstalk that is present, regardless of what type it is.

Synchronization of Signals for Transmission Line Crosstalk Analysis   Another consideration in the test setup is synchronization. Because the application is looking for correlations between victims and aggressors, the acquisitions should be captured simultaneously, using matched cable lengths when possible to ensure that the waveforms remain synchronized in time.

Sometimes that may not be possible, and even when it is, there can be propagation delays between victims and aggressors. The application anticipates moderate propagation delays, and will automatically deskew the different waveforms. (However, the ideal case is to construct the setup in a way that minimizes the need for automatic deskew.)
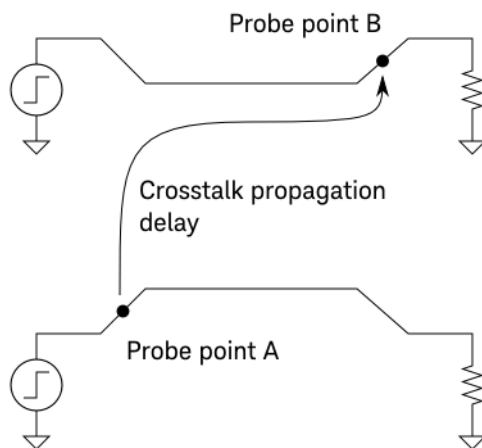
Time skews can be introduced by crosstalk propagation delay, signal access points, and difference in the probing cables. Minimizing this skew can improve calculation time and the quality of measurement results.

The Crosstalk Analysis application is able to de-skew the time skew introduced by crosstalk propagation delay, location of signal access points, and different in probing cables. By default, the application accommodates up to 10 ns of time skew between victims and aggressors, which is equivalent to the delay of about two meters of high-quality coax cable. The automatic deskew range can be adjusted in the advanced configuration up to 1 s (see "Crosstalk Advanced Configuration Dialog Box" on page 67), but it is limited by the sample rate and memory depth settings.

Test Patterns for Transmission Line Crosstalk Analysis   The Crosstalk Analysis application works with arbitrary serial data patterns, though periodic patterns produce better results with shorter calculation times. However, note that, in order to distinguish between distortions caused by ISI and the various aggressors, each serial data channel must transmit different patterns or run at different data rates.

Also, note that longer data patterns are not necessarily helpful or desirable in the Crosstalk Analysis application. One reason is simply practicality. A jitter analysis tool looks only at timing errors in the data, so it needs to process only one data point per data edge (transition), whereas the crosstalk analysis uses all of the waveform data. Therefore, moderate pattern lengths, up to 2^{11}-1 or less are recommended.

Clock Recovery for Transmission Line Crosstalk Analysis   Clock recovery needs to be performed on all serial data waveforms. The application uses the recovered clocks to determine the ideal serial data patterns, which are then used as inputs to the crosstalk network models. Therefore, it is necessary to ensure that the measurement thresholds and clock recovery settings are configured correctly for all serial data inputs.

If an input signal is too noisy for clock recovery, one option is to perform equalization on the waveform before sending it to the Crosstalk Analysis application. This can be done directly on the oscilloscope using the Infiniium Equalization application (and then selecting **FFE** as the signal **Source** for crosstalk analysis). Keep in mind that equalization will remove some ISI from the signal before the crosstalk application has a chance to analyze it. Alternatively, aggressor waveforms can be defined as type Other, which does not use clock recovery. Use type Other only when necessary because of the increased accuracy clock recovery provides.

Sample Rate for Transmission Line Crosstalk Analysis   The sample rate should be high enough to capture all of the input signal's spectral content without aliasing. Using a sampling rate which is about 16 times the signal's data rate is typically recommended. The minimum sample rate that can be used is 4 times the data rate. Interpolation rarely improves the accuracy of the extraction calculations, but it can improve the visual quality of the application's resultant waveforms, at the cost of longer calculation times. Eye diagrams in particular benefit from additional interpolation.

Bandwidth Limit for Transmission Line Crosstalk   Limiting the oscilloscope's bandwidth can sometimes improve the quality of results. Oscilloscopes typically default to their full bandwidth setting, but that may include out-of-band noise in the measurement from the oscilloscope. Viewing FFT math functions of the input signals can help you determine an optimum bandwidth limit setting that removes the out-of-band noise while preserving the signal's full spectral content.

Acquisition Memory Depth for Transmission Line Crosstalk Analysis   A large amount of data is needed to perform the crosstalk analysis because the measured victim waveform may be the result of many different distortions, such as ISI, random noise, and crosstalk. Comparatively speaking, the crosstalk may appear as only a subtle change compared to the other noise sources. Choosing the right acquisition depth can be especially important if a victim has multiple aggressors. A sufficient amount of data is needed to identify and estimate accurate models for all of these interactions. However, too much data will slow the algorithm down. Using an acquisition memory depth of at least 1 Mpts is typically recommended. Note that the crosstalk analysis is performed on the full acquired memory depth, and not on just what is displayed on screen. Setting the memory depth manually is highly recommended.

Performing Transmission Line Crosstalk Analysis

Once the test setup is complete, open the Infiniium software on your oscilloscope, and choose **Analyze > Crosstalk...**. You will see the following dialog box:
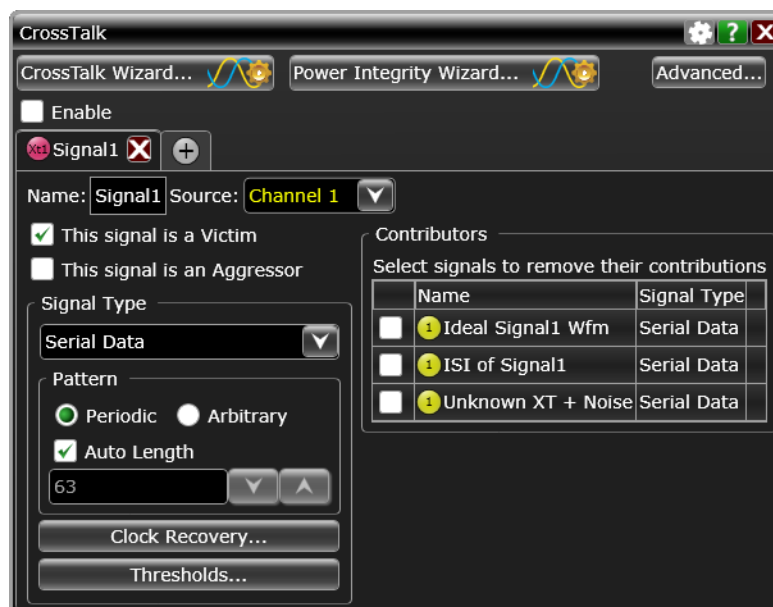
Figure 8   The main configuration dialog box for the Crosstalk Analysis application

One way to configure the test setup is to use the crosstalk wizard, by clicking the button at the top of the dialog box. This will take you through the configuration step-by-step. The wizard is meant to help set up a simple test scenario, and so limits the number of victims to one. In order to add more victims or better understand what the different inputs mean, refer to the following section that describes the manual entries in the main dialog window.

Signal Tabs in the Crosstalk Dialog Box   The tabs near the top of the dialog box (directly below the **Enable** check box) are the main organization component of the GUI.

Each tab represents a different input waveform, and the input boxes that appear below that tab are used to describe the properties of that waveform. Use the victim and aggressor check boxes to identify the signal as a victim, aggressor, or both. Later, you will pair specific victims with specific aggressors, but for now you can simply identify what role the signal will play.

The signal can come from a variety of sources, such as the 4 channel inputs of the oscilloscope, or from a waveform memory, or as the output of a oscilloscope math function, so there is a great deal of flexibility in what signals can be analyzed. The only caution is that all of the signals must be (at least approximately) synchronous in time, so that a proper correlation between them can be established. Thus, comparing a live waveform with one stored in memory will likely not work without careful consideration.

Signal Types in the Crosstalk Dialog Box   Because there are many types of crosstalk, it is necessary to identify the type of signal, so that the application knows what needs to be done:

· **Serial Data** — Selecting the **Serial Data** signal type tells the application that the input signal represents a digital bit stream, and that it needs to do a clock recovery using the parameters in the dialog box.

Users of other oscilloscope applications that use clock recovery, such as Real-Time Eye, or EZJIT, will be familiar with the GUI dialog boxes for **Clock Recovery...**, which allow you to select from many different clock recovery schemes, and the **Thresholds...** dialog box that defines how the application identifies logic transitions in the analog input waveforms.

Serial data can be further identified as being periodic (uses a repeating data pattern) or arbitrary (does not). In order to take advantage of periodic data patterns, select the **Periodic** label in the **Pattern** box. The application can automatically determine the pattern length (by selecting the **Auto Length** check box), or you can input it directly. If the signal does not have a test pattern, you can select the **Arbitrary** option instead.

You should not use periodic data mode for victims that have the same pattern length and data rate, even if the actual patterns are different. In this case, the algorithm will find correlation between the aggressor's crosstalk and the victim's pattern, and treat it like ISI. Using arbitrary mode instead, will alleviate this problem for the victim.

If an input signal is too noisy for clock recovery, one option is to perform equalization on the waveform before sending it to the Crosstalk Analysis application. This can be done directly on the oscilloscope using the Infiniium Equalization application (and then selecting **FFE** as the signal **Source** for crosstalk analysis). Keep in mind that equalization will remove some ISI from the signal before the crosstalk application has a chance to analyze it. Alternatively, aggressor waveforms can be defined as type Other, which does not use clock recovery. Use type Other only when necessary because of the increased accuracy clock recovery provides.

·   **Other** — Aggressor signals that are not also defined as victims can be defined with the type Other. Other-type signals are not converted to an ideal serial data signal and therefore do not require clock recovery be performed on them. They are applied directly to the linear network crosstalk model as a measured analog waveform.

·   **Power Supply** — Selecting this signal type tells the application to use the specialized algorithms for power supply analysis, covered in sections “Power Supply Aggressor Crosstalk" on page 26 and “Power Supply Victim Crosstalk" on page 39.

NOTE	You cannot have both a power supply victim and a power supply aggressor in the same setup because these require different algorithms.

Victim-Aggressor Pairs in the Crosstalk Dialog Box   The tabs near the top of the dialog box and the signal type controls are used to describe the individual signals, but crosstalk is all about how the different signals interact with each other. In the bottom right corner of the GUI is a box that connects victim and aggressor pairs. If a signal is identified as a victim, the **Contributors** box will contain a list of signals that were identified as possible aggressors. You can use this box to select which aggressors to include in that victim's crosstalk analysis. Different victims can have different combinations of aggressors, but each victim must have at least one aggressor.

Crosstalk Analysis Advanced Configuration   The **Advanced...** dialog box has some additional options for users who want to have more control over the construction of the crosstalk model. One of the important parameters is the filter length. The network model is composed of a series of linear filters (finite impulse response filters) that represent the various interactions. An ISI filter, for example, is the filter that represents the channel model, and can therefore convert an ideal input waveform into the one that is band-limited and containing reflections, for example. Similarly, crosstalk filters describe how an aggressor signal is transformed into a crosstalk signal (such as NEXT and/or FEXT), and what magnitude it will have. The length of the filter is related to the bandwidth and time span of the interaction. Short filters can much more efficiently and accurately represent high bandwidth interactions that occur over a short time span, such as FEXT, while longer filters are needed when the interaction is spread out over a larger time span, such as NEXT. By default, the Crosstalk Analysis application uses a proprietary algorithm to automatically determine an ideal filter length for a given situation. The application further tries to optimize the shape of the filter by adaptively placing more taps in areas that are needed. However, you can override the default behavior by specifying the time span (filter length in time) directly. In this case, a FEXT filter length should be at least as long as an edge rise time, and a NEXT filter length should be at least twice the propagation delay of the channel (see the description of FEXT and NEXT in "Far-End Crosstalk (FEXT)" on page 13 and "Near-End Crosstalk (NEXT)" on page 14).
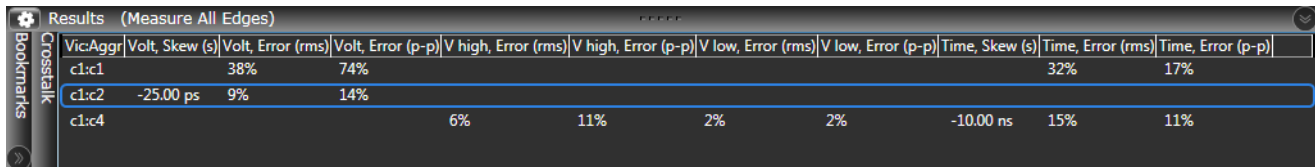
One other note about the bandwidth of the crosstalk: when trying to capture high bandwidth crosstalk, such as FEXT, it might be helpful to increase the sampling rate, so that the acquisition is sure to capture that level of detail.

The **Advanced...** dialog box also gives you more control over the "deskew" algorithm. As mentioned above, the application is tolerant of input waveforms that are not entirely in sync with each other. It uses a proprietary cross-correlation method for aligning the waveforms in time. The algorithm searches over a finite range of delays to find the best possible alignment. The search range corresponds to about 2 m of difference in cable length, which is sufficient for most situations. But, you can change the search range in the dialog box, or turn off the deskew algorithm entirely if the waveforms are believed to be already in sync.

Running Transmission Line Crosstalk Analysis   Once the configuration is complete, it is time to run the application. To do so, simply select the **Enable** check box at the top of the dialog box. The Crosstalk Analysis application needs a certain amount of data in order to compute the network model. Depending on the amount and type of ISI, noise, and crosstalk, the number of aggressors, and the acquisition depth, the model construction may complete within a single acquisition, or require several acquisitions. If the oscilloscope is in **Run** mode, the application will continue acquiring data automatically as needed. If the oscilloscope is in **Single** mode, you need to manually acquire enough acquisitions to complete the model.

The model is complete when the results at the bottom of the screen are available, and when the crosstalk waveform appears on the oscilloscope. If the oscilloscope is in **Run** mode, results will continue to be updated, and new crosstalk waveforms will appear as they are computed. In **Single** acquisition mode it is the same, except that you have control over when to process the next acquisition.

Results for Transmission Line Crosstalk Analysis

Vic:Aggr	Volt, Skew (s)	Volt, Error (rms)	Volt, Error (p-p)	V high, Error (rms)	V high, Error (p-p)	V low, Error (rms)	V low, Error (p-p)	Time, Skew (s)	Time, Error (rms)	Time, Error (p-p)
c1:c1		38%	74%						32%	17%
c1:c2	-25.00 ps	9%	14%							
c1:c4				6%	11%	2%	2%	-10.00 ns	15%	11%

After the Crosstalk Analysis completes, the Results pane is populated with 1) the computed skew, and 2) the crosstalk magnitude for the different victim-aggressor pairs. By default, crosstalk magnitudes are expressed as percent rms values (%rms). Percent rms is defined as the ratio (as a percent), of the standard deviation of the crosstalk error waveform to the standard deviation of the original measured victim waveform. This roughly correlates to the portion of victim signal's power that is attributed to crosstalk. A ratio of <1% for example, indicates a small, perhaps insignificant amount of crosstalk, whereas a ratio of >10% indicates a significant amount. These values quantify which aggressors are the most significant sources of crosstalk on a given victim, and can help a designer determine where changes would be most useful. You can even compare the magnitude of the crosstalk to the magnitude of the ISI, which is also shown. These values can also be used to quantify the effectiveness of design changes made to improve signal quality.

Note that the crosstalk magnitude values can also be displayed as percent peak-peak (%pp). Percent peak-peak is defined as the ratio (as a percent), of the peak-peak range of the crosstalk error waveform to the peak-peak range of the original measured victim waveform. Although percent peak-peak has a more relevant meaning than percent rms, it is not normally as repeatable as percent rms.

In addition to the crosstalk magnitudes, you will also see new waveform(s) appear on the oscilloscope. For each victim, a new composite waveform is displayed that is comprised of user-selected components.
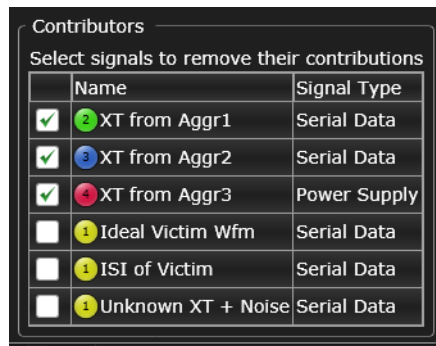
The Crosstalk Analysis application uses a network model that breaks up the measured waveform into these components:

> Measured waveform = Ideal waveform + ISI + (Known XT) + (Unknown XT + Noise)

To display the crosstalk-removed waveform, the known crosstalk is subtracted from the measured waveform (leaving the ideal waveform, ISI, and unknown crosstalk plus noise). This lets you perform comparisons with the measured waveform to analyze crosstalk. You can also choose to remove other combinations of victim signal contributers to make other waveform comparisons. For example, to analyze the residual "unknown crosstalk and noise", you can remove the ideal victim waveform and the victim ISI. Then, using an FFT math function on the resulting crosstalk waveform (or other types of analysis), you may be able to pinpoint the source of the residual crosstalk.

Example: Far-End Crosstalk (FEXT)   The following figure shows the results of a crosstalk analysis of a single victim-aggressor pair, where FEXT is the dominant form of crosstalk. The victim waveform is in yellow, and the aggressor is in green. Note that the rising edge of the aggressor adds a negative going spike to the victim, and the falling edge adds a positive going spike. The red waveform is the crosstalk-removed waveform, which no longer contains those spikes. Note: both waveforms interfere with each other, and it would have been possible to simultaneously treat each as both victim and aggressor, but to keep the illustration simple, this example considers them separately.
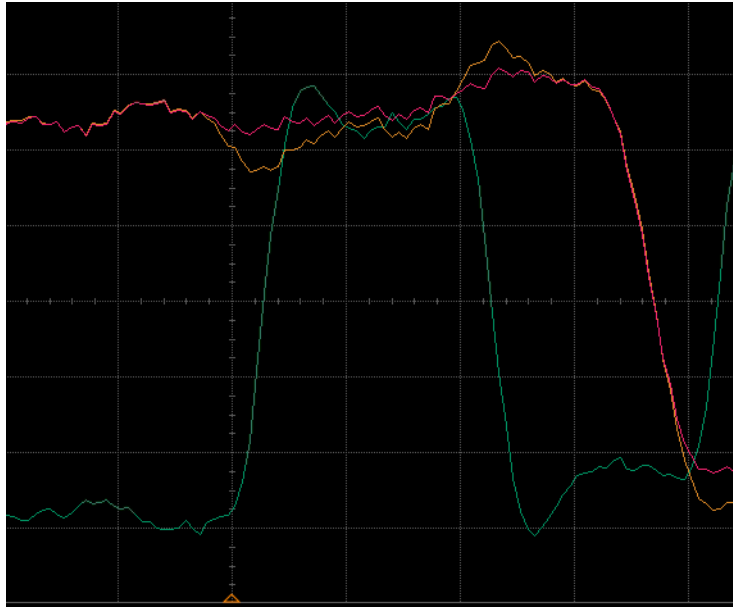
Figure 9   FEXT crosstalk removed from a victim waveform. Victim (yellow), Aggressor (green), Crosstalk removed from victim (red)

The following figure shows the step response of the crosstalk (which is not shown by the application, but included here for illustration). The initial dip, or negative spike near the beginning (left side) of the curve represents the narrow pulse created by FEXT. After the negative spike, the curve moves back towards zero, but not all the way. It remains on a non-zero value for some time. This "square" function is indicative of NEXT, which means that the victim was also experiencing crosstalk due to NEXT.
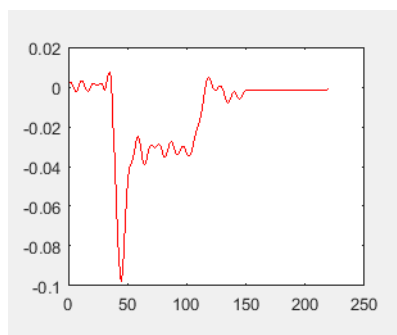
Figure 10   Step response of the crosstalk received by the victim waveform. It shows signs of both FEXT and NEXT

Example: Near-End Crosstalk (NEXT)   The crosstalk generated by NEXT is more difficult to recognize with the naked eye, because its effect is spread out over a larger time range. An eye diagram is one way to visualize it. The following figure shows the victim and aggressor waveforms (in yellow and blue) in the top plot, along with the crosstalk-removed waveform in red. You can see small differences in the before and after waveforms, but there are no tall crosstalk peaks indicative of FEXT, which are easier to see. But when you open up eye diagrams the differences are more apparent. The middle plot shows the eye diagram for the victim waveform, and the lower trace shows the eye diagram for the crosstalk-removed waveform. This particular example does not have a lot of crosstalk; the magnitude reported at the bottom of the figure is only about 7%. Nevertheless, there is a noticeable improvement in the eye diagram.

Figure 11   Before and after view of a victim waveform with NEXT. The top plot shows the victim waveform in yellow, the aggressor in green, and the crosstalk-removed waveform in red. The middle plot is the eye diagram of the victim, and the bottom plot is the eye diagram of the victim after removing crosstalk

The following figure shows the step response of the crosstalk, as derived from the network model (again this curve is not generated by the application, but given here for illustration only). There is a small negative spike when the curve first turns downward, indicating some FEXT, but the curve is predominantly a square or block function, indicative of NEXT.
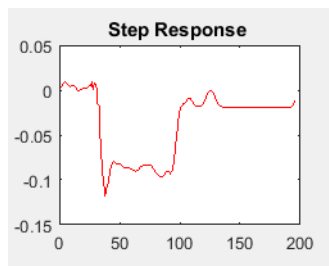
Figure 12   Step response of the crosstalk model for the previous waveforms. This shape indicates a dominant NEXT component

Power Supply Aggressor Crosstalk

The previous section dealt exclusively with crosstalk that occurs on parallel transmission lines, which is mainly caused by parasitic impedances between the two lines.

Power supplies can also be a significant source of interference on a data line, creating both noise and jitter. This type of interference may simply be referred to as "power supply noise", but its effects are similar to traditional crosstalk, and so it is straightforward to think of a power supply as just another source of crosstalk.

And, although the network model for power supply crosstalk is more complicated than for transmission lines, it can still be constructed and used to estimate the magnitude and shape of crosstalk, and to simulate "clean", crosstalk-removed waveforms. This section covers the case of a power supply acting as an aggressor, but we can also consider the power supply to be a victim, which we consider in "Power Supply Victim Crosstalk" on page 39. Note: in both sections we use the term power supply to indicate either logic rail, including ground.

- "Timing Noise (Jitter) Caused by Power Supplies" on page 27
- "Amplitude Noise Caused by Power Supplies" on page 27
- "Bandwidth of Power Supply Noise" on page 28
- "Delays of Power Supply Induced Crosstalk" on page 29
- "Power Supply Aggressor Crosstalk Test Setup" on page 29
- "Performing Power Supply Aggressor Crosstalk Analysis" on page 30

Timing Noise (Jitter) Caused by Power Supplies

Noise and voltage drift on the power supplies of an output driver can affect both the timing and amplitude of the serial data waveforms they output. Timing errors can occur through a number of different mechanisms, such as phase changes which are caused by voltage-dependent driver impedances, and frequency changes caused by voltage controlled oscillators. The resulting jitter is called Power Supply Induced Jitter (PSIJ). PSIJ can be a complex mixture of different sources, so it can be difficult to construct an equivalent circuit model, like the one previously illustrated (Figure 4) for transmission lines. However, a generic small-signal network model can be constructed, and parameters estimated using a direct measurement of the waveforms as we did for transmission lines.

Unlike transmission lines, however, jitter analysis is done using time interval error (TIE) data rather than the waveform data itself. This is handled by the Crosstalk Analysis application, and no additional steps are required by the user, but it is important to understand when looking at the results. Specifically, the crosstalk magnitude is defined as the ratio of the RMS value of the TIE data that is attributable to power supply noise, divided by the RMS value of the total TIE data. So it is the same definition as before, except that the vectors are TIE data rather than raw waveform data. This result is fairly simple compared to the results of a more sophisticated jitter analysis application such as EZJIT. However, it is possible (and straightforward) to get those additional insights by running EZJIT directly on both the original and "clean", crosstalk-removed waveforms. The Crosstalk Analysis application can indicate when a problem exists, in which case EZJIT can used to explore further. It is also important to chose appropriate clock recovery settings. Using a SW PLL type clock recovery with too high of loop bandwidth may remove all the PSIJ before the crosstalk application gets to analyze it.

Amplitude Noise Caused by Power Supplies

The effect a power supply has on the amplitude of a victim is more straightforward, in that the power supply may be directly connected to the transmission line when the logic level switches to that value. Noise and voltage perturbations on the voltage rail can therefore transfer directly to the bit stream. While this seems straightforward, it too is more complicated than the parallel transmission line case. This is because the interference may be present only when the bit stream is at a particular logic level. It is therefore possible for the logic-high bits to experience a lot of crosstalk error, while the logic-low bits experience very little, or vice versa. This is a non-linear, or voltage-dependent type of interference.

That is the basic idea, but it is slightly more complicated because bits don't switch instantaneously from one level to another, so the resulting noise can be a mixture of logic-high and logic-low errors during transitions. But again, like the transmission line case, the crosstalk application can still construct a model for this type of interference, and it can be quantified and removed. You do not need to take any additional actions to accommodate these additional complications, but it is

important to understand them when reviewing the results. Specifically, the magnitude of the amplitude crosstalk is presented separately for high and low bit values.

Bandwidth of Power Supply Noise

One other difference between power supply aggressors and transmission line aggressors is the bandwidth of the interaction. For transmission lines, NEXT and FEXT describe a relatively high bandwidth interaction, which happens over a relatively short time interval. In other words, a short section of one waveform impacts a short section of another. With power supply aggressors, high frequency aggressors can produce both low-frequency ripple and high frequency noise, such as in the example in the following figure.
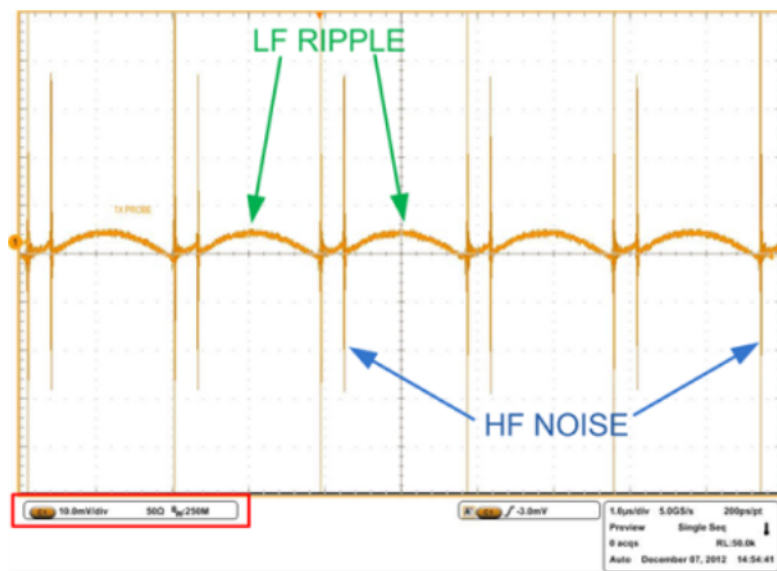
Figure 13   A waveform capture of a power supply that exhibits both low frequency ripple and high frequency noise. Source: "Understanding, Measuring, and Reducing Output Voltage Ripple". Texas Instruments

Depending on the coupling mechanism, an aggressor's waveform shape may couple directly to the victim, preserving its full bandwidth. But it is also common for the aggressor's waveform shape to be heavily low-pass filtered. The effect of power supply bypassing capacitors are a good example. A sudden change in current on a power supply may create a voltage distortion that takes a long time to settle. When the bandwidths or time durations of the aggressor signal and victim interference are significantly different, you may get superior results by manually adjusting the filter lengths used in the network model. More about this is discussed in "Filter Lengths for Power Supply Aggressor Crosstalk Analysis" on page 32 which covers configuring the application.

Delays of Power Supply Induced Crosstalk

Another important difference between transmission line and power supply aggressors is that there can be larger delays between the measured perturbation on the aggressing power supply and the resulting effect measured on the victim. For transmission lines the actual delay between aggressor and victim is defined by the electrical propagation delay between the two lines, which is typically short, if noticeable at all. Differences in cable lengths and fixtures may account for the majority of skew seen between two signals. For power supplies, buffers and other circuitry may create much longer delays, that are proportional to, for example, the charging time of a large capacitor.

Power Supply Aggressor Crosstalk Test Setup

- "Probing for Power Supply Aggressor Crosstalk Analysis" on page 29
- "Synchronization of Signals for Power Supply Aggressor Crosstalk Analysis" on page 29
- "Test Patterns for Power Supply Aggressor Crosstalk Analysis" on page 29
- "Acquisition Memory Depth for Power Supply Aggressor Crosstalk Analysis" on page 30

Probing for Power Supply Aggressor Crosstalk Analysis   The Crosstalk Analysis application allows signals to be probed anywhere, but for best results, the recommendations for power supply aggressor crosstalk are:

- Victim: probe close to receiver (this allows the tool to calculate what the receiver sees more accurately).
- Aggressor: probe anywhere along same voltage node as suspected transmitter's power supply pin.

Because the frequency content of the power supply is so low, there are no distributed (transmission line) effects on the supply; therefore, it does not matter where (along a single electrical voltage node) you probe the power supply.

Keep in mind that supplies of both the transmitter and receiver can contribute to crosstalk.

Synchronization of Signals for Power Supply Aggressor Crosstalk Analysis

As with the transmission line case, synchronization between the waveforms is important in order to establish a correlation between them, so it is again important to minimize skew between the two waveform acquisitions, by using cables of the same length, and so forth.

Test Patterns for Power Supply Aggressor Crosstalk Analysis   Also like the transmission line case, it is helpful to use periodic test patterns for the serial data, such as PRBS5, PRBS7, or PRBS9.

Acquisition Memory Depth for Power Supply Aggressor Crosstalk Analysis   It is even more important in the power supply aggressor scenario to have a sufficient amount of data because the model is more complicated and is divided into two parts. First a network model must be constructed for the jitter. Once this model is complete, the algorithm will construct the first iteration of the crosstalk-removed waveform, which is a waveform that has the same amplitude, but has the timing adjusted to remove the jitter. Once that is complete, the algorithm begins constructing the voltage-dependent amplitude model. Although the algorithm computes the high and low interferences simultaneously, each of them can only use half of the data (the high or low parts of the data), which roughly doubles the amount of data needed. All of these things mean that the power supply algorithm will likely require more acquisitions than the simple transmission line case, but this is to be expected because the nature of the crosstalk is considerably more complex.

Performing Power Supply Aggressor Crosstalk Analysis

The configuration will be similar to the transmission line setup described in "Performing Transmission Line Crosstalk Analysis" on page 18, so refer to that section for additional details if needed. This section will instead focus on the differences. The following figure shows the Crosstalk application dialog box. The second tab is open (the tab for the second signal), and the crosstalk **Signal Type** is set to **Power Supply**.

Figure 14   The Crosstalk application dialog box, showing the second signal is identified as a power supply

- "Clock Recovery for Power Supply Aggressor Crosstalk Analysis" on page 31
- "Deskew for Power Supply Aggressor Crosstalk Analysis" on page 31
- "Filter Lengths for Power Supply Aggressor Crosstalk Analysis" on page 32
- "Running Power Supply Aggressor Crosstalk Analysis" on page 34
- "Results for Power Supply Aggressor Crosstalk Analysis" on page 34
- "Example: Power Supply Aggressor Generating Jitter" on page 34

· **"Example: Power Supply Aggressor Generating Voltage-Dependent Noise"** on page 37

Clock Recovery for Power Supply Aggressor Crosstalk Analysis   To analyze the jitter in power supply crosstalk analysis, the application must first perform clock recovery on the serial data victim signal. There are several options for configuring the clock recovery.

When the crosstalk is in the form of low-frequency drift, care must be taken when choosing a clock recovery method. If you choose a phase-locked loop (PLL) clock recovery method, it will track and remove all low-frequency jitter. The PLL clock recovery method is often preferred when using a jitter analysis tool such as EZJIT Plus, because it simulates the PLL that may be present in the actual circuit. However, if your goal is to determine whether your power supply is generating jitter, then the PLL may remove jitter caused by the power supply, and the application will not be able to see nor analyze it. You can use the PLL method as long as the loop bandwidth is set lower than the spectral content of the crosstalk jitter, but in general, the **Constant Frequency** clock recovery method is preferred.

Deskew for Power Supply Aggressor Crosstalk Analysis   As mentioned in the test setup section, it may be necessary to use manual adjustments to the network parameters in order to get a good result, due to the increased uncertainty in circuitry delays and buffers.

The following figure shows the Advanced Configuration dialog box that appears when a power supply aggressor is present. The upper half of the dialog box is for serial data aggressors, such as from a transmission line, which may also be included in the analysis. The lower half of the dialog box is specific to the power supply aggressor.

You can see that the default search range used by the deskew algorithm is larger for a power supply than for a transmission lines. This is because buffers and other circuit components can create delays much larger than the propagation distance. These delays may vary greatly from one circuit to another, so keep in mind that changing the default value may produce better results.
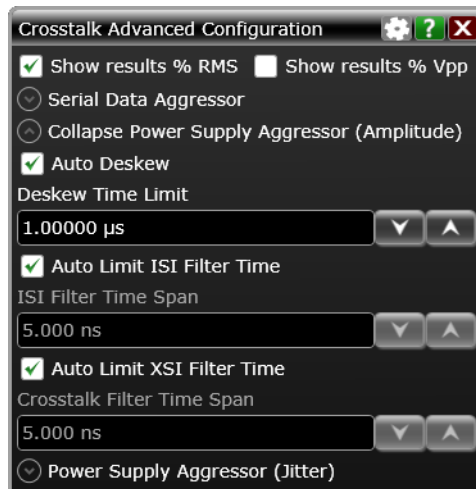
Figure 15   The "Advanced Configuration" dialog box for power supply aggressors

Filter Lengths for Power Supply Aggressor Crosstalk Analysis   A linear crosstalk filter simply takes an aggressor waveform, applies a transform to it, and adds the result to the victim waveform. So the optimal length of the crosstalk filter is dependent on both the time duration of the aggressor waveform's stimulating events and the time duration of the victim waveform's responses to those events. The filter's length should be long enough to cover both of those time durations. For FEXT, both of those durations are roughly equal to the rise time of a data edge. In general, the filter needs to be long enough to produce any change in shape. If there is no change in shape, such as when an aggressor transfers noise directly to the victim with only a change in magnitude, then a small filter will suffice. The default filter lengths used by the algorithm are dynamically computed, and generally produce good results.

For power supplies, you may not know which crosstalk mechanisms may be present, so some manual adjustment might be helpful. The following figure shows an example power supply waveform where a high frequency stimulus event is followed by a low frequency response. This might be caused by, for example, an output capacitor needing to recharge itself. If the noise translates directly to the victim, with only a change in magnitude (which should be easily visible), a small filter will suffice. However if the disturbance pattern of the aggressor creates a different pattern on the victim, you might need a filter length that is the same length as the entire disturbance, which for this example is about 1 microsecond. Because every situation is different, no single default value can cover every case, so some adjustment may be necessary to get optimal results.
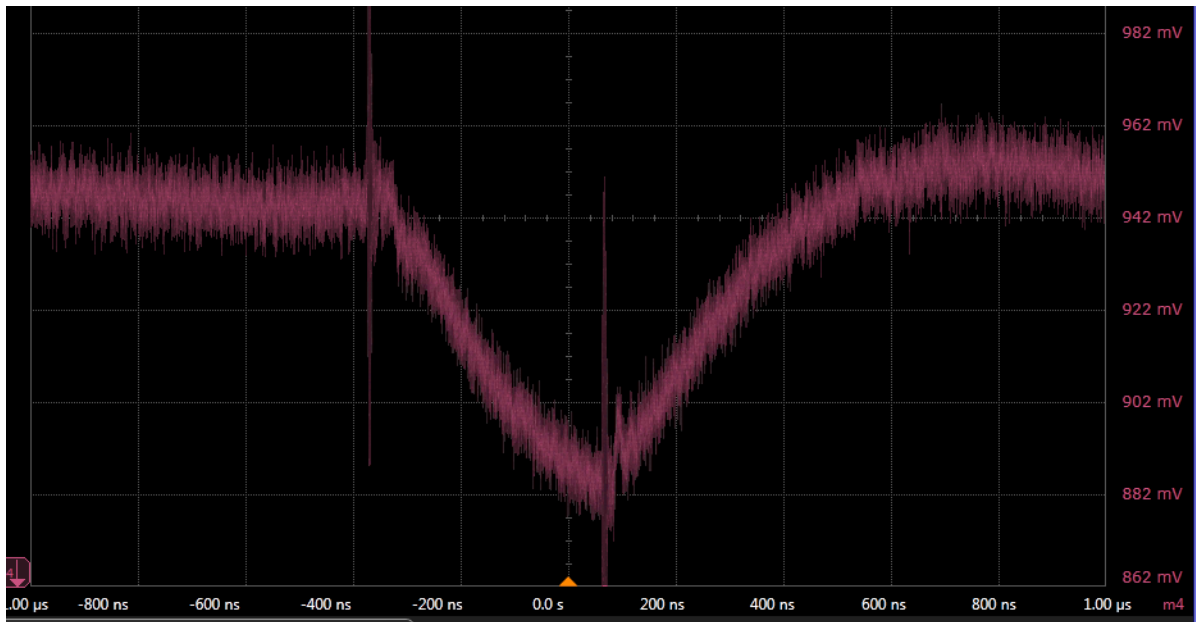
Figure 16   A high frequency disturbance on a power supply is followed by a low frequency response

Experience with power supplies has shown that the response is often long for amplitude crosstalk, and even longer for jitter. This can be due to, for example, a large capacitor being pulled due to a stimulus, and then needing a long time to charge back up in response, which can affect both the amplitude and jitter on the victim waveform. The shape of the response is often in the form of ringing, which can continue for some time. Specifically for jitter, very long responses can result from coupling onto a physical PLL within the victim's driving circuitry. If the timing changes abruptly, the PLL will adapt to that, but it is designed specifically to do that with a lower bandwidth, so that it does not correct right away (that is how it filters out spurious changes).

The crosstalk analysis tool's defaults are designed to be conservative, to make sure that when there is crosstalk of this type that it is able to capture it (to avoid a false negative).

But there are disadvantages to using too long of a filter length. The obvious disadvantage is excessive computation time. Longer filter lengths results in longer computation times. Excessive filter length can also degrade the quality of results in the form of false positives. Long lengths creates large degrees of freedom in the fitting process, which can lead to "over-fitting". Over-fitting produces filters correlated to local, random variations that are not persistent over longer time spans.

Running Power Supply Aggressor Crosstalk Analysis   Once the setup is complete, select the **Enable** check box near the top of the dialog box to run the application. The process is similar to the one described for the transmission line case, the main difference being that more data may be required for power supply analysis because the model is more complicated. The application must first compute a model for jitter, and then once complete, compute another model for the nonlinear amplitude noise.

Results for Power Supply Aggressor Crosstalk Analysis   The results section of the application at the bottom of the oscilloscope screen is organized as before. The main difference is that when a power supply is an aggressor, there are now several different types of crosstalk, including both timing and amplitude noise. The amplitude noise is further split between the cases of high and low logic levels on the victim waveform. The Results pane shows the magnitude of all three of these, expressed as the ratio of the rms value of the crosstalk waveform, divided by the rms value of the victim waveform. For jitter, the "waveform" is the time interval error (TIE) of the waveforms.

Example: Power Supply Aggressor Generating Jitter   The following example illustrates the effect a noisy power supply can have on the jitter of a serial data signal. The following figure shows an oscilloscope capture of a victim waveform (top), its eye diagram (middle), and the eye diagram of the crosstalk-removed victim waveform (bottom). The power supply aggressor waveform is shown in green, but is not very interesting at this time scale. The next figure shows the power supply waveform at a much longer time scale. Note that the crosstalk analysis is performed on the full acquired memory depth, and not on just what is displayed on screen. This example set the memory depth to a large value manually. The power supply is creating excessive jitter on the victim, as seen in the middle eye diagram. In this example, the time interval error (TIE) for each transition (not shown) tends to follow the voltage on the power supply. As the power supply increases in voltage, the TIE grows more positive. As the power supply decreases in voltage, the TIE grows in the negative direction. This trend was captured by the application, and a network model was constructed that allows the jitter to be removed. The eye diagram of the crosstalk-removed waveform is considerably improved, showing that the power supply aggressor was responsible for most of the total jitter. Some vertical improvement can also be seen in the eye diagram, although that is not the main point of this example. The next sections gives a more thorough example of amplitude crosstalk.

Figure 17   Crosstalk example of a power supply aggressor generating jitter on a victim

To quantify the timing improvement, EZJIT can be used to compare magnitudes of the jitter with and without the presence of crosstalk. The following figure shows a screen capture of the original victim signal (top), the power supply aggressor (middle), and the RJPJ histogram (bottom) for the original signal. The power supply has a strong periodic component that is showing up primarily as a large PJdd value in the jitter statistics (at the very bottom). The large PJdd value also creates large PJrms and DJdd values.

Figure 18   Jitter analysis results using EZJIT, showing the large amount of jitter in the
original waveform

The next figure shows the same results for the crosstalk-removed waveform. Note
the improvement in the RJPJ histogram, and the large reduction in PJdd, and
related statistics such as DJdd and PJrms.

Figure 19   Jitter analysis results using EZJIT, demonstrating the improvement in jitter statistics for this example, after removing the jitter generated by the power supply

Example: Power Supply Aggressor Generating Voltage-Dependent Noise

This example illustrates a power supply aggressor that is creating voltage-dependent amplitude noise on a victim. The following figure shows the oscilloscope capture of a serial data victim (in yellow), and a power supply with voltage drift (in green) being treated as an aggressor.
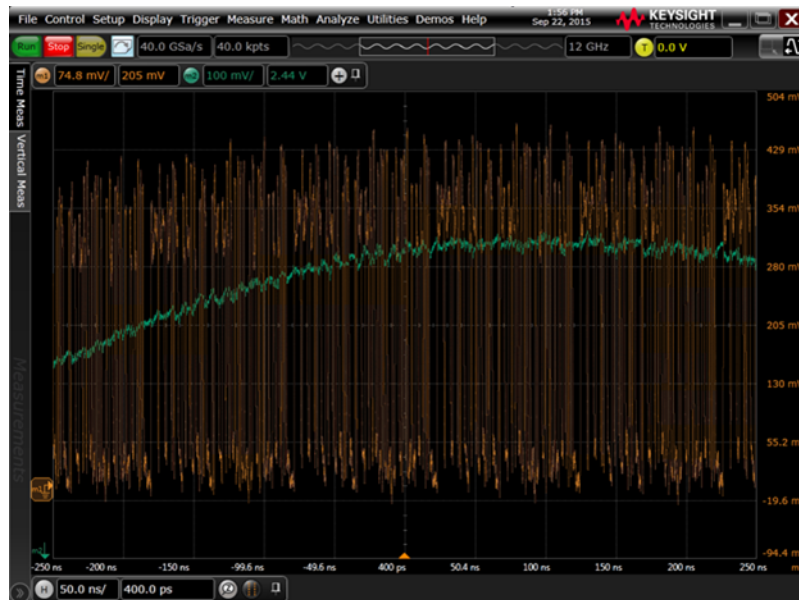
Figure 20   Oscilloscope capture of a serial data victim (in yellow), and a power supply with voltage drift (in green) being treated as an aggressor

From this figure we can see that the rise in voltage on the power supply causes the voltage level of the high bits to rise higher, while leaving the voltage level of the low bits largely unchanged. The following figure gives a zoomed-in view of the original waveform (yellow), and the crosstalk-removed waveform (red) at a point in time, where the voltage has drifted higher. The crosstalk-removed waveform corrects this bias, by bringing the amplitude down to nominal levels. Note that the low voltage levels are largely unchanged, as expected.

Figure 21   Victim waveform (yellow), power supply aggressor (green), and crosstalk-removed waveform (red). The high level of the bits has been reduced to remove a bias generated by voltage drift on the power supply. Low bit levels are unaffected

Power Supply Victim Crosstalk

Simultaneous Switching Noise (SSN) and Ground Bounce

The quality of power supply voltages (including ground) can be affected by the circuits they are driving. One common example of this is Simultaneous Switching Noise (SSN), which can produce Ground Bounce (the Vcc rail can also "bounce" and may be referred to as Vcc sag). SSN can occur as a result of parasitic

inductances and resistances that lie between the device (chip) ground and the system (board) ground. The following figure shows a circuit schematic that illustrates the parasitic inductances that contribute to ground bounce.
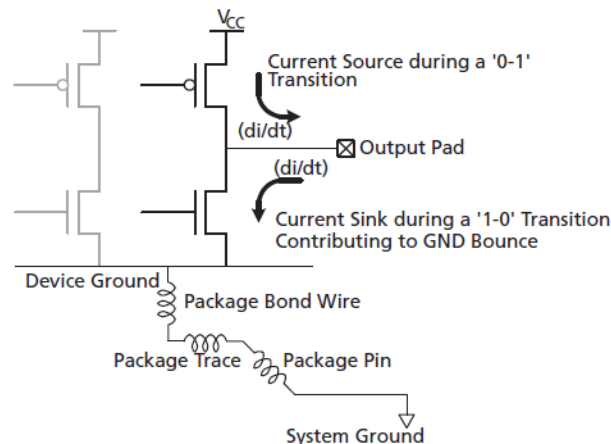

Figure 22   A simplified circuit showing the parasitic inductances that contribute to ground bounce. Source: "Simultaneous Switching Noise and Signal Integrity", Microsemi application note AC263

As the voltage on the output changes state, it draws a current through the switching transistors. As that current flows to ground, it causes a voltage drop across the parasitic inductances (shown at the bottom of the figure). That voltage drop in turn changes the voltage you would measure at the device ground. The voltage measured there may bounce up and down in correlation with data transitions. The effect is amplified when more than one line is switching states at the same time because this will draw more current. And depending on the impedance, and the various switching delays, the ground bounce may appear to have a ringing effect as well.

Unlike the low frequency drift that we looked at when we considered the power supply to be an aggressor, SSN is typically a high frequency event. In order to capture this event, it is necessary to use a probe with sufficient bandwidth. The Keysight N7020A Power Rail Probe is a good option for this. See the the ▣ Making Your Best Power Integrity Measurements application note, or the following YouTube video for more information.

▶ Power Integrity Measurements: Using the N7020A Power Rail Probe

Learn about Keysight's unmatched power integrity solution, the N7020A power rail probe.

Power Supply Victim Crosstalk Test Setup

Probing for Power Supply Victim Crosstalk Analysis   The Crosstalk Analysis application allows signals to be probed anywhere, but for best results, the recommendations for power supply victim crosstalk are:

- Victim: Anywhere along same voltage node where crosstalk distortion is observed.
- Aggressor(s): close to suspected transmitter. (This allows the tool to extract the aggressor's signature more accurately.)

For power supply victim crosstalk, it is possible to have up to 3 aggressors, but all of them must be serial data aggressors. This requirement is because ground bounce is a result of the current drawn from a supply during data transitions, so it is necessary to find those transitions.

Only one power supply victim (Vcc or Ground) can be analyzed at a time due to the complexity of the algorithm.

Other Setup Considerations for Power Supply Victim Crosstalk Analysis   It is possible to have additional aggressors (up to 3), but all of them must use clock recovery. This is because ground bounce is a result of the current drawn from a supply during data transitions, so it is necessary to find those transitions. Only one power supply victim can be analyzed at a time, due to the complexity of the algorithm. As always, synchronization between the waveforms, the use of test patterns, and acquiring sufficient amounts of data are important to the success of the algorithm.

Example: Vcc Bounce

This example demonstrates the Crosstalk Analysis application's ability to identify crosstalk corruption of a power supply. Although this example uses the Vcc rail, the methods and results can apply to the ground rail as well.

The following figure shows a power supply waveform (in yellow) that is a victim of crosstalk from a clock signal aggressor (in green).

Figure 23   Example of a power supply being treated as a victim. Victim waveform (yellow), aggressor (green), and crosstalk-removed waveform (red)

Note the large ringing in the power supply that is time-correlated with the edges of the clock. The red signal is the power supply signal after removing the crosstalk generated by the clock edges. There appears to be some residual crosstalk in the red signal, but the component of error that is time-correlated to our specified aggressor waveform has successfully been removed.

The crosstalk magnitude of the victim-aggressor (C1 C2, Amp-XSI), which is the RMS value of the crosstalk divided by the RMS value of the measured waveform reported, shown at the bottom of the figure is over 95%, which indicates a strong correlation of the clock edges aggressing at the power supply.

Using the Crosstalk Wizard

The Crosstalk Wizard guides you through the steps necessary to quickly set up crosstalk analysis and create a new waveform with the crosstalk removed.

The wizard sets up a single-victim signal with multiple aggressor signals only. To set up multiple victim signals, you must use the Crosstalk dialog box directly. See "Manually Setting Up Crosstalk Analysis" on page 54.

NOTE	The wizard does not set up waveform sources, so you need to have whatever channel, function, or waveform memory signals you want to perform crosstalk analysis on already set up on the oscilloscope. The wizard assumes the signals are already there.

To begin, see:

· "Step 1: Start the Crosstalk Wizard" on page 43

Step 1: Start the Crosstalk Wizard

1 From the main menu, choose **Analyze > Crosstalk...** to open the Crosstalk dialog box.

2 In the Crosstalk dialog box, click **Crosstalk Wizard...**.

At any time during the wizard, you can click **Cancel** to undo any selections or changes you make in the wizard.

Next   · "Step 2: Select/name/characterize the victim signal" on page 43

Step 2: Select/name/characterize the victim signal

The first step after the Welcome page, is the **Victim** page which lets you select, name, and characterize the victim signal.
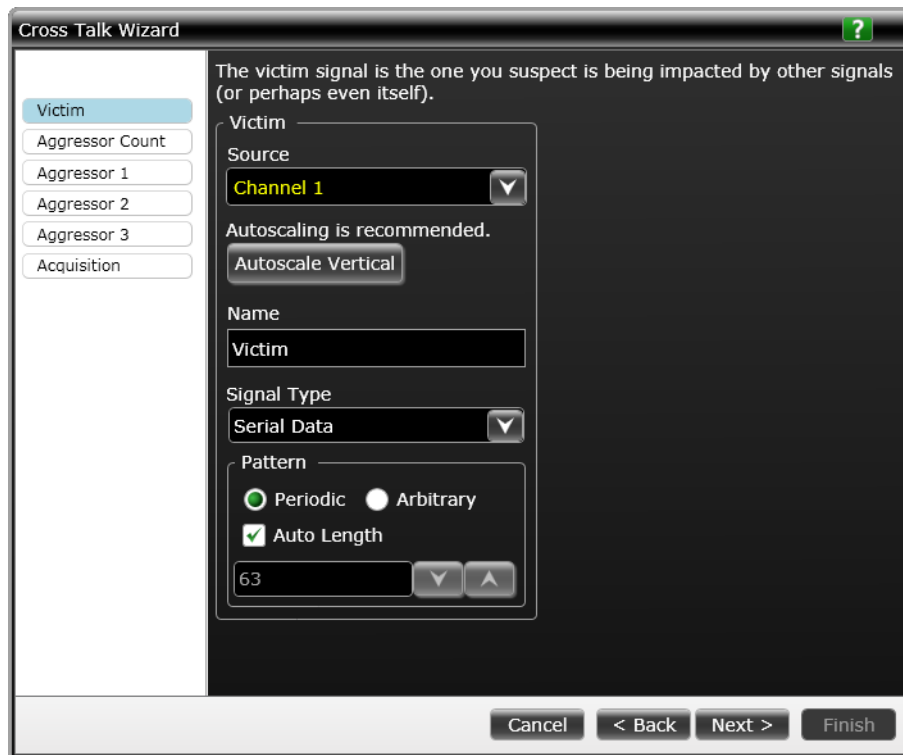
- **Source** — Select an analog channel, math function, or waveform memory.
- **Autoscale Vertical** — This button automatically sets the vertical V/division scale and vertical offset to the optimal values for the selected channel.
- **Name** — Enter the name of the victim signal.
- **Signal Type** — Crosstalk analysis algorithms are different for different types of victim/aggressor signals. Select one of these types of signals:
  - **Serial Data** — Selecting the **Serial Data** signal type tells the application that the input signal represents a digital bit stream, and that it needs to do clock recovery.

    When the signal type is data Serial Data, these controls become visible:
    - **Pattern** — These controls let you specify **Arbitrary** or **Periodic** data patterns and the pattern length (if known) or **Auto Length**. See "Crosstalk Analysis Pattern Length Controls" on page 66.

   See "Transmission Line Crosstalk" on page 12.
  - **Power Supply** — Selecting this signal type tells the application to use the specialized algorithms for power supply analysis, covered in sections "Power Supply Aggressor Crosstalk" on page 26 and "Power Supply Victim Crosstalk" on page 39.

You cannot have both a power supply victim and a power supply aggressor in the same setup because these require different algorithms.

If the victim signal type is **Serial Data**, there are substeps for:

• Specifying the victim signal's threshold voltage and hysteresis:
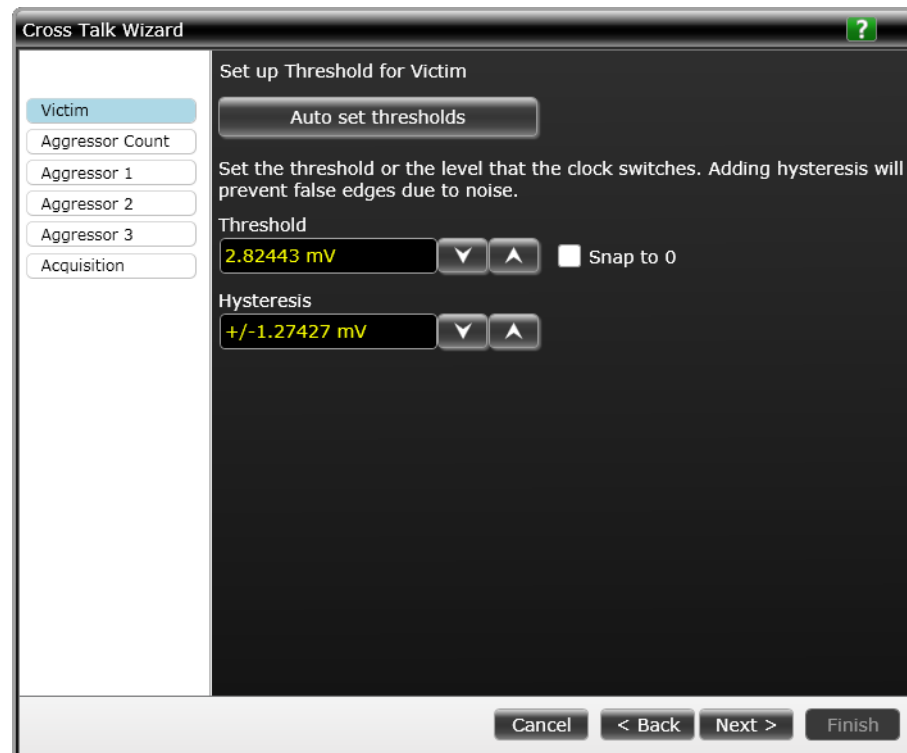
• **Auto set thresholds** — Clicking this button performs an analysis of the signal to automatically determine good threshold and hysteresis settings.

  The threshold level is defined to be the voltage level above which the signal is considered to be a logical 1 and below which the signal is considered to be a logical 0.

• **Threshold** — Lets you set the threshold voltage (switching) level.

• **Snap to 0** — When enabled, thresholds within ±10 mV are moved to zero. This is useful for differential signals.

• **Hysteresis** — The hysteresis helps define what is considered an edge by the oscilloscope.

  For example, if hysteresis is set to +/-5 mV, this means the signal must go through a 10 mV swing (-5 mV to 5 mV) in order to be considered an edge. If you make the hysteresis value too large, the oscilloscope may skip edges and incompletely recover the clock. If you make this value too small, the

oscilloscope will mistake noise for edges. In most cases, +/-5 mV is a good setting, although you may need to increase or decrease this setting based upon your specific signal and the amount of noise.

For more information on setting threshold voltage levels and hysteresis, see Measurement Thresholds dialog box in the online help.

· Selecting a clock recovery preset and specifying a data rate (if known). You can enter the data rate or click **Measure Data Rate** to populate the **Nominal Data Rate** field with the data rate measured on the input signal.
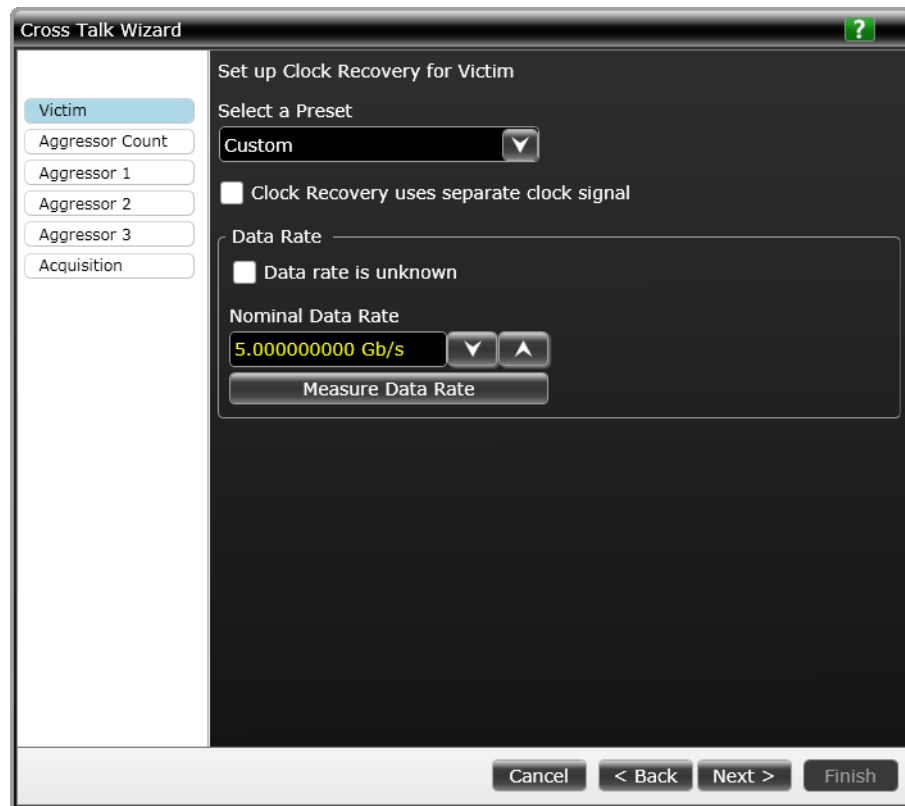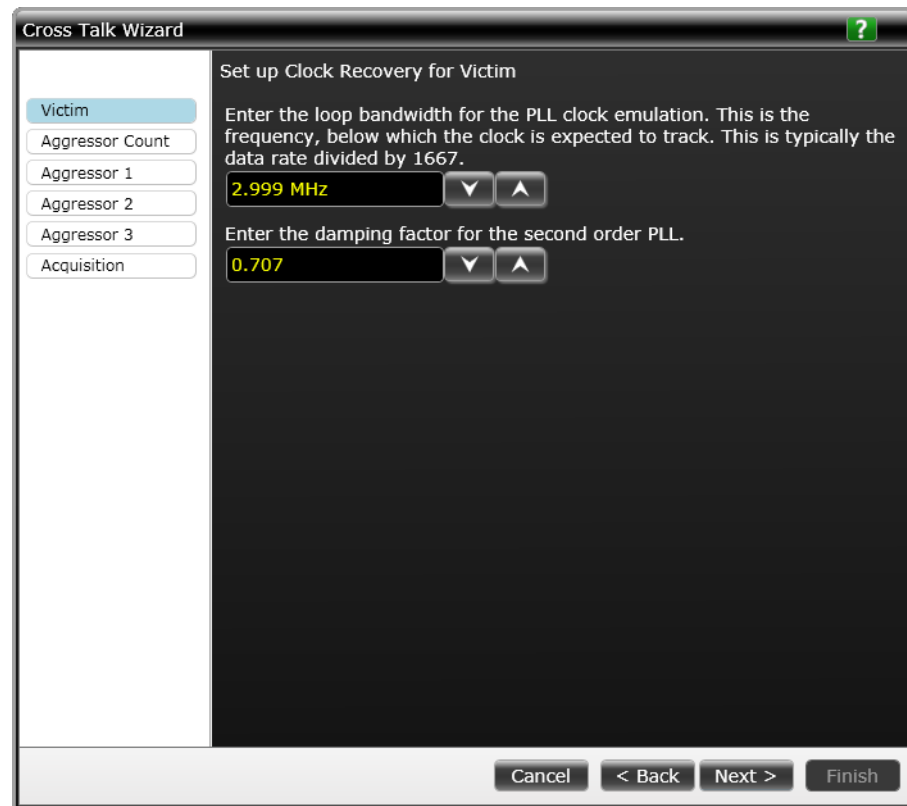

For more information on the clock recovery presets and nominal data rate settings, see Clock Recovery Dialog Box Controls in the online help.

· Specifying the clock recovery method to use.
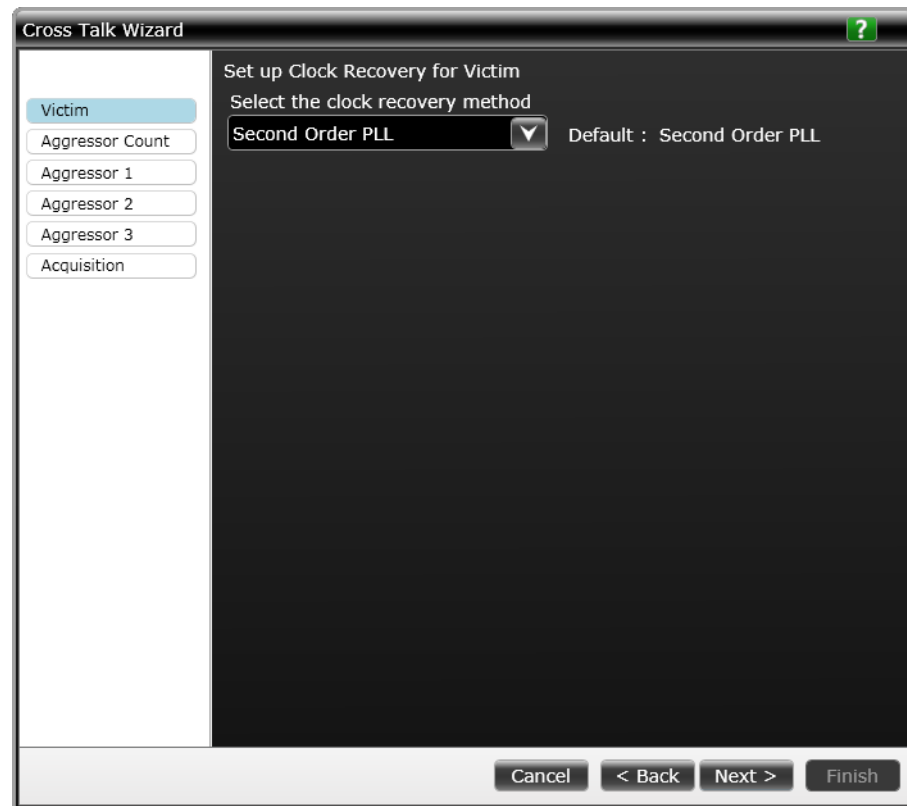
For more information on the clock recovery methods you can select, see Clock Recovery Dialog Box Controls in the online help.

· Specifying the options for the selected clock recovery method.

For more information on the clock recovery method options, see Clock Recovery Dialog Box Controls in the online help.

Next   ·   on page 48

Step 3: Specify the number of aggressor signals

The next step after specifying the victim signal is to specify the number of aggressor signals.

Next   ·   **"Step 4: Select/name/characterize the aggressor signals"** on page 49

Step 4: Select/name/characterize the aggressor signals

Next, for each aggressor signal, select the source, whether the signal is also a victim, autoscale vertical, enter the name, and characterize the signal.

As with the victim signal, if the aggressor signal type is **Serial Data**, there are also substeps for:

- Specifying the clock recovery method to use for the signal.

   For more information on the clock recovery methods you can select, see Clock Recovery Dialog Box Controls in the online help.

- Specifying the clock recovery options.

   For more information on the clock recovery method options, see Clock Recovery Dialog Box Controls in the online help.
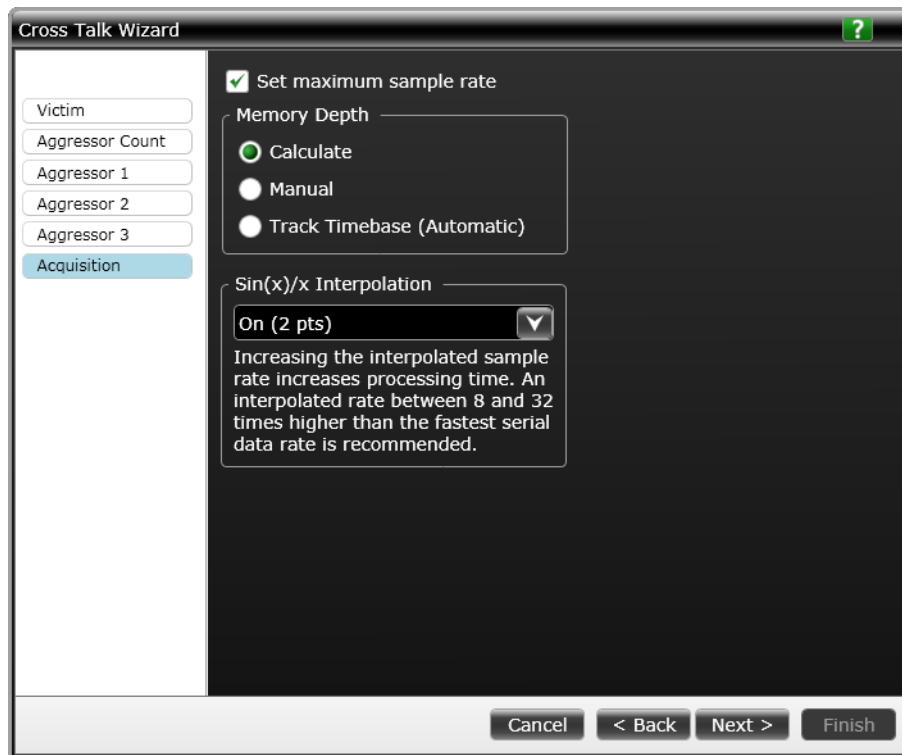
- Specifying the aggressor signal's threshold voltage and hysteresis.

   These options are described in .

Next   ·

Step 5: Specify acquisition options

Next, specify the acquisition options.

- **Set maximum sample rate** — Setting the oscilloscope to its maximum sample rate minimizes the chance of under-sampling the input signals. However, the application's processing time can sometimes be improved by a careful reduction in sample rate. When unchecked, you can specify the sample rate.

- **Memory Depth** — You can choose from these options:

  - **Calculate** — An optimal memory depth is automatically chosen based on the maximum serial data rate and the selected sample rate.

  - **Manual** — Lets you specify the memory depth. To be able to detect patterns and have enough data to perform the crosstalk analysis, the minimum recommended memory depth is 1 Mpts.

  - **Track Timebase (Automatic)** — The memory depth is automatically chosen based on the timebase setting (like the Automatic memory depth selection in the Acquisition dialog box). This selection is generally not recommended for crosstalk analysis.

  See also:

  - "Acquisition Memory Depth for Transmission Line Crosstalk Analysis" on page 18

  - "Acquisition Memory Depth for Power Supply Aggressor Crosstalk Analysis" on page 30

· **Sin(x)/x Interpolation** — An interpolated sample rate of about 16 times higher than the fastest serial data rate is recommended. Sin(x)/x interpolation can increase the waveform sample density without increasing the actual sample rate. Increasing the interpolated sample rate can sometimes improve the visual quality of the waveforms at the expense of increased processing time. Eye diagrams in particular benefit from increased sample density.

Crosstalk analysis requires the **Real Time** sampling mode.

The **Peak Detect** acquisition mode is not supported.

Next   ·

Step 6: Finish the Crosstalk Wizard

In the final Crosstalk Wizard screen, select the **Document waveforms with bookmarks** check box to display bookmarks that explain the analyzed and generated waveforms.

Click **Finish** to:

· Overwrite all previous settings.

· Calculate the crosstalk model.

· Complete the crosstalk analysis setup.

You are left in the Crosstalk dialog box, with the feature enabled.

The signal with the crosstalk removed appears in the waveform display area and is given the ground marker "xt1".

The **Contributors** area of the Crosstalk dialog box lets you select aggressor signals (and parts of the victim signal) whose effects should be removed from the displayed crosstalk-removed waveform.

The Crosstalk Analysis application uses a network model that breaks up the measured waveform into these components:

Measured waveform = Ideal waveform + ISI + (Known XT) + (Unknown XT + Noise)

To display the crosstalk-removed waveform, the known crosstalk is subtracted from the measured waveform (leaving the ideal waveform, ISI, and unknown crosstalk plus noise). This lets you perform comparisons with the measured waveform to analyze crosstalk.

You can also choose to remove additional parts of the victim signal to make other types of analyses.

For example, to analyze the residual "unknown crosstalk and noise", you can also remove the ideal victim waveform and the victim ISI. Then, using an FFT math function on the resulting crosstalk waveform (or other types of analysis), you may be able to pinpoint the source of the residual crosstalk.

See Also
-
-
-

Manually Setting Up Crosstalk Analysis

To be guided step-by-step through a simple single-victim crosstalk analysis configuration, you can use the Crosstalk Wizard (see "Using the Crosstalk Wizard" on page 43).

However, to specify more than one victim signal, you must manually set up the crosstalk analysis configuration using the controls in the Crosstalk dialog box.

To manually set up crosstalk analysis:

1 Display and scale the waveforms that will be included in the crosstalk analysis.

2 Choose an acquisition memory depth and sampling rate such that the serial data can be detected.

The minimum recommended memory depth is 1 Mpts.

Crosstalk analysis requires the **Real Time** sampling mode.

The **Peak Detect** acquisition mode is not supported.

3 From the main menu, choose **Analyze > Crosstalk...** to open the Crosstalk dialog box.
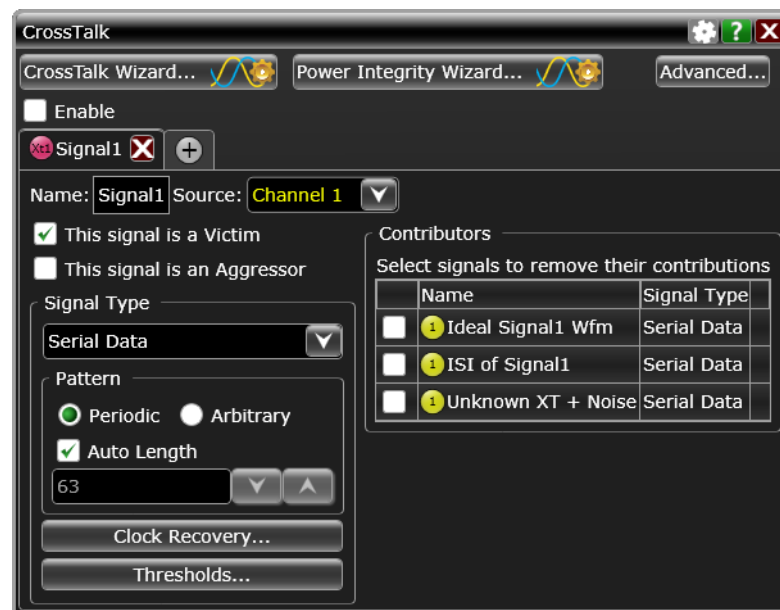
4 Each tab in the Crosstalk dialog box specifies an individual victim/aggressor signal to be included in the crosstalk analysis.

Click the **+** button to add another signal.

For each signal in the crosstalk analysis:

a   Click the **Name** field to enter a name for the signal (optional).

b   Click the **Source** drop-down list to select the source of the signal waveform.

You can choose an analog channel, math function, or waveform memory source.

c   If the signal should be analyzed as a victim signal, select the **This signal is a Victim** check box.

Victim signals with crosstalk (or other specified components) removed are displayed as a result of the crosstalk analysis.

Because modified victim signals are displayed independently of the original measured victim signal, **Vertical** controls become visible in the Crosstalk dialog box to let you set the displayed modified victim's scale and offset.

Also, **Contributors** controls become visible in the Crosstalk dialog box to let you quickly add or remove aggressor signals from the analysis of this victim.

d   If the signal should be analyzed as an aggressor signal, select the **This signal is an Aggressor** check box.

e   Select the signal type:

·   **Serial Data** — Selecting the **Serial Data** signal type tells the application that the input signal represents a digital bit stream, and that it needs to do a clock recovery.

When the signal type is data Serial Data, these controls become visible:

·   **Pattern** — These controls let you specify **Arbitrary** or **Periodic** data patterns and the pattern length (if known) or **Auto Length**. See "Crosstalk Analysis Pattern Length Controls" on page 66.

·   **Clock Recovery...** — Opens the Clock Recovery dialog box where you can specify the clock recovery options for this signal.

·   Note that the default clock recovery settings are often not the best and need to be changed. See Clock Recovery Recommendations in the online help.

·   **Thresholds...** — Opens the Measurement Thresholds dialog box where you can specify the voltage thresholds used for this signal.

·   The proper threshold settings are important for determining edges in clock recovery.

·   Note that the default measurement threshold definitions using **10%,50%,90% of top, base** should be changed to **Custom: threshold +/- hysteresis** (as is done when using the crosstalk wizard).

If an input signal is too noisy for clock recovery, one option is to perform equalization on the waveform before sending it to the Crosstalk Analysis application. This can be done directly on the oscilloscope using the Infiniium Equalization application (and then selecting **FFE** as the signal

Source for crosstalk analysis). Keep in mind that equalization will remove some ISI from the signal before the crosstalk application has a chance to analyze it. Alternatively, aggressor waveforms can be defined as type Other, which does not use clock recovery. Use type Other only when necessary because of the increased accuracy clock recovery provides.

See "Transmission Line Crosstalk" on page 12.

· **Other** — Aggressor signals that are not also defined as victims can be defined with the type Other. Other-type signals are not converted to an ideal serial data signal and therefore do not require clock recovery be performed on them. They are applied directly to the linear network crosstalk model as a measured analog waveform.

· **Power Supply** — Selecting this signal type tells the application to use the specialized algorithms for power supply analysis, covered in sections "Power Supply Aggressor Crosstalk" on page 26 and "Power Supply Victim Crosstalk" on page 39.

NOTE   You cannot have both a power supply victim and a power supply aggressor in the same setup because these require different algorithms.

The **Contributors** area of the Crosstalk dialog box lets you select aggressor signals (and parts of the victim signal) whose effects should be removed from the displayed crosstalk-removed waveform.

The Crosstalk Analysis application uses a network model that breaks up the measured waveform into these components:

Measured waveform = Ideal waveform + ISI + (Known XT) + (Unknown XT + Noise)

To display the crosstalk-removed waveform, the known crosstalk is subtracted from the measured waveform (leaving the ideal waveform, ISI, and unknown crosstalk plus noise). This lets you perform comparisons with the measured waveform to analyze crosstalk.

You can also choose to remove additional parts of the victim signal to make other types of analyses.

For example, to analyze the residual "unknown crosstalk and noise", you can also remove the ideal victim waveform and the victim ISI. Then, using an FFT math function on the resulting crosstalk waveform (or other types of analysis), you may be able to pinpoint the source of the residual crosstalk.

5   Finally, to begin the crosstalk analysis, select the **Enable** check box.

When the analysis completes, the victim signal with selected contributors removed appears in the waveform display area.

See Also   ·   **"Performing Transmission Line Crosstalk Analysis"** on page 18

·   **"Crosstalk Dialog Box"** on page 63

·   **"Analyzing the Signal with Crosstalk Removed"** on page 58

·   **"Crosstalk Advanced Configuration Dialog Box"** on page 67

Analyzing the Signal with Crosstalk Removed

After you have set up crosstalk analysis and the victim signal(s) with specified contributors removed appear in the waveform display area, you can perform measurements or real-time eye analysis on them to see how crosstalk is affecting your signal margins.
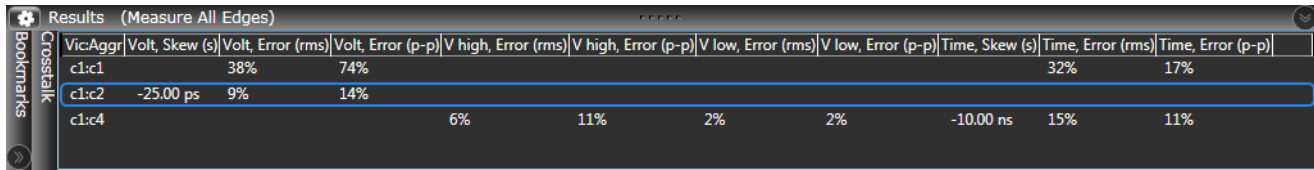

Victim waveforms with crosstalk removed can also be:

- Used by InfiniiSim and EZJIT Complete.
- Used by Equalization and Mask test.
- Saved into a waveform file.

Crosstalk Analysis Results Window   Listed in the Crosstalk analysis results window are the relative magnitudes of crosstalk that were identified by the analysis application.

For each potential crosstalk effect, these values are displayed:

Result Column	Aggressor Signal Type	Description
Vic:Aggr	all	Labels the crosstalk victim/aggressor pair whose results are shown in the row (c1:c1 refers to the ISI on c1).
Volt, Skew (s)	Serial Data	The determined time skew between the victim and aggressor that applies to voltage crosstalk.
Volt, Error (rms) **Volt, Error (p-p)**	Serial Data	The % voltage error caused by the aggressor. For signals that are aggressors to themselves, this shows the effect of ISI.
V high, Error (rms) **V high, Error (p-p)** **V low, Error (rms)** **V low, Error (p-p)**	Power Supply	The % error caused by the aggressor by power supplies. The results are listed separately for logic low and logic high levels of the victim waveform.
Time, Skew (s)	Power Supply	The time skew (s) between aggressor and victim of the jitter crosstalk as determined from the time interval error (TIE) data.
Time, Error (rms) **Time, Error (p-p)**	Power Supply	The % timing jitter caused by the aggressor as determined from the time interval error (TIE) data.

Percent rms (%rms) values are the ratio of the rms value of the crosstalk error waveform, divided by the rms value of the victim waveform. This roughly correlates to the portion of the victim signal's power that is attributed to crosstalk.

A ratio of <1% for example, indicates a small, perhaps insignificant amount of crosstalk, whereas a ratio of >10% indicates a significant amount. These numbers illustrate which aggressors are the most significant causes of crosstalk on a given victim, and can help you know where design changes would be most useful.

You can also display the crosstalk magnitude values as percent peak-peak (%pp). Percent peak-peak is defined as the ratio (as a percent), of the peak-peak range of the crosstalk error waveform to the peak-peak range of the original measured victim waveform. Although percent peak-peak has a more relevant meaning than percent rms, it is not normally as repeatable as percent rms.

These crosstalk magnitude values can be used to determine the relative contributions of various signal errors and quantify the effectiveness of design changes made to correct the errors.

Even if the metric seems unfamiliar, you can compare the magnitude of the ISI (also shown) to the magnitude of the crosstalk to get an idea of where the problem lies.

With so many result values available for display, you may wish to limit the display to a select set of values. To specify which columns appear in the crosstalk analysis results, use the Results tab, Crosstalk subtab of the Display dialog box.

Crosstalk Analysis Errors

Error messages that can occur when using crosstalk analysis, their cause, and how to respond to the error are:

- **Sorry, you can't invoke crosstalk on these sources.** — This message can occur when a source is invalid, for example, like when the source is a magnify math function of an FFT waveform.

- **Crosstalk analysis failed:** — These types of failures can occur:

  - **Insufficient Sample Rate: C1 has 3 samples per bit. Need at least 4.** — You need to set the sample/interpolation rate so that there are at least 4 samples per bit.

  - **Run-Time Error** — A problem occurred during the crosstalk analysis. Try re-running the analysis.

  - **Sample Rate or Interp Setting Changed. Must re-enable App.** — You cannot change the sample rate or the interpolation rate during the crosstalk analysis. Normally, the oscilloscope will restart the crosstalk analysis automatically; you see this message when the analysis fails to restart correctly.

  - **Too Few Points. Need at least 5 patterns per waveform, have 3.** — The acquisition memory depth needs to be large enough so that there are at least 5 patterns per acquisition in periodic mode.

  - **Victim (<source>) and Aggressor (<source>) cannot have the same pattern length. Set victim to arbitrary mode.** — When both the victim and aggressor have the same pattern length in periodic data mode, the algorithm cannot distinguish between ISI and crosstalk. Setting the victim's mode to **Arbitrary** allows the algorithm to separate them.

- **Crosstalk: Failed to find pattern for signal: <source>.** — This message occurs when the software is unable to find a pattern in the data stream (similar to EZJIT jitter analysis software). This is usually caused by an unsuccessful clock recovery. Try adjusting the clock recovery settings. If the pattern is too long, try increasing the memory depth first. If the pattern is still too long or is not truly periodic, you may need to select the **Arbitrary** data setting. If the signal is an aggressor you could alternatively change the signal type to **Other**.

- **Crosstalk: Failed to save clock results for signal: <source>.** — This message indicates a file write failure of the clock results. This is likely an operating system disk space or file permissions issue.

- **Crosstalk: Failed to find TIE data for signal: <source>.** — This message occurs when TIE results for the specified signal cannot be retrieved.

- **Crosstalk: Failed to save pattern data for signal: <source>.** — This message indicates a file write failure for the pattern data. This is likely an operating system disk space or file permissions issue.

- **Crosstalk: Failed to save TIE data for signal: <source>.** — This message indicates a file write failure for the TIE data. This is likely an operating system disk space or file permissions issue.

- **Crosstalk: <source> Invalid pattern state.** — The crosstalk measurement was found, but it had a bad pattern. Make sure the pattern length is correct. If the error still occurs, you may need to specify an **Arbitrary** pattern or change the signal type to **Other**.

- **Crosstalk: <source> Signal analysis not found.** — Could not find a crosstalk measurement on the signal.

- **Crosstalk: <source> Signal analysis incorrect.** — The crosstalk measurement was bad.

Crosstalk Dialog Box

When signals have Aperiodic Bounded Uncorrelated Jitter (ABUJ), and you suspect it may be due to crosstalk from nearby signals or a power supply, crosstalk analysis can help you determine whether crosstalk is truly the cause. Crosstalk analysis can be performed on a total of four signals.

Crosstalk analysis analyzes the input signals, removes inter-symbol interference (ISI), finds the crosstalk effects, and shows you the victim signal with the crosstalk removed. You can then make measurements or perform real-time eye analysis on the signal with crosstalk removed to see how crosstalk is affecting your signal quality.

For more information on crosstalk analysis, see "Crosstalk Analysis Overview" on page 7.

The Crosstalk dialog box is where you launch the crosstalk analysis set up wizard (see "Using the Crosstalk Wizard" on page 43) or manually enter your crosstalk analysis settings (see "Manually Setting Up Crosstalk Analysis" on page 54).

Controls

- **Crosstalk Wizard...** — Launches the Crosstalk Wizard that guides you step-by-step through a simple single-victim crosstalk analysis configuration. See "Using the Crosstalk Wizard" on page 43.

To specify more than one victim, use the controls in the dialog box to manually set up the crosstalk analysis configuration. See "Manually Setting Up Crosstalk Analysis" on page 54.

- **Power Integrity Wizard...** — Launches a simplified version of the Crosstalk Wizard intended for a single power supply signal and a single serial data signal. This is the same wizard used by the Power Integrity Analysis application for 9000 Series and S-Series oscilloscopes.

- **Advanced...** — Opens the "Crosstalk Advanced Configuration Dialog Box" on page 67 where you can find additional options that give you more control over the construction of the crosstalk analysis network model.

- **Enable** — Turns on crosstalk analysis and displays victim signals with selected contributors removed.

  The Crosstalk Analysis application currently works with NRZ (non-return-to-zero) signals only and is not available for PAM signal types.

- **+** — Lets you add signals to be included in the crosstalk analysis.

- Controls in the signal tabs:

  - **Name** — Click to enter a name for the signal (optional).

  - **Source** — Select an analog channel, math function, or waveform memory. Note that it is also possible to select these sources:

    - FFE — When a serial data input signal is too noisy for clock recovery.

    - Meas Trend — Measurement trend waveforms can be used in crosstalk analysis when looking for correlation between measurement changes and potential aggressor signals, similar to the way aggressors can affect a power supply victim.

      One example of where this can be useful is when aggressor signals cause errors that can be seen in time (TIE) but no longer in voltage, perhaps because of buffers between where the voltage coupling occurs and where the effect of the coupling causes a problem. Treating the TIE measurement trend waveform as a power supply victim, the crosstalk analysis can analyze the correlation between the TIE and other serial data signals.

  - **This signal is a Victim** — Select the check box if you want the signal to be analyzed as a victim (and have the resulting victim signal without crosstalk or other specified components displayed).

  - **This signal is an Aggressor** — Select the check box if the signal should be analyzed as an aggressor signal.

  - **Signal Type** — Crosstalk analysis algorithms are different for different types of victim/aggressor signals. Select one of these types of signals:

    - **Serial Data** — Selecting the **Serial Data** signal type tells the application that the input signal represents a digital bit stream, and that it needs to do a clock recovery.

When the signal type is data Serial Data, these controls become visible:

- **Pattern** — These controls let you specify **Arbitrary** or **Periodic** data patterns and the pattern length (if known) or **Auto Length**. See "Crosstalk Analysis Pattern Length Controls" on page 66.

- **Clock Recovery...** — Opens the Clock Recovery dialog box where you can specify the clock recovery options for this signal.

- Note that the default clock recovery settings are often not the best and need to be changed. See Clock Recovery Recommendations in the online help.

- **Thresholds...** — Opens the Measurement Thresholds dialog box where you can specify the voltage thresholds used for this signal.

- The proper threshold settings are important for determining edges in clock recovery.

- Note that the default measurement threshold definitions using **10%,50%,90% of top, base** should be changed to **Custom: threshold +/- hysteresis** (as is done when using the crosstalk wizard).

If an input signal is too noisy for clock recovery, one option is to perform equalization on the waveform before sending it to the Crosstalk Analysis application. This can be done directly on the oscilloscope using the Infiniium Equalization application (and then selecting **FFE** as the signal **Source** for crosstalk analysis). Keep in mind that equalization will remove some ISI from the signal before the crosstalk application has a chance to analyze it. Alternatively, aggressor waveforms can be defined as type Other, which does not use clock recovery. Use type Other only when necessary because of the increased accuracy clock recovery provides.

See "Transmission Line Crosstalk" on page 12.

- **Other** — Aggressor signals that are not also defined as victims can be defined with the type Other. Other-type signals are not converted to an ideal serial data signal and therefore do not require clock recovery be performed on them. They are applied directly to the linear network crosstalk model as a measured analog waveform.

- **Power Supply** — Selecting this signal type tells the application to use the specialized algorithms for power supply analysis, covered in sections "Power Supply Aggressor Crosstalk" on page 26 and "Power Supply Victim Crosstalk" on page 39.

NOTE   You cannot have both a power supply victim and a power supply aggressor in the same setup because these require different algorithms.

- **Vertical** — When the tab is for a signal that is a victim, the **Vertical** controls become visible; these are the usual vertical scaling controls applied to the crosstalk-removed waveform.

· **Contributors** — When the tab is for a signal that is a victim, the **Contributors** controls become visible; they let you select the aggressor signals whose crosstalk is to be removed from this signal. See "Victim-Aggressor Pairs in the Crosstalk Dialog Box" on page 20.

The Crosstalk Analysis application uses a network model that breaks up the measured waveform into these components:

Measured waveform = Ideal waveform + ISI + (Known XT) + (Unknown XT + Noise)

To display the crosstalk-removed waveform, the known crosstalk is subtracted from the measured waveform (leaving the ideal waveform, ISI, and unknown crosstalk plus noise). This lets you perform comparisons with the measured waveform to analyze crosstalk.

You can also choose to remove additional parts of the victim signal to make other types of analyses.

For example, to analyze the residual "unknown crosstalk and noise", you can also remove the ideal victim waveform and the victim ISI. Then, using an FFT math function on the resulting crosstalk waveform (or other types of analysis), you may be able to pinpoint the source of the residual crosstalk.

Accessing   There are two ways to access the Crosstalk dialog box:

· Choose **Analyze > Crosstalk...** from the main menu.

· In the Results pane's Crosstalk window, right-click and choose **Edit...**.

See Also   · "Signal Tabs in the Crosstalk Dialog Box" on page 19

· "Signal Types in the Crosstalk Dialog Box" on page 19

· "Victim-Aggressor Pairs in the Crosstalk Dialog Box" on page 20

Crosstalk Analysis Pattern Length Controls

When the Serial Data signal type is selected for a crosstalk victim or aggressor signal, you can use the **Pattern** controls to further identify the signal as being periodic (uses a repeating test pattern) or arbitrary (does not have a repeating test pattern):
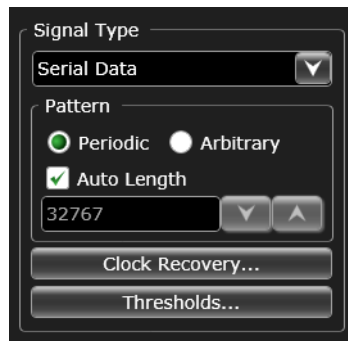
- **Periodic** — Select this to take advantage of data test patterns.

  - **Auto Length** (pattern length) — Select this check box to have the application automatically determine the pattern length.

    To enter the pattern length directly, clear the **Auto Length** check box and enter the value.

- **Arbitrary** — If the signal does not have a test pattern, you can select the **Arbitrary** option instead.

  When both the victim and aggressor have the same pattern length in periodic data mode, the algorithm cannot distinguish between ISI and crosstalk. Setting the victim's mode to **Arbitrary** allows the algorithm to separate them.

See Also
- "Test Patterns for Transmission Line Crosstalk Analysis" on page 17
- "Power Supply Aggressor Crosstalk Test Setup" on page 29
- "Power Supply Victim Crosstalk Test Setup" on page 41

Crosstalk Advanced Configuration Dialog Box

Controls / 68

Accessing / 69

The Crosstalk Advanced Configuration dialog box has some additional options when you want to have more control over the construction of the crosstalk analysis network model.

The crosstalk network model is composed of a series of linear filters (finite impulse response filters) that represent the various interactions.

Filter time span values are used to control the shape of the filter which can aid in reducing the noise that it introduces when acting on the crosstalk.

The length of the filter is related to the bandwidth and time span of the interaction. Short filters can much more efficiently and accurately represent high bandwidth interactions that occur over a short time span, such as FEXT, while longer filters are needed when the interaction is spread out over a larger time span, such as NEXT.

Controls
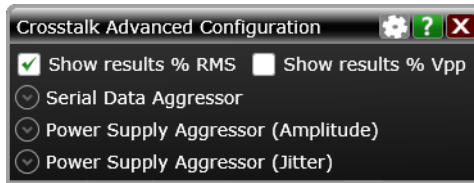
- **Show results % RMS** — Selecting this check box adds % RMS crosstalk measurement values to the Results pane.

- **Show results % Vpp** — Selecting this check box adds % Vpp crosstalk measurement values to the Results pane.

The following controls can be set individually for **Serial Data Aggressor**, **Power Supply Aggressor (Amplitude)**, and **Power Supply Aggressor (Jitter)**. Click the chevrons to access the controls.
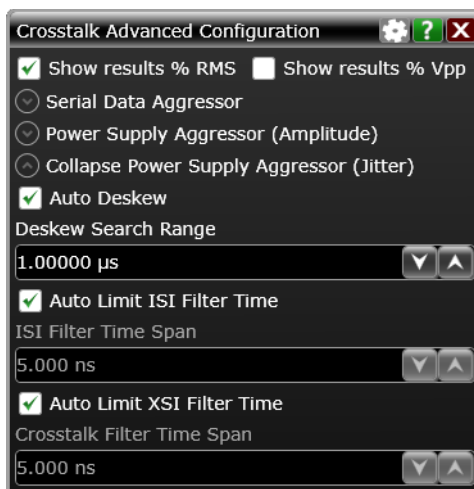
- **Auto Deskew** — When selected, the Crosstalk Analysis application uses a proprietary cross-correlation method for aligning the waveforms in time. The algorithm searches over a finite range of delays to find the best possible alignment. The search range corresponds to the equivalent delay of about 2 m of cable length, which is sufficient for most situations.

  If the waveforms are believed to be already in sync, you can clear the check box to turn off the deskew algorithm entirely.

- **Deskew Search Range** — Lets you change the deskew search range.

  Notice that the default **Deskew Search Range** value is larger for a power supply than for serial data transmission lines. This is because buffers and other circuit components can create delays much larger than the propagation distance. These delays may vary greatly from one circuit to another, so keep in mind that changing the default value may produce better results.

- The ISI filter represents the channel model and can therefore convert an ideal input waveform into the one that is band-limited and containing reflections.

    - When **Auto Limit ISI Filter Time** is selected, the Crosstalk Analysis application uses a proprietary algorithm to automatically determine an ideal ISI filter length for a given situation. The application further tries to optimize the shape of the filter by adaptively placing more taps in areas that are needed.

    - When **Auto Limit ISI Filter Time** is cleared, you can specify the **ISI Filter Time Span** by entering the value.

- Crosstalk filters describe how an aggressor signal is transformed into a crosstalk signal (such as NEXT or FEXT), and what magnitude it will have.

    - When **Auto Limit XSI Filter Time** is selected, the Crosstalk Analysis application uses a proprietary algorithm to automatically determine an ideal crosstalk filter length for a given situation. The application further tries to optimize the shape of the filter by adaptively placing more taps in areas that are needed.

    - When **Auto Limit XSI Filter Time** is cleared, you can specify the **Crosstalk Filter Time Span** by entering the value.

        A FEXT filter length should be at least as long as an edge rise time, and a NEXT filter length should be at least twice the propagation delay of the channel (see the description of FEXT and NEXT in "Far-End Crosstalk (FEXT)" on page 13 and "Near-End Crosstalk (NEXT)" on page 14).

Accessing   To access the Crosstalk Advanced Configuration dialog box:

1 Choose **Analyze > Crosstalk...** from the main menu.

2 In the Crosstalk dialog box, click **Advanced...**.

See Also   · "Crosstalk Analysis Advanced Configuration" on page 21

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Crosstalk Analysis Application User's Guide