Subject: Example NRZ SerDes System Using IBIS-AMI Models

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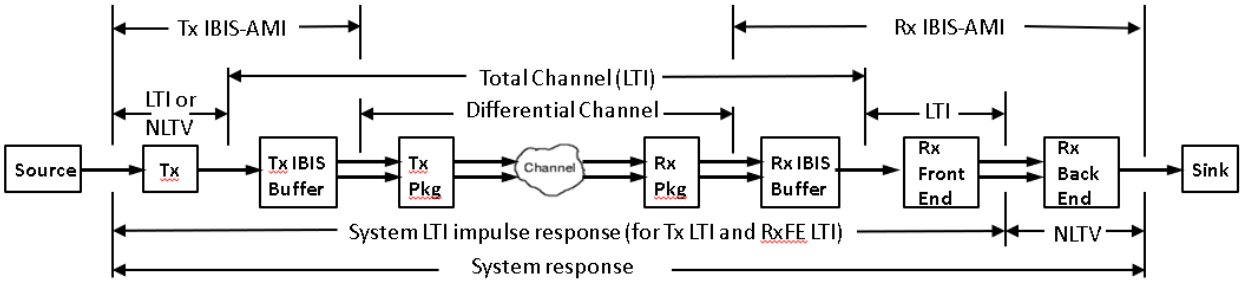
Date: Jun. 27, 2022; updated 7/31/2025

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

A SerDes system for a single channel has the typical structure shown in this figure.



See details in **About the SerDes System Simulator Tool...**

Many of the features available in the SerDesDesign.com tools are free; others are available for a fee. This document is on the modeling and simulation of a SerDes system using NRZ signaling, Tx/Rx IBIS-AMI models, S4P data for the channel, and using the SerDesDesign.com channel simulator.

Discussion on the IBIS-AMI Models

Every IBIS-AMI model is based on the IBIS standard with these files (as a minimum):

- *.ibs: the IBIS file that defines the IBIS buffer.
- *.ami: the AMI file that defines the Algorithmic model and possibly an alternate for the IBIS buffer.
- *_x64.dll: the 64 bit Windows dynamic linked library.
- *_x64.so: the 64 bit Linux shared object file.

In this example, the Tx IBIS-AMI model has these files:

- SerDes_TxFFE.ibs, .ami, _x64.dll, _x64.so
- This model is for a linear and time invariant (LTI) Tx feed forward equalizer (FFE) that allows one to set up to two pre-cursors and two post-cursors.
- For your use, the Tx IBIS-AMI is made available here:
  - **SerDes_TxFFE.zip**
  - In the AMI file, set the default values to the desired values and upload the AMI file with these desired values into the SerDesDesign tool.

In this example, the Rx IBIS-AMI model has these files:

- SerDes_RxCTLE_CDRDFE.ibs, .ami, _x64.dll, _x64.so
- This model is a nonlinear and time variant (NLTV) model with an LTI

continuous time linear equalizer (CTLE), clock and data recovery circuit (CDR) and a decision feedback equalizer (DFE). The CDR is Bang-Bang type of CDR. The DFE has 5 taps.

- For your use, the Rx IBIS-AMI is made available here:
  - **SerDes_RxCTLE_CDRDFE.zip**
  - In the AMI file, set the default values to the desired values and upload the AMI file with these desired values into the SerDesDesign tool.

Top Level Page Overview

The top-level channel simulator used is at this web page:
https://www.serdesdesign.com/home/serdes-system-tool/
Registration is required to use. Registration is free and available on the home page.

In the following discussion, the Windows based SerDes System Tool is used. Its use is similar to the use of the Web based Linux tool.

For this example, this top-level page is changed from the default values to these settings:

- Define Transmitter section: TransmitterType = 0
- Define Channel section: ChannelType = 3
  - EnableTxBuffer = 2
  - IBS_File = SerDes_TxFFE.ibs
  - IBS_ModelName = SerDes_TxFFE
  - EnableRxBuffer = 2
  - IBS_File = SerDes_RxCTLE_CDRDFE.ibs
  - IBS_ModelName = SerDes_RxCTLE_CDRDFE
- Define Receiver section:
  - ReceiverFEType = 0
  - ReceiverNLTVType = 0
- Setup Analysis section:
  - SymbolRate = 25e9
  - SetupBitByBitMode = 1
- Setup Options
  - AnalysisSymbols = 1000000

The resultant top-level page will appear as shown here:

1. Define Analysis Name

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

2. Define Transmitter - nonlinear and/or time variant (NL/NLTV) model forces Bit-by-Bit Analysis mode.

Name	Description	Entry Value(s)	Status	Type	Limits
TransmitterJitterType	Transmitter jitter type	0		Integer	[0, 1]
TransmitterType	Transmitter type	0		Integer	[0, 4]

3. Define Channel - model is LTI or NLTV.

Name	Description	Entry Value(s)	Status	Type	Limits
ChannelType	Channel specification type	3		Integer	[0, 3]

4. Define Receiver - nonlinear and/or time variant (NL/NLTV) model forces Bit-by-Bit Analysis mode.

Name	Description	Entry Value(s)	Status	Type	Limits
ReceiverFEType	Receiver LTI front end type	0		Integer	[0, 6]
ReceiverNLTVType	Receiver NLTV type	0		Integer	[0, 4]
ReceiverJitterType	Receiver jitter type	0		Integer	[0, 1]

5. Setup Analysis - Analysis uses Statistical or Bit-by-Bit mode based on the selected models.

Name	Description	Entry Value(s)	Status	Type	Limits
SymbolRate	Symbol rate (same as bit rate for NRZ)	2.50E+10		Real	> 0
SamplesPerSymbol	Samples per symbol (same as samples per bit for NRZ)	32		Integer	[4, 128]
SetupOptions	Setup analysis options	1		Integer	[0, 1]

Setting Up the Channel with IBIS-AMI Models

In the ‘Define Channel’ section with ChannelType = 3, select the ‘Open…’ button.

Set up the Tx IBIS-AMI model with these lines:

Name	Description	Entry Value(s)	Status	Type	Limits	Comment
EnableTxBuffer	Enable transmit IBIS buffer	2		Integer	[0, 3]	0 = No 1 = Yes 2 = Use IBIS 3 = Use Alt IBIS
IBS_File	Tx *.ibs file. Alpha-numeric or underbar; start with alpha	SerDes_TxFFE.ibs Choose File N... en		File		Upload a Tx IBIS file (*.ibs format) or list previously uploaded file
UseIBS_RampOrWaveform	Use Tx *.ibs file [RAMP] or [Rising/Falling Waveform] tables	0		Integer	[0, 1]	0 = Use [Ramp] 1 = Use[Rising / Falling Waveform] tables
IBS_CornerCase	Tx IBIS model corner case; including AMI Reserved_Parameters;0=Typ;1=Min;2=Max	0		Integer	[0, 2]	0 = Typical 1 = Min 2 = Max
IBS_ModelName	Tx model name. Alpha-numeric or underbar; start with alpha	SerDes_TxFFE		String		

The default channel is used, Channel_25Gbps.s4p, which has 32 dB loss at Nyquist (12.5 GHz).

Set up the Rx IBIS-AMI model with these lines:

EnableRxBuffer	Enable receive IBIS buffer	2		Integer	[0, 3]	0 = No 1 = Yes 2 = Use IBIS 3 = Use Alt IBIS
IBS_File	Rx *.ibs file. Alpha-numeric or underbar; start with alpha	SerDes_RxCTLE_CDRDFE.ibs Choose File No file chosen		File		Upload a Rx IBIS file (*.ibs format) or list previously uploaded file
IBS_CornerCase	Rx IBIS model corner case; including AMI Reserved_Paameters;0=Typ;1=Min;2=Max	0		Integer	[0, 2]	0 = Typical 1 = Min 2 = Max
IBS_ModelName	Rx model name. Alpha-numeric or underbar; start with alpha	SerDes_RxCTLE_CDRDFE		String		

Select the HELP button at the bottom of this page for more detail on this Channel model.

Select the APPLY button to verify the settings. If they are good, then each parameter will have a green circle with a check mark will appear in its 'Status' field.

Select the OK button to close this dialog box. If the box was setup properly, then a green circle with a check mark will appear in the ChannelType 'Status' field.

Setting Up the Analysis Options

In the 'Setup Analysis section, select the SetupOptions 'Open…' button.

The setup dialog box is displayed. This page is changed from the default values to these settings:

- AnalysisSymbols = 1000000

Select the HELP button at the bottom of this page for more detail on this Channel

model.

Select the APPLY button to verify the settings. If they are good, then each parameter will have a green circle with a check mark will appear in its 'Status' field.

Select the OK button to close this dialog box. If the box was setup properly, then a green circle with a check mark will appear in the SetupOptions 'Status' field.

Run the Analysis

In the 'Run Analysis section, select the Run button. If the SerDes design was setup properly, then each top-level page parameter will have a green circle with a check mark appear in its 'Status' field.

As the simulation is run, the number of run seconds will display to the right of the Run button.

During simulation the following steps will be performed.

- The total channel (inclusive of the Tx IBIS and Rx IBIS) is analyzed and represented with a single ended impulse response.
- The Tx AMI model will be setup and initialized.
- The Rx AMI model will be setup and initialized.
- The simulator will set the 'IgnoreSymbols' to the value set for the Rx model AMI file. The simulator will run the simulation for the AnaysisSymbols after these IgnoreSymbols.
    - The AnalysisSymbols will be rounded up to a power of 2, 1,048,576 in this case.
- The simulator will run a time domain simulation using a time step = 1/SampleRate = 1/SymbolRate/SamplesPerSymbol = 1/25e9/32 = 1.25e-12 sec.
    - The simulator will create NRZ symbols using bits from a PRBS bit generator. The PRBS generator length will be set to 20 because, the Analysis setup used the default PRBS_Len = 0. The value 20 is used because 2^20 = 1,048,576/2.
- The simulator will collect a histogram database of amplitude vs time values. This database will be post processed after the simulation run to derive all metrics, include eye density and BER plots.

At the end of the simulation run, the 'Analysis log file' will open at the bottom of the page.

Observe in the log file:

- The Tx AMI model AMI_Init() output message.
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- The Rx AMI model AMI_Init() output message.

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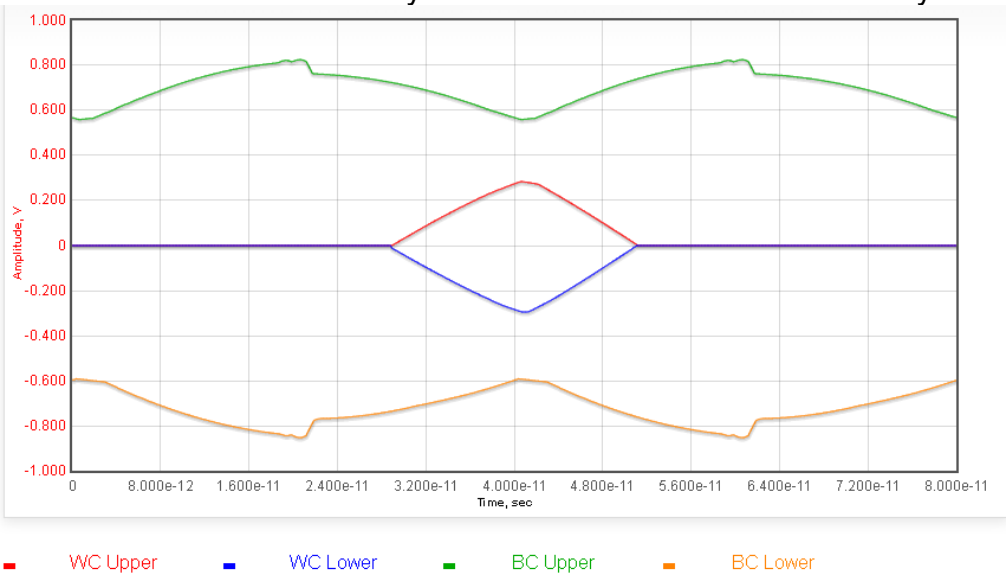
- For this Rx AMI model, a message file, RxCTLE_CDRDFE_MessageFile.txt, is written to the user's account 'model_data' directory.
- The simulation of 1,048,576 symbols plus the ignore symbol took 13 sec.

Observe Quick Results

On this top-level page, the 'Display Results' section provides the ability to see quick results.

For example, here is a quick display of the eye best and worst case contours. Note: This does not show the full eye detail which can be seen in the Eye Analysis Tool.

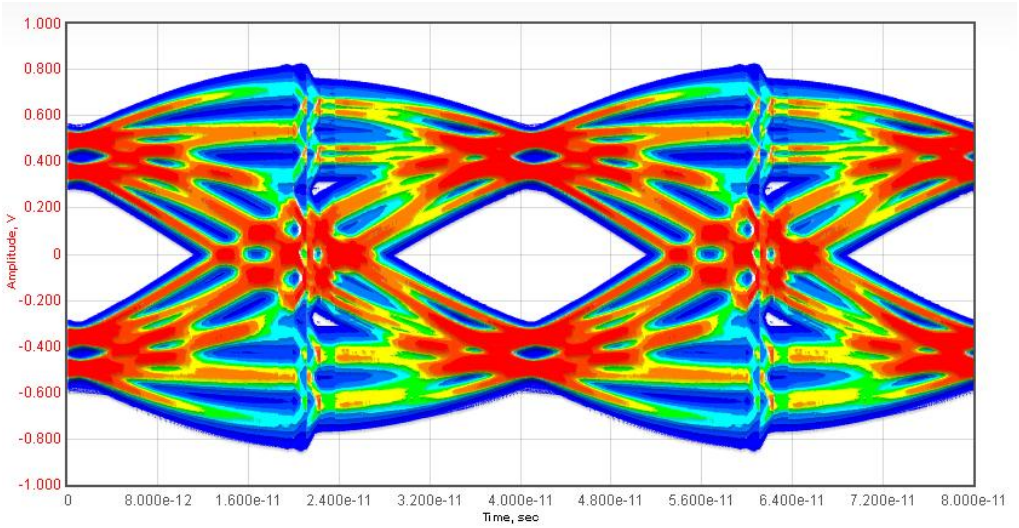


For detail results for eye density, BER and more, open the Eye Analysis Tool.

In this tool, one can set up many ways to post process the channel simulation output data. To do this, as a minimum, set the 'ChAnalysisName' to the same 'Analysis name' used in the prior page, 'Serdes_SystemTest' is used in this case.

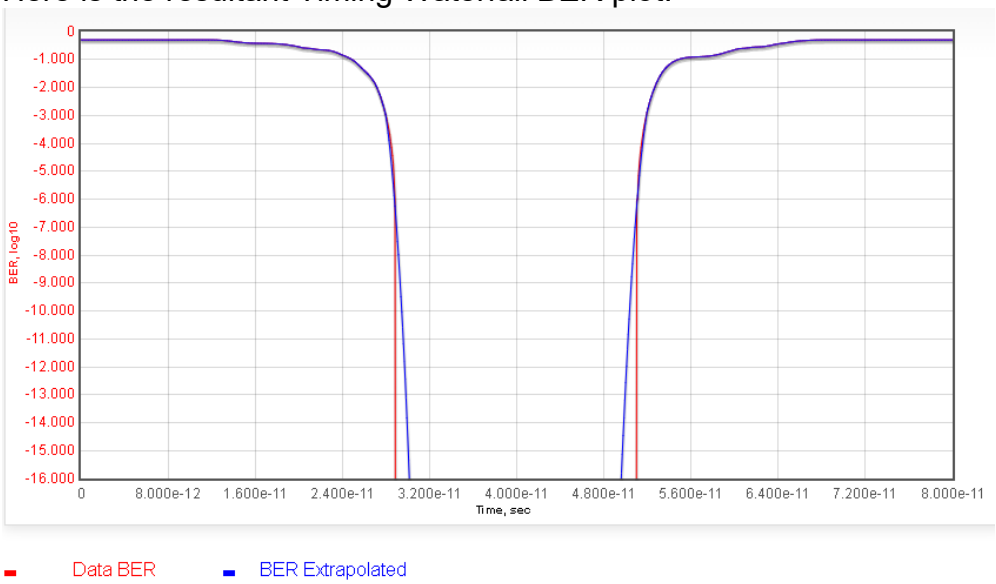
After Eye Analysis Tool setup, run the Eye Analysis by selecting the Run button.

Here is the resultant Eye Density plot:



Redish colors are for higher densities. Bluish colors are for lower densities.

Here is the resultant Timing Waterfall BER plot.



The raw (Monte-Carlo based) BER curve is shown along with the extrapolated BER curve. The raw BER goes down to the level (in this case) of 10^(-6). The extrapolated BER goes down to 10^(-16). The display of both shows that the extrapolated BER curves overlap the raw BER data very well above 10^(-6).

Many ways of displaying the channel simulation data are possible.