Subject: About the CrossTalk Simulation Tool

Author: John Baprawski; John Baprawski Inc. (JB)

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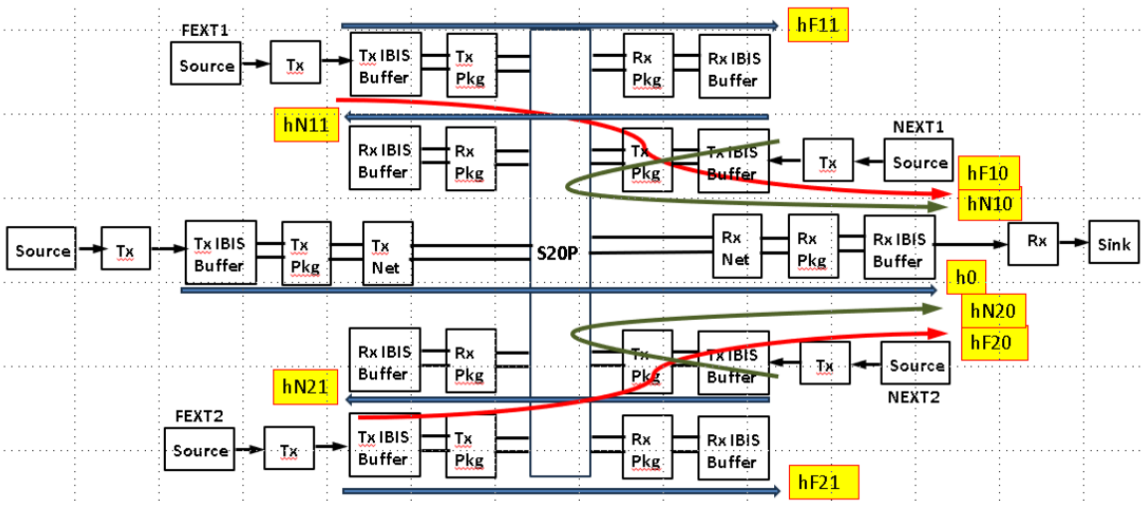
This paper discusses features on the web site: https://www.serdesdesign.com/

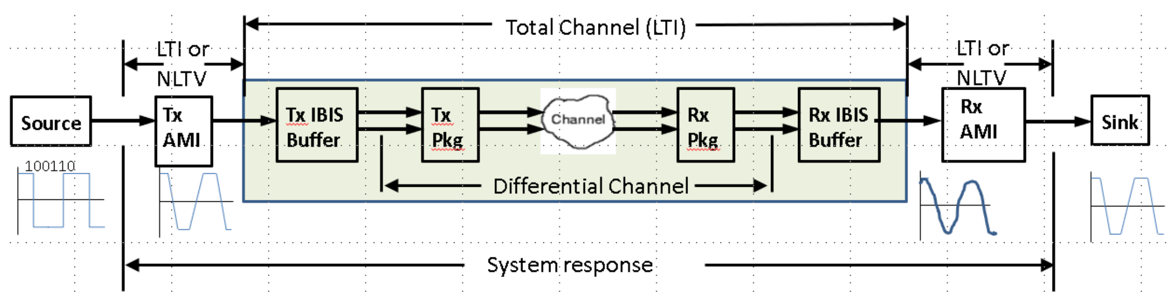
See this Web-Based tool: **SerDes Crosstalk Simulation Tool**.

The CrossTalk Simulation Tool analyzes a SerDes system that has a typical structure shown in this figure.



The SerDes CrossTalk Simulation Tool analyzes a SerDes system that may include up to two far-end crosstalk (FEXT) channels and up to two near-end crosstalk (NEXT) channels. Thus, there can be up to 5 channels: 1 main channel (Ch0), two FEXT channels (FEXT1, FEXT2) and two NEXT channels (NEXT1, NEXT2). The tool displays channel characteristics in the frequency and time domains.

Each channel has a typical structure shown in this figure:



Only the main channel can have an Rx AMI block. The one main channel Rx AMI block receives signal from the main channel and the crosstalk channels.

The differential channel often includes a transmit (Tx) package and a receive (Rx) package.

- The differential channel represents a hardware SerDes channel and is typically characterized by measuring its N-port S-parameters and is typically a 4-port. The 4-port differential input ports are typically port 1 (+) and port 3 (-). The associated differential output ports are typically port 2 (+) and port 4 (-). The differential characteristic (Port 1 – Port 3 vs. Port 2 – Port 4) is the channel transmission characteristic and is observed versus frequency.
- See S-parameter detail in References > **S-Parameter Channel Examples**
- The S-parameters may also be obtained from various simulators.
- A high speed digital SerDes channel typically has substantial high frequency attenuation at and beyond the bit/symbol rate Nyquist frequency and requires compensation using equalizers at the transmit and/or receive side of the channel.

The total channel is inclusive of the Tx IBIS Buffer and Rx IBIS Buffer.

- See IBIS Buffer detail in: **IBIS Buffers used in SerDes Simulations**
- The total channel, inclusive of the S-parameters, is converted to an equivalent single ended impulse response.
- See channel impulse response detail in References > **Channel Time-Domain Response**
- The typical approach involves zero-padding the S-parameters for the time domain SampleRate (SampleRate = BitRate * SamplesPerBit) for a maximum frequency of SampleRate/2.0 and applying the constraints for physical realizability which include meeting the mathematical aspects of the Kramers-Kronig relations applied to linear time invariant (LTI) systems. This zero-padding approach often results in high frequency aliasing.
- SerDesDesign.com uses a proprietary algorithm to obtain the causal channel impulse response which inherently does not result in any high frequency aliasing.
- See Causal S-Parameters detail in: **About the Generate Causal S-Parameters Tool**

For detail discussion about a SerDes system with no cross talk, see **About_the_Channel_Simulation_Tool.pdf**

The discussion in that PDF is not repeated in this document.

Within the above system crosstalk figure, all hxxx responses represent impulse responses inclusive of the channel Tx IBIS buffer through the channel Rx IBIS buffer.

- h0 represents the main channel Tx IBIS Buffer through Rx IBIS Buffer impulse response.
- hF11/hF21 represents the FEXT1/FEXT2 adjacent channel Tx IBIS Buffer through adjacent channel Rx IBIS Buffer impulse response.
- hF10/hF20 represents the FEXT1/FEXT2 adjacent channel Tx IBIS Buffer through main channel Rx IBIS Buffer impulse response impulse.

- hN11/hN21 represents the NEXT1/NEXT2 channel Tx IBIS Buffer through Rx IBIS Buffer impulse response.
- hN10/hF20 represents the NEXT1/NEXT2 channel Tx IBIS Buffer through main channel Rx IBIS Buffer impulse response impulse.

List of Cross Talk Channel Configurations Supported

XTalk type	Number of FEXT	Number of NEXT	Link to Figure
0	0	0	**No XTalk ...**
1	1	0	**1FEXT ...**
2	0	1	**1NEXT ...**
3	1	1	**1FEXT 1NEXT ...**
4	2	0	**2FEXT ...**
5	0	2	**2NEXT ...**
6	2	1	**2FEXT 1NEXT ...**
7	1	2	**1FEXT 2NEXT ...**
8	2	2	**2FEXT 2NEXT ...**

For more detail on the data and graphs available from this tool, see the article: and **Typical CrossTalk Analysis Characteristics and Displays...**

To use the CrossTalk Simulation Tool, follow the steps on the web page.

Step 1: Define the Analysis name.

Description and Name Prefix	Name	Status	Comment	Action	Action
Analysis name: Serdes_	SystemTest		Alpha-numeric characters or underbar - case sensitive - start with alpha character	Recall	Info...

- An alpha-numeric character string; including underbar - case sensitive - start with alpha character.
- The full analysis name = Serdes_<your entered name>
- This full name is used in the Eye Analysis Tool for further processing of the SerDes system analysis output data.
- A prior analysis can be recalled by listing its name and selecting the ‘Recall’ button.

Step 2: Define the Main Channel (Ch0) Transmitter.

Name	Description	Entry Value(s)	Status	Type	Limits	Comment	Action
TransmitterJitterType	Transmitter jitter type	0		Integer	[0, 1]	0 = Use Ch0 IBIS-AMI jitter 1 = Apply this jitter	Open...
TransmitterType	Transmitter type	0		Integer	{0,1}	0 = Use Ch0 IBIS-AMI 1 = Use Ch0 IBIS with this FFE	Open...

- For transmitter jitter, either use the jitter defined in the Ch0 Tx AMI model (TransmitterJitterType = 0), or the jitter can be defined locally (TransmitterJitterType = 1). For local tx jitter, open its dialog box and set EnableTxJitter to 1 (for time units) or 2 (for UI units).

Name	Description	Entry Value(s)	Status	Type	Limits	Comment
EnableTxJitter	Enable Tx jitter parameters	2		Integer	[0,2]	0 = No 1 = Yes in sec 2 = Yes in UI units
Tx_Rj	Standard deviation of a random white Gaussian phase noise process in sec/UI units	0		Real	>=0	
Tx_Dj	Worst case half the peak to peak deterministic variation in sec/UI units	0		Real	>=0	
Tx_DCD	Half the peak to peak clock duty cycle distortion in sec/UI units	0		Real	>=0	
Tx_Sj	Half the peak to peak amplitude of a sinusoidal jitter in sec/UI units	0		Real	>=0	
Tx_Sj_Frequency	Frequency, in Hz, of the sinusoidal jitter	10e6		Real	>0	

- The Tx jitter values for Tx_Rj, Tx_Dj, Tx_DCD, Tx_Sj and Tx_Sj_Frequency can be set (select Apply and OK).
- See the model documentation for details: **IBIS_AMI_Jitter_Summary.pdf**
- The transmitter type can either be defined in the Ch0 Tx AMI model (TransmitterType = 0), or it can be defined locally (TransmitterType = 1). For local type, the transmitter is an FFE model. Open its dialog box and set EnableFFEType to 1 (for use with arbitrary taps) or 2 (for use with limited tap values), or 3 (for use with quantized tap values).

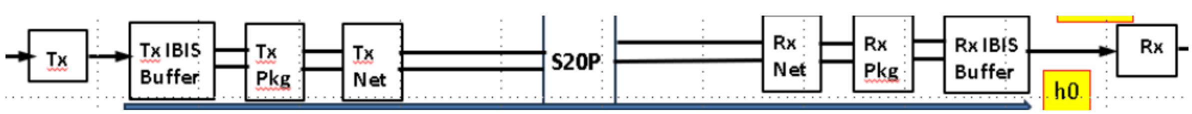
EnableFFEType	FFE type	1		Integer	[1,3]	1 = FFE 2 = FFE with value range 3 = FFE with code range

- See the Tx model documentation for details: **TxFFE.pdf**

Step 3.1: Define the Main Channel (Ch0) including IBIS-AMI.

XTalk0Type	Main channel specification type	1		Integer	[1]	1 = Enable main channel (Ch0)	Open...

- Its dialog box represents this block diagram:



- See detail documentation at: **XTalkCh0_wTxRx_IBIS_Pkg**
- The blocks Tx_Pkg, Tx_Net, crosstalk block (S20P in this example), Rx_Net, and Rx_Pkg are all S-parameter files. The Tx/Rx IBIS buffers may optionally be represented with S-parameter files..
- The crosstalk block in this figure is a 20 port S-parameter file and is the crosstalk S-parameter file relevant for when two FEXT and two NEXT channels are used. The number of ports for this file should be Nports = 4 + 4*NumFEXT + 4*NumNEXT. Thus, if no FEXT or NEXT channels are used, then this S20P should then be an S4P.

- The crosstalk block includes all loading from the crosstalk channels.

The transmitter can be defined without or with an AMI portion. The AMI portion is defined by referencing the IBS file.

The Tx IBIS Buffer can be setup with the EnableTxBuffer parameter:

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EnableTxBuffer	Enable transmit IBIS buffer	0		Integer	[0, 3]	0 = No 1 = Yes 2 = Use IBIS 3 = Use Alt IBIS

- When EnableTxBuffer = 0, no Tx IBIS-AMI model is used. When EnableTxBuffer = 1, no Tx AMI model is used, but the Tx IBIS buffer is defined with an R/L/C network per output differential pin. When EnableTxBuffer = 2, the Tx IBIS-AMI model is defined by uploading the Tx *.ibs file and the Tx model name used in the *.ibs file. The AMI model referenced in the .ibs file is used when TransmitterType = 0. When EnableTxBuffer = 3, the Tx IBIS buffer is modeled with an S4P file or S2P file.
- See model documentation for details: **IBIS Buffers used in SerDes Simulations**

The Rx IBIS Buffer can be setup with the EnableRxBuffer parameter in a similar way as was done with the Tx IBIS buffer.:

The receiver can be defined without or with an AMI portion. The AMI portion is defined by referencing the IBS file.

Any S-parameter file used is automatically adjusted as needed to conform to the physical realizability constraints of passivity, reciprocity, and causality, as well as reduction of noise in the S-parameters.

Step 3.2: Define the FEXT1 Channel (F1) including IBIS-AMI.

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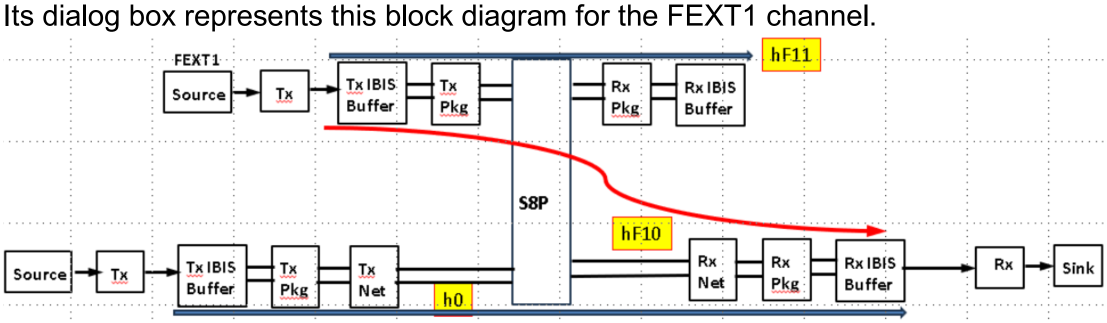
XTalkF1Type	FEXT 1 channel specification type	0		Integer	[0, 1]	0 = None 1 = Enable FEXT 1 Channel (F1)

- Its dialog box represents this block diagram for the FEXT1 channel.
- 

- See detail documentation at: **XTalkF1_wTxRx_IBIS_Pkg**
- The blocks FEXT1 Tx_Pkg, crosstalk block (S8P in this example), and FEXT1 Rx_Pkg are all S-parameter files. The FEXT1 Tx/Rx IBIS buffers may optionally be represented with S-parameter files..

- The crosstalk block in this figure is an 8 port S-parameter file and is the crosstalk S-parameter file relevant for when one FEXT is used. The crosstalk block includes all loading from the main and crosstalk channels.
- The FEXT1 source can be set to be the same or different from the main channel source.
- The FEXT1 transmitter can be defined without or with an AMI portion. The AMI portion is defined by referencing the IBS file.
- The FEXT1 receiver only has an IBIS buffer. There is no FEXT1 Rx AMI portion used.
- The FEXT1 Tx/Rx IBIS buffers can be set up in the same way as was done for the main channel.
- Any S-parameter file used is automatically adjusted as needed to conform to the physical realizability constraints of passivity, reciprocity, and causality, as well as reduction of noise in the S-parameters.

<u>Step 3.3: Define the NEXT1, FEXT2, NEXT2 channels as needed.</u>

- Follow a process same as used for FEXT1 channel.

<u>Step 4: Define the Main Channel (Ch0) Receiver.</u>

Name	Description	Entry Value(s)	Status	Type	Limits	Comment	Action
ReceiverFEType	Receiver LTI front end type	0		Integer	{0,1}	0 = Use Ch0 IBIS-AMI 1 = Use Ch0 IBIS with this RxFE1	Open...
ReceiverNLTVType	Receiver NLTV type	0		Integer	{0,2}	0 = Use Ch0 IBIS-AMI 2 = Use Ch0 IBIS with this CDR/DFE	Open...
ReceiverJitterType	Receiver jitter type	0		Integer	[0, 1]	0 = Use Ch0 IBIS-AMI jitter 1 = Apply ths jitter	Open...

- For receiver jitter, either use the jitter defined in the Ch0 Rx AMI model (ReceiverTransmitterJitterType = 0), or the jitter can be defined locally (ReceiverJitterType = 1). For local rx jitter, open its dialog box and set EnableRxJitter to 1 (for time units) or 2 (for UI units).

Name	Description	Entry Value(s)	Status	Type	Limits	Comment
EnableRxJitter	Enable Rx jitter parameters	2		Integer	[0,2]	0 = No 1 = Yes in sec 2 = Yes in UI units
Rx_Rj	Standard deviation of a random white Gaussian phase noise process in sec/UI units	0		Real	>=0	
Rx_Dj	Worst case half the peak to peak deterministic variation in sec/UI units	0		Real	>=0	
Rx_DCD	Half the peak to peak clock duty cycle distortion in sec/UI units	0		Real	>=0	
Rx_Sj	Half the peak to peak amplitude of a sinusoidal jitter in sec/UI units	0		Real	>=0	

- The Rx jitter values for Rx_Rj, Rx_Dj, Rx_DCD, and Rx_Sj can be set (select Apply and OK).
- See the model documentation for details: **IBIS_AMI_Jitter_Summary.pdf**
- The receiver LTI front end type can either be defined in the Ch0 Rx AMI model (ReceiverFEType = 0), or it can be defined locally (ReceiverFEType = 1). For local type, the receiver is a CTLE model with optional AGC. Open its dialog box and set

EnableModelType to 1 (for use with peaking dBs), or 2 (for use with a set of poles and zeros), or 3 (for use with a set of step responses), or 4 (for a set of spectrum responses).

EnableModelType	Model type	0		Integer	[0,4]	0=No equalization 1=List of peaking dBs 2=File with set of poles and zeros 3=File with set of step responses 4=File with set of spectrums
- See the Rx model documentation for details: **RxFE1.pdf**
- The receiver NTLV back end type can either be defined in the Ch0 Rx AMI model (ReceiverNLTVType = 0), or it can be defined locally (ReceiverNLTVType = 1). For local type, the receiver is a CDR/DFE model. Open its dialog box and set EnableDFE_Type to 1 (for use with taps), or 2 (for use with limited taps), or 3 (for use with tap codes).
EnableDFE_Type	DFE type	1		Integer	[1,3]	1 = with taps 2 = with limits 3 = with codes
- See the Rx model documentation for details: **RxCDRDFE.pdf**

5. Setup the analysis.

SymbolRate	Symbol rate (same as bit rate for NRZ)	2.50E+10		Real	> 0	Symbols per second (same as bits per second for NRZ)
SamplesPerSymbol	Samples per symbol (same as samples per bit for NRZ)	32		Integer	[4, 128]	
SetupOptions	Setup analysis options	1		Integer	[1]	0 = No 1 = Yes
- Define the bit (symbol) rate in bits (symbols) per second.
- Define the number of samples per bit (symbol).
- Set SetupOptions = 1 to 'Open' its dialog box.
- See detail documentation at: **Setup Options**
- Note: Set ForceBitByBitMode =1 to force Bit-by-Bit simulation model when the SerDes system is LTI.
- Note: Set XTalkDisplayType for FEXT/NEXT channel time domain display type: = 1 (for impulse response), = 2 (for step response), = 3 (for pulse response).

6. Run the analysis.

Select to run analysis	Run

7. Display results.

Analysis log file	Open
0. Channel spectrum magnitude	Open
1. FEXT/NEXT channel spectrum magnitude	Open
2. FEXT/NEXT channel time domain response	Open
3. Corrected channel impulse response	Open
4. System worst/best case eye contours	Open
5. System amplitude bathtub BER	Open
6. System Rx input waveform	Open
7. System Rx output waveform	Open

- Observe that the channel frequency domain characteristic, its equivalent impulse response, its eye diagram, and its BER bathtub curve.
- See detail: **Typical CrossTalk Simulation Characteristics and Displays**
- After the Analysis is Run, the Analysis Log file is displayed.
- Look at the bottom of the file to see that the analysis was successful.

Go to the Eye Analysis Tool for detail eye analysis for this SerDes system (set ChAnalysisName = Serc
Exiting SerDes System Analysis with success; run time = 17 sec.

8. Open the Eye Analysis Tool to observe the detail eye analysis results.

- Fill in the ChAnalysisName to be the same name used in the Channel Simulation Tool.

ChAnalysisName	Channel analysis name	Serdes_SystemTest

- See detail discussion at: **About_the_Eye_Analysis_Tool**
- These displays are available:

1. System eye worst/best case contours; no additional applied jitter	Open
2. Applied jitter PDF	Open
3. System eye amplitude PDF	Open
4. System eye timing PDF	Open
5. System eye density plot	Open
6. System eye amplitude bathtub BER	Open
7. System eye timing bathtub BER	Open
8. System BER vs eye height	Open
9. System BER vs eye width	Open
10. System constant BER eye contours	Open

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