Subject: About the SerDes System Single Channel Tool (Sys)

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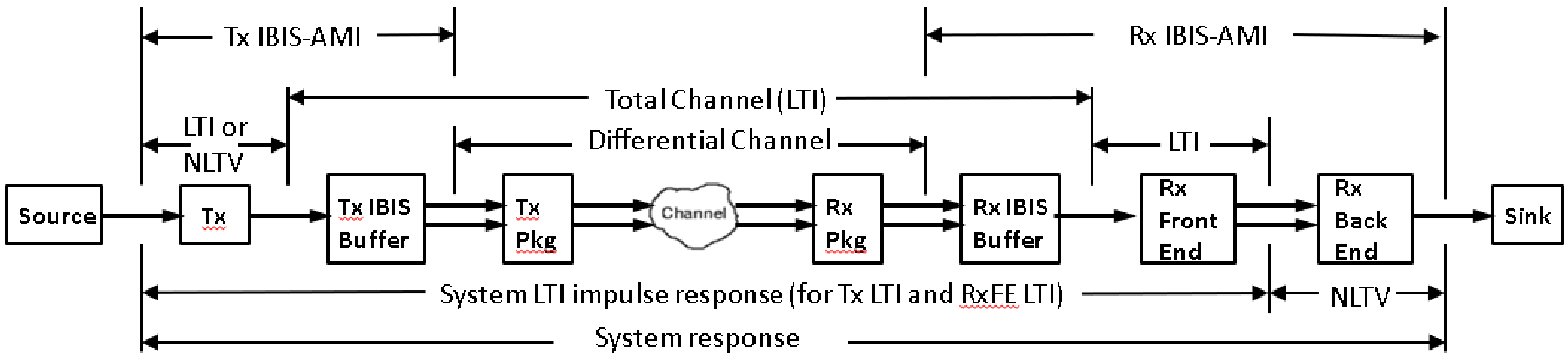
Date: Jan 3, 2019; updated 7/31/225

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

The SerDes System Single Channel Tool analyzes a SerDes system that has the typical structure shown in this figure.



This tool is located on the web at: **https://www.serdesdesign.com/home/serdes-system-tool/**

The differential channel often includes a transmit (Tx) package and a receive (Rx) package and is linear and time invariant (LTI).

- 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. Per the IBIS-AMI standard, the IBIS Buffers are to be considered LTI for use in a Channel Simulator. Thus, the total channel is LTI.

- See IBIS Buffer detail in: **IBIS Buffers used in SerDes Simulations**
- The total channel, as used in a Channel Simulator and 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 = Bit/Symbol Rate * SamplesPer Bit/Symbol) 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**

In addition to the total channel, the single channel SerDes system includes:

- SOURCE: a signal source that supports either an NRZ or PAM4 signal.
- TX: a transmit equalizer (Tx) that is LTI as used in this Channel Simulator.
- Rx Front End: a receiver front end equalizer that is LTI as used in this Channel Simulator.
- Rx CDR/DFE: receiver clock and data recovery (CDR) unit and decision feedback equalizer (DFE) and is a nonlinear and/or time variant (NLTV) model.

To use the SerDes System Single Channel Tool, follow the steps on the web page.

1. Define the analysis name

    - 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.

2. Define the Transmitter.

- The transmitter (Tx) is considered to be LTI and can be defined in a number of different ways.
    - As a feed forward equalizer (FFE) with optional filtering.
    - As an FFE with quantized values defining the pre and post cursors with optional filtering.
    - As an FFE with integer codes defining the pre and post cursors with optional filtering.
    - As an FFE with digital register codes including filtering.
    - As an FFE defined as a black box (with response defined for each tap state).
    - As a family of step responses
- See detail: **Define Transmitter**
- In all of these above transmitter cases, there can be an associated Tx IBIS buffer defined with the channel definition.
- Additionally, the transmitter can be defined with a LTI or NLTV Tx IBIS-AMI model associated with the channel definition.

3. Define the Channel.

- The channel is inclusive on any Tx/Rx IBIS-AMI models and NLTV if any AMI model is NLTV; otherwise it is LTI. It can be defined in a number of ways.
    - ChannelType = 0; no channel is included
    - ChannelType = 1; channel is defined with impulse response data file with *.csv (comma separated variables) format with two columns. First column is for time (with constant time step) and second column is for impulse value. The time data must start with zero and have constant time step equal to the sampling interval (= 1/SampleRate = 1/SymbolRate/SamplesPerSymbol).
    - ChannelType = 2; channel is defined with an S-parameter file with at least 4 ports that represent a differential channel.
    - ChannelType = 3; channel is defined with an S-parameter file with at least 4 ports that represent a differential channel pulse options for:
        - Transmitter IBIS output buffer. See detail: **IBIS Buffers used in SerDes Simulations**
        - Transmitter IBIS-AMI model. See Tx AMI detail: **IBIS.org Ver 7.2**

    - Transmitter differential channel packaging S-parameter file with at least 4 ports.
    - Receiver differential channel packaging S-parameter file with at least 4 ports.
    - Receiver IBIS input buffer. See detail: **IBIS Buffers used in SerDes Simulations**
    - Receiver IBIS-AMI model. See Rx AMI detail: **IBIS.org Ver 7.2**
- Any S-parameter file used is automatically adjusted as needed to conform to the physical realizability constraints of causality, as well as reduction of noise in the S-parameters with option to force reciprocity.
- See detail: **Define Channel**

4. Define the Receiver Front End.

- The receiver (Rx) front end is considered to be LTI and can be defined in a number of different ways.
    - As a 1 section continuous time linear equalizer (CTLE) defined with a family of peaking factors in time or frequency domains, poles and zeros, or step responses and with optional automatic gain control (AGC).
    - As a 2 section CTLE each defined with a family of step responses and with optional AGC.
    - As a 3 section CTLE each defined with a family of step responses and with optional AGC.
    - As a 4 section CTLE each defined with a family of step responses and with optional AGC.
- See detail: **Define ReceiverFrontEnd**
- In all of these above receiver front end cases, there can be an associated Rx IBIS buffer defined with the channel definition.
- Additionally, the receiver front end can be defined with a LTI Rx IBIS-AMI model associated with the channel definition.

5. Define the Receiver NLTV Back End.

- The receiver (Rx) back end is considered to be nonlinear and/or time variant (NLTV) and can be defined in a number of different ways.
    - As a pass through model for use with Bit-by-bit analysis.
    - As a model with only a clock and data recovery (CDR) model.
    - As a model with a nonlinearity and a clock and data recovery (CDR) model.
    - As a model with a CDR and decision feedback equalizer (DFE).
    - As a model with a nonlinearity and a CDR and decision feedback equalizer (DFE).
    - The DFE can be defined with taps, quantized taps, taps defined with integer codes.
- See detail: **Define ReceiverCDRDFE**

- Additionally, the receiver NLTV model can be defined with a NLTV Rx IBIS-AMI model associated with the channel definition.

6. Setup the analysis.

- Define the bit (symbol) rate in bits (symbols) per second.
- Define the number of samples per bit (symbol).
- Set up analysis options: **Setup Options**
- Set GenerateModels to generate a Tx IBIS-AMI model from the Tx behavioral data (GenerateModels = 1) or to generate a Rx IBIS-AMI model from the Rx behavioral data (GenerateModes = 2).

7. Run the analysis.

- 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:

```
Writing Impulse files.
Writing Spectrum files.
Writing Waveform response files.
Writing System worst/best case eye contour files
Writing BER metric files

Exiting Channel Analysis with success; run time = 14 sec.
```

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8. Display results.

- Observe the channel frequency domain characteristic, its equivalent impulse response, its eye diagram, and its BER bathtub curve.
- See detail: **Typical SerDes System Characteristics and Displays**

10. Reuse the generated channel data files.

- The total channel impulse response (inclusive of the Tx/Rx IBIS models) is defined with name: Serdes_<AnalysisName>.csv.
  - Located in directory: C:\SerDesDesign\user-<number>\files\channel_data
  - This total channel impulse response file can be used when the ChannelType = 1.

- If the Tx IBIS or Rx IBIS was defined with a channel facing S2P impedance data file, <filename>.s2p, then that S2P data was converted to the required IBIS S4P data with name: <filename>.s2p.s4p.
  - Located in directory: C:\SerDesDesign\user-<number>\files\channel_data
  - This S4P data file can be used instead of the original S2P data file.

11. If GenerateModels > 0, then one can complete the generation of the portable IBIS-AMI models.

- See detail as: **Generate Portable IBIS-AMI Models**

12. Open the **Eye Analysis Tool** for detail eye and BER analysis of the SerDes system results.

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