Subject: SerDesDesign.com RxAFE with NL Modeling Tool

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For the past 10+ years, John Baprawski has provided cost-efficient high-quality IBIS-AMI models to 40+ high speed digital (HSD) integrated circuit (IC) companies using his IBIS-AMI Model Development Environment for use in any standards compliant SerDes system channel simulator. That work has relied on his free web-based tools including his SerDes Channel Simulator (**https://www.serdesdesign.com/home/**). That work has also focused on collecting correct circuit data and automating the process for converting that data into IBIS-AMI models.

This paper highlights the process for creating a perfect Rx AFE with Nonlinearity IBIS-AMI model from circuit data.

- **Small signal levels: Perfect = IBIS-AMI model exactly agrees with circuit.**
- **Large signal levels: Perfect = IBIS-AMI model agrees with circuit for peak and step levels with some variation in the pulse shape allowed as the signal goes into compression.**

Overview

Be sure to read these two documents first:

READ_ME_FIRST - License_Agreement.pdf

READ_ME_SECOND - Instructions.pdf

This Rx Tool has this directory structure:

- C:/AMI/AFE/ModelBuilder – SerDesDesign.com IBIS-AMI Build Environment (partial).
- C:/AMI/AFE/README – Documents; including this one.
- C:/AMI/AFE/RxAFE_NL_Modeling_Tool - Rx AFE with Nonlinearity Modeling Tool.
- C:/AMI/AFE/RxCTLE_SS_Modeling_Tool - Rx CTLE Small Signal Modeling Tool.
- C:/AMI/AFE/RxNonlinearityData – directory for the circuit nonlinearity data files.
- C:/AMI/AFE/RxWaveformLargeSignalData – directory for the circuit data files.
- C:/AMI/AFE/RxWaveformSmallSignalData – directory for the circuit data files.
- C:/AMI/AFE/RxAMI_Solution_SerDes_AFE_NL - SerDesDesign.com IBIS-AMI build directory.

Circuit Data Collection

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The circuit is assumed to be for a SerDes receiver (Rx) nonlinear analog front end (AFE) with differential inputs that interface with a differential SerDes channel.

The data to be collected is:

- The Rx circuit input differential impedance versus frequency.
- The Rx circuit input waveform.
- The Rx circuit AFE output waveform for each AFE state and input drive level.

For detail instruction on this required circuit data see these reports:

Modeling_an_NLTV_RxSerDes_AFE_with_Nonlinearity_wih_CircuitData.pdf

Place this circuit data into the directories:

- C:\AMI\AFE\RxNonlinearityData.
- C:\AMI\AFE\RxWaveformLargeSignalData.
- C:\AMI\AFE\RxWaveformSmallSignalData.

Within these directories create the file InputFileNameList.txt (LS_InputFileNameList.txt for the large signal directory) which is to contain a list of all the files in the desired order.

Setting up the Small Signal RxCTLE_SS Modeling Tool

It is assumed that when the AFE is running in its small signal region, then it is essentially being used as a continuous time linear equalizer (CTLE). In this section, the term CTLE is used to mean operating the AFE in this small signal region.

The RxCTLE_SS_NL Modeling tool is in the directory C:\AMI\AFE\RxCTLE_SS_Modeling_Tool.

Within that directory, the file DataFiles\RxCTLE_SS_Modeling.txt needs to be set up by the user.

This file contains two lines. In the following, the user entered values are within angle braces <…>.

Line 1: SetupAnalysis BitRate <bit_rate> SamplesPerBit <samples_per_bit> NumStepResp <num_step_resp>

<bit_rate>: this is the maximum bit rate for an NRZ data pattern.

<samples_per_bit>: can remain at 32.

<num_step_resp>: number of CTLE states.

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Line 2: RxCTLE_Modeling DirName <small_signal_dir_name> IBIS_SParamFile <s2p_filename> SkipLines <skip_lines> ExtractionTStart <extraction_tstart> ExtractionTLength <extraction_tlength>

<small_signal_dir_name>: can remain at C:\AMI\AFE\RxWaveformSmallSignalData.

<s2p_filename>: Name of the s2p data file.

<skip_lines>: Number of lines at the top of the waveform files to skip.

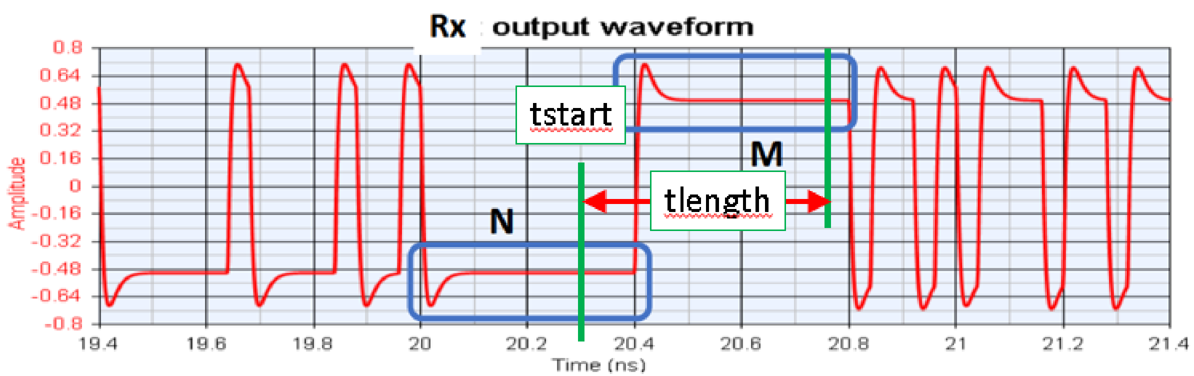
<extraction_tstart>: the time stamp in the waveform file used to start waveform extraction.

<extraction_tlength>: the time length after the tstart for the end of the waveform extraction.

Discussion:

It is assumed that all CTLE waveform files use the same NRZ data pattern and the same time samples. As such, all files have the same NRZ segment with N zeros and M ones. Set tstart to a reference time before the zero-to-one transition. Set tlength to the point after this transition and before the next transition.

This figure shows this concept.



Running the RxCTLE Modeling Tool

The RxCTLE Modeling tool is run by selecting the batch file C:\AMI\AFE\RxCTLE_SS_Modeling_Tool\RxCTLE_SS_Modeling.bat

When this is done, a Windows Command window pops up and displays the running simulation status. The following screen captures show the starting and ending screen captures.

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```
C:\AMI_CTLE\RxCTLE_SS_Modeling_Tool>RxCTLE_SS_Modeling_Tool.exe

*** Starting RxCTLE_Modeling_Tool
BitRate = 2.57812e+10
SamplesPerBit = 32
NumStepResp = 32
*** Completed Analysis Setup.
DirName = C:\AMI_CTLE\RxWaveformSmallSignalData
IBIS_SParamFile = RxSerDes_CTLE.s2p
SkipLines = 4
ExtractionTStart = 5.05e-08
ExtractionTLength = 1.4e-09
*** Completed RxCTLE_Modeling_Tool Setup.
```

```
Exiting RxCTLE_Modeling_Tool with success.

Hit any key to continue and exit this program.
```

The process produces its log files in the RxWaveformSmallSignalData directory: Log_RxCTLE_Modeling_Tool.log.

This process takes several steps along the way. Each step produces a log file and other output files into the RxWaveformSmallSignalData directory.

Step 1: Combine the circuit waveform files.

```
*** Starting RxCTLE_ResampleWaveform
    Running RxCTLE_ResampleWaveform Sweep
    Running RxCTLE_ResampleWaveform CreateOutFile
    For detail log, see file:  C:\AMI_Test\WaveformSmallSignalData\Log_ResampleWaveformData.log
    Generated file:  C:\AMI_Test\WaveformSmallSignalData\Combined.csv
*** Completed RxCTLE_ResampleWaveform
```

Step 2: Generate the IBIS S4P file and IBIS impulse response.

```
*** Starting RxCTLE_GenerateIBIS_Impulse
    Running RxCTLE_GenerateIBIS_Impulse Convert IBIS S2P to impulse response; this may take several minutes.
    For detail log, see file:  C:\AMI_Test\WaveformSmallSignalData\Log_GenerateIBIS_Impulse.log
    Generated files:
            C:\AMI_Test\WaveformSmallSignalData\RxCTLE.s2p.s4p
            C:\AMI_Test\WaveformSmallSignalData\RxCTLE.s2p.ImpulseResponse.csv
*** Completed RxCTLE_GenerateIBIS_Impulse
```

Step 3: Extract the desired waveform segment from the combined waveform file.

```
*** Starting RxCTLE_ExtractStepResponseData
    Running RxCTLE_ExtractStepResponseData output step response extracted waveform.
    Running RxCTLE_ExtractStepResponseData input step response extracted waveform.
    For detail log, see file:  C:\AMI_Test\WaveformSmallSignalData\Log_ExtractStepResponseData.log
    Generated files:
            C:\AMI_Test\WaveformSmallSignalData\Combined.OutputStepExtracted.csv
            C:\AMI_Test\WaveformSmallSignalData\Combined.InputStepExtracted.csv
*** Completed RxCTLE_ExtractStepResponseData
```


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Step 4: Deembed the input waveform segment with IBIS impulse applied from the output waveform segment to achieve the step response data for the AMI model.

```
*** Starting RxCTLE_DeembedInputResp
    Running Get OutputStepData.
    Running Write Final and Peak Output Step Values.
    Running Get InputStepData.
    Running Write Input Step Gain Levels.
    Running Get IBIS_ImpulseData.
    Running Derive Output Gain and Peaking Ratios; this may take several minutes.
    Running Convolve Input Step with IBIS Impulse.
    Running Deembed Input with IBIS from Output.
    Running Write Input Step with IBIS.
    Running Validate Deembedded Output Steps
    For detail log, see file:  C:\AMI_Test\WaveformSmallSignalData\Log_DeembedInputResp.log
    Generated files:
              C:\AMI_Test\WaveformSmallSignalData\Combined.InputStepExtracted.InputStepLevels.csv
              C:\AMI_Test\WaveformSmallSignalData\Combined.OutputStepExtracted.InputDeembeded.GainAndPeakingValues.csv
              C:\AMI_Test\WaveformSmallSignalData\Combined.OutputStepExtracted.InputDeembedded.csv
              C:\AMI_Test\WaveformSmallSignalData\Combined.OutputStepExtracted.InputWithIBISDeembedded.csv
              C:\AMI_Test\WaveformSmallSignalData\Combined.InputStepExtracted.WithIBIS_Impulse.csv
*** Completed RxCTLE_DeembedInputResp
```

The log file, Log_DeembedInputResp.log, shows the internal test results comparing the resultant IBIS-AMI model responses with the original data output responses.

```
*** Begin validation process by convolving deembedded step responses with input with IBIS impulse responses
and comparing to the original step responses.
*** During validation the maximum final step value % error = 0.000483397 %.
*** During validation the maximum peak step value % error = 0.3205 %.
*** Completed validation process.
```

This verification step shows excellent between model and data agreement.

One file contains all the combined waveform data: Combined.csv

Two files are used in creating the Rx AFE NL IBIS-AMI model:

- <your_file_name>.s2p.s4p.
- Combined.OutputStepExtracted.InputWithIBISDeembedded.csv

Setting up the RxAFE_NL Modeling Tool

The RxAFE_NL Modeling tool is in the directory C:\AMI\AFE\RxAFE_NL_Modeling_Tool.

Within that directory, the file DataFiles\RxAFE_LS_Modeling.txt needs to be set up by the user.

This file contains three lines. In the following, the user entered values are within angle braces <…>.

Line 1: SetupAnalysis BitRate <bit_rate> SamplesPerBit <samples_per_bit> Num_SS_StepResp <num_step_resp> Num_LS_Resp <num_ls_resp> Num_LS_Levels <num_ls_levels>

<bit_rate>: this is the maximum bit rate for an NRZ data pattern.

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<samples_per_bit>: can remain at 32.

<num_step_resp>: number of small signal AFE states.

<num_ls_resp>: number of large signal AFE states. Can be either the same as <num_step_resp> or 3 where 3 implies that the three states are for minimum emphasis, intermediate emphasis and maximum emphasis. If <num_ls_resp> = 3, then the large signal model for all <num_step_resp> states will be derived from these 3 states.

<num_ls_levels>: number of input signal levels used to characterize the <num_ls_resp> from small signal level to larger levels towards the AFE compression limit.

Line 2: RxAFE_LS_Modeling SS_DirName <small_signal_dir_name> LS_DirName <large_signal_dir_name> IBIS_SParamFile <s2p_filename> SkipLines <skip_lines> ExtractionTStart <extraction_tstart> ExtractionTLength <extraction_tlength>

<small_signal_dir_name>: can remain at C:\AMI\AFE\RxWaveformSmallSignalData.

Note: The small signal directory only contains the AFE small signal data.

<large_signal_dir_name>: can remain at C:\AMI\AFE\RxWaveformLargeSignalData.

Note: The large signal directory include the small signal data for the <num_ls_resp> states.

<s2p_filename>: Name of the s2p data file.

<skip_lines>: Number of lines at the top of the waveform files to skip.

<extraction_tstart>: the time stamp in the waveform file use to start waveform extraction.

<extraction_tlength>: the time length after the tstart for the end of the waveform extraction.

Line 3: RxAFE_NonlinearityModeling NumResamplesPerVolt <num_samp_pervolt> NonlinearityDirName <nonlin_dir_name> SkipLines <skip_lines>

<num_samp_pervolt>: can remain at 100

<nonin_dir_name>: can remain at C:\AMI\AFE\RxNonlinearityData.

<skip_lines>: Number of lines at the top of the nonlinearity files to skip.

Discussion:

It is assumed that all AFE waveform files use the same NRZ data pattern and the same time samples. As such, all files have the same NRZ segment with N zeros and M ones. Set tstart to a reference time before the zero-to-one transition. Set tlength to the point after this transition and before the next transition.

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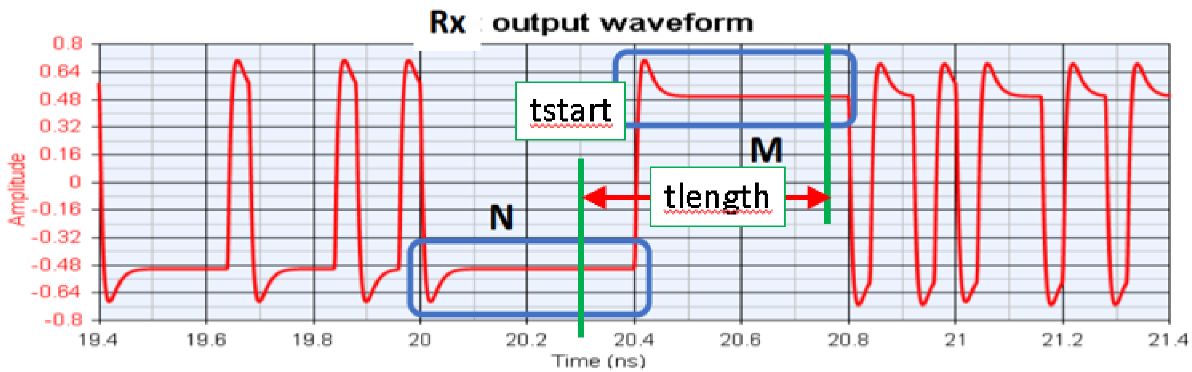
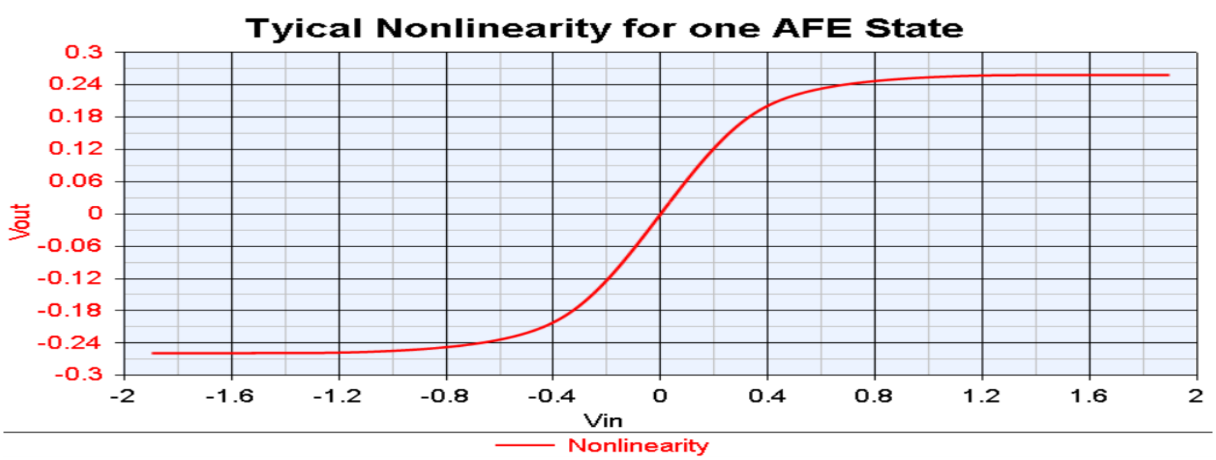
This figure shows this concept.



It is assumed that all AFE nonlinearity files contain the DC into DC out (Vin to Vout) characteristic of the AFE with the +/- DC value large enough to drive the output to saturation.

This figure show this concept:



Running the RxAFE_NL Modeling Tool

The RxAFE_NL Modeling tool is run by selecting the batch file C:\AMI\AFE\RxAFE_NL_Modeling_Tool\RxAFE_NL_Modeling.bat

When this is done, a Windows Command window pops up and displays the running simulation status. The following screen captures show the starting and ending screen captures.

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```
C:\AMI\AFE\RxAFE_NL_Modeling_Tool>RxAFE_LS_Modeling_Tool.exe  RxAFE_LS_Modeling.txt

*** Starting RxAFE_LS_Modeling_Tool
Physical address = F0-9E-4A-93-46-AD
Valid physical address.
BitRate = 2.57812e+10
SamplesPerBit = 32
Num_SS_StepResp = 32
Num_LS_Resp = 3
Num_LS_Levels = 5
*** Completed RxAFE LS Analysis Setup.
SS_DirName = C:\AMI\AFE\RxWaveformSmallSignalData
LS_DirName = C:\AMI\AFE\RxWaveformLargeSignalData
IBIS_SParamFile = RxSerDes_CTLE.s2p
SkipLines = 4
ExtractionTStart = 5.05e-08
ExtractionTLength = 1.4e-09
*** Completed RxAFE LS Data Setup.
NumResamplesPerVolt = 100
NonlinearityDirName = C:\AMI\AFE\RxNonlinearityData
SkipLines = 4
*** Completed RxAFE Nonlinearity Setup.
```

```
Exiting RxAFE_LS_Modeling_Tool with success.

Hit any key to continue and exit this program.
```

The process produces its log files in the RxWaveformLArgeSignalData directory: Log_RxAFE_NL_Modeling_Tool.log.

This process takes several steps along the way. Each step produces a log file and other output files into the RxWaveformLargeSignalData directory.

Step 1: Combine the circuit waveform files.

```
*** Starting RxAFE LS ResampleWaveform
```

```
    For detail log, see file:  C:\AMI\AFE\RxWaveformLargeSignalData\Log_ResampleWaveformData.log
    Generated file:  C:\AMI\AFE\RxWaveformLargeSignalData\Combined.csv
*** Completed RxAFE LS ResampleWaveform
```

Step 2: Generate the IBIS S4P file and IBIS impulse response.

```
*** Starting RxAFE GenerateIBIS_Impulse
```

```
    Generated files:
              C:\AMI\AFE\RxWaveformLargeSignalData\RxSerDes_CTLE.s2p.s4p
              C:\AMI\AFE\RxWaveformLargeSignalData\RxSerDes_CTLE.s2p.ImpulseResponse.csv
*** Completed RxAFE GenerateIBIS_Impulse
```

Step 3: Extract the desired waveform segment from the combined waveform file.

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```
*** Starting RxAFE LS ExtractStepResponseData
```

```
    Generated files:
              C:\AMI\AFE\RxWaveformLargeSignalData\Combined.OutputStepExtracted.csv
              C:\AMI\AFE\RxWaveformLargeSignalData\Combined.InputStepExtracted.csv
*** Completed RxAFE LS ExtractStepResponseData
```

Step 4: Deembed the input waveform segment with IBIS impulse applied from the output waveform segment to achieve the data for the AMI model.

```
*** Starting RxAFE LS DeembedInputResp
```

```
    Generated files:
              C:\AMI\AFE\RxWaveformLargeSignalData\Combined.InputStepExtracted.InputStepLevels.csv
              C:\AMI\AFE\RxWaveformLargeSignalData\Combined.OutputStepExtracted.InputDeembeded.GainAndPeakingValues.csv
              C:\AMI\AFE\RxWaveformLargeSignalData\Combined.OutputStepExtracted.InputDeembedded.csv
              C:\AMI\AFE\RxWaveformLargeSignalData\Combined.OutputStepExtracted.InputWithIBISDeembedded.csv
              C:\AMI\AFE\RxWaveformLargeSignalData\Combined.InputStepExtracted.WithIBIS_Impulse.csv
*** Completed RxAFE LS DeembedInputResp
```

The log file, Log_DeembedInputResp.log, shows the internal test results comparing the resultant IBIS-AMI model responses with the original data output responses.

```
*** Begin validation process by convolving deembedded step responses with input with IBIS impulse responses
and comparing to the original step responses.
*** During validation the maximum final step value % error = 0.000780283 %.
*** During validation the maximum peak step value % error = 0.989662 %.
*** Completed validation process.
Completed Validate LS Deembedded Output Steps
```

This verification step shows excellent agreement.

Step 5: Combine the circuit nonlinearity files.

```
*** Starting RxAFE ResampleNonlinearityData
```

```
    Generated file:
              C:\AMI\AFE\RxWaveformLargeSignalData\Nonlinearity_LS_Combined.csv
*** Completed Nonlinearity_LS_Combined.csv Generation
```

Step 6: Derive the nonlinearity compensation.

```
*** Starting RxAFE Derive NL Compensation
```

```
*** Completed RxAFE Derive NL Compensation
```

If the <num_ls_resp> = 3, then the full set of compensation factors for all <num_step_resp> are derived from the compensation factors for these three by applying the next step.

Step 7: Extend compensation factors.

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```
*** Starting RxAFE Extend LS Compensation Factors

*** Completed RxAFE Extend LS Compensation Factors
```

One file contains all the combined large signal waveform data: Combined.csv

Five files are used in creating the Rx AFE NL IBIS-AMI model:

- Combined.InputStepExtracted.WithIBIS_Impulse.InputStepLevels.csv
- Combined.OutputStepExtracted.InputWithIBISDeembedded.GainFactors.csv
- Combined.OutputStepExtracted.InputWithIBISDeembedded.GainSplitFactors.csv
- Combined.OutputStepExtracted.InputWithIBISDeembedded.RootValues.csv
- Nonlinearity_Combined.csv

Generating the RxAFE_NL IBIS-AMI Model

This section provides instructions on building the IBIS-AMI models – only with the instructions needed to be successful. This section does not include detail discussion of these steps, the reasons for these steps, the structure of the files generated, or other such detail. That detail is available in the separate SerDesDesign.com product called the 'SerDesDesign.com IBIS-AMI Model Development Environment'. The content included with this RxAFE_NL tool is a subset of that full model development environment.

The full IBIS-AMI Model Development Environment for Windows/Linux is available at the SerDesDesign.com store (https://www.serdesdesign.com/home/store/products/products).

Creating IBIS-AMI models on a Windows 64-bit PC requires installing the free Microsoft Visual Studio 2019 tool.

See this link for instruction on installing Visual Studio 2019:
http://www.serdesdesign.com/home/web_documents/models/Installing_Visual_Studio_2019.pdf

The RxAMI_Solution_SerDes_AFE_NL directory is used for building the IBIS-AMI model. It has this structure:

RxAMI_Solution_SerDes_AFE_NL	Contains: Configure-for-win64-vs2019.bat
source	Contains: CMakeLists.txt
RxSerDes_AFE_NL	Contains: CMakeLists.txt; IBIS-AMI model files
RxSerDes_AFE_NL_TestWaveform	Contains file: CMakeLists.txt; IBIS-AMI model files

RxSerDes_AFE_NL is the AFE NL Rx IBIS-AMI model.

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RxSerDes_AFE_NL_TestWaveform is a Tx IBIS-AMI model that contains the combined set of large signal waveform data and is used to test the RxSerDes_AFE_NL model in a channel simulator to test Model vs Data waveforms.

Within RxSerDes_AFE_NL, there is a batch file: _get_files.bat.

You may need to change one line in this batch file. Change this line as needed:

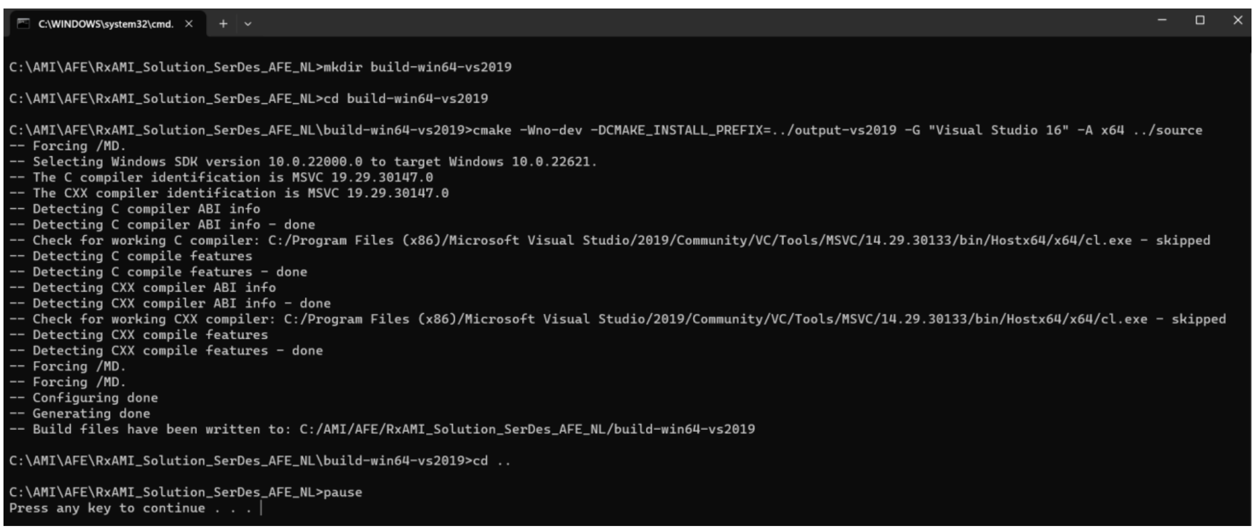
copy /Y C:\AMI\AFE\RxWaveformSmallSignalData\<your_s2p_filename>.s2p.s4p .\RxSerDes_AFE.s2p.s4p

where you use that actual S2P file name in place of <your_s2p_filename>.

Running this batch file copies the required files, as identified earlier, from the RxWaveformSmallSignalData and RxWaveformLargeSgnalData directories.

With Visual Studio 2019 installed and operable, build this AMI_Solution by running the batch file Configure-for-win64-vs2019.bat. When this batch file is run, a Windows Command window opens and runs the process to build the Visual Studio solution.

A screen captures for a successful running of this build process is shown here.



Press any key to continue. You will see the directory build-win64-vs2019 within RxAMI_Solution_SerDes_AFE_NL.

Though many files were generated, only one file is used for our purpose.

See the file RxAMI_Solution_SerDes_AFE_NL.sln within the build-win64-vs2019 directory.

Double click on this *.sln file and Visual Studio 2019 will open with this view:

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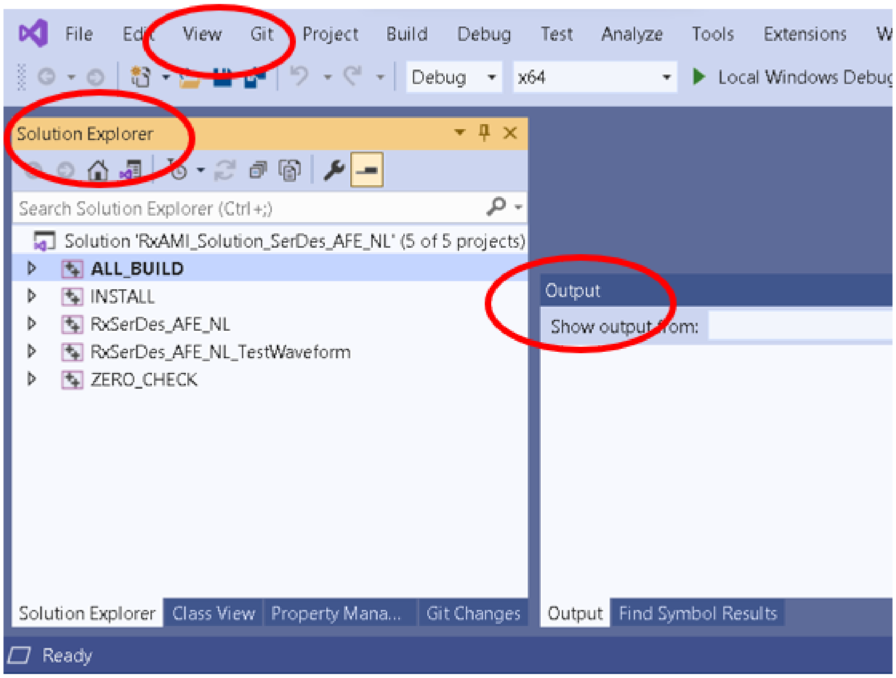

Observe the display for the '**Solution Explorer**' and '**Output**' windows.

You may have to use the '**View'** menu on the top toolbar to display these windows.

The IBIS/AMI/Source code is in the RxSerDes_AFE_NL sub folder.

To build the IBIS-AMI model, Set the Solution Configuration to '**Release'**. Select INSTALL, right mouse click; select '**Build'**.

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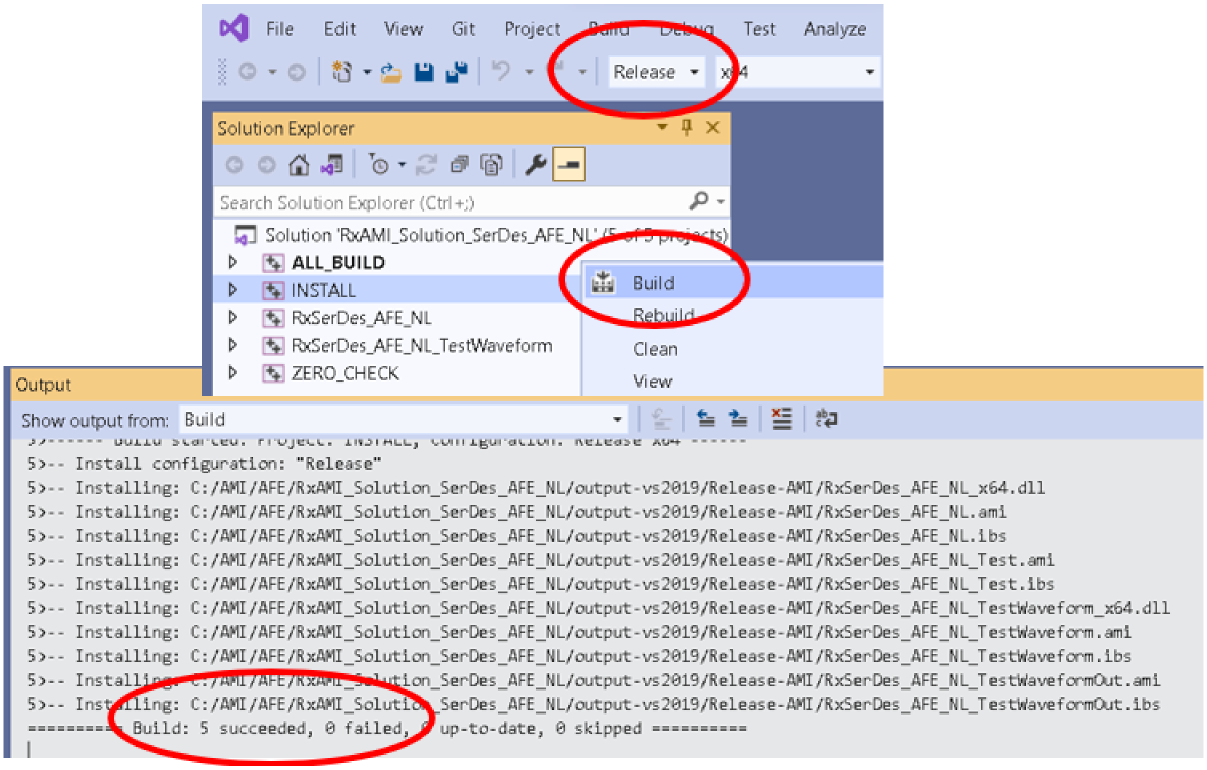

The Output displays build success message. The IBIS-AMI files are placed into '**output-vs2019\Release-AMI**'. **We are DONE!!!**

Files RxSerDes_AFE_NL.ibs/.ami/_x64.dll along with the s4p file can be used in any Channel Simulator on your Windows PC.

Files RxSerDes_AFE_NL_Test.* and RxSerDes_AFE_NL_TestWaveform*.* the s4p file can be used in any Channel Simulator on your Windows PC and are used ONLY for validating the AFE_NL waveforms (Model) with the TestWaveforms (Data).

Use of these IBIS-AMI files a channel simulator is discussed in the separate document RxSerDes_AFE_NL_Use_In_SerDesDesign_on_Windows.pdf.

An unlimited number of IBIS-AMI models can be generated with this Tool and used with any Channel Simulator on this Windows PC.

How to Remove IBIS-AMI Model Licensing Restrictions

The IBIS-AMI models generated by this Tool have the same time-based node-locked licensing restrictions as the Tool.

Use of the IBIS-AMI model on any Windows or Linux machine requires that the built-in licensing restrictions must be removed. To do this, zip up and send your

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RxAMI_Solution_SerDes_AFE_NL project, with any additional instructions, to **admin@serdesdesign.com**.

An IBIS-AMI model with licensing restrictions removed will be sent to you after your payment in the SerDesDesign.com store (**https://www.serdesdesign.com/home/store**) for an amount that is 50% of standard model pricing as defined in the response you receive from **admin@serdesdesign.com**.

- For example: Standard pricing for an Rx IBIS-AMI model on Windows or Linux is $2,000. So, the 50% pricing results in a price of $1,000.

Instead of purchasing the single distributable IBIS-AMI model, you can also obtain the source code and Window/Linux build projects for your IBIS-AMI model for unlimited modification and distribution for any other IBIS-AMI models with the same architecture by purchasing IBIS-AMI Training for the IBIS-AMI model. The training fee is as published on the Store web page.

- For example: The store published price (subject to change) is 6,000 USD for IBIS-AMI Model Training (reduced for prior customers). Delivery is with source code and Windows/Linux build projects.

Example Tool Process with the Included Circuit Data Files

The example circuit data files are in the RxWaveformSmallSignalData, RxWaveformLargeSignalData, and RxNonlinearityData directory.

Within the RxWaveformSmallSignalData directory are these files:

- RxSerDes_CTLE.s2p - the Rx circuit differential input S-parameters.
- CTLE_<n>.tim – the 32 waveform files (n=1 to 32) for the 32 CTLE states. These files were generated using the Keysight ADS Spice circuit simulator and use the ADS text file *.tim format. The top four lines contain header information and are to be skipped.
  - Any circuit simulator text output file can be used provided it follows the required format.
- InputFileNameList.txt – the text file with 32 lines listing the 32 CTLE waveform file names.

Within the RxWaveformLargeSignalData directory are these files:

- RxSerDes_CTLE.s2p - the Rx circuit differential input S-parameters (this must be the same as in the RxWaveformSmallSignalData directory).
- CTLE_1_50m, …, CTLE_1_800m, CTLE_8_50m, …, CTLE_8_800m, CTLE_31_50m, …, CTLE_31_800m.tim. These are files with the least emphasis (CTLE_1), intermediate emphasis (CTLE_8) and maximum emphasis (CTLE_31) each for 5 peak-to-peak input

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levels (50 mv, 200mv, 400mv, 600mv, 800mv). This is a total of 15 files. These files were generated using the Keysight ADS Spice circuit simulator and use the ADS text file *.tim format. The top four lines contain header information and are to be skipped.
  - Any circuit simulator text output file can be used provided it follows the required format.
  - Note: Instead of large signal data for just 3 CTLE states (15 files), it would be better to have large signal data for all 32 CTLE states (32*5=160 files). Having the full set of large signal data results in a more accurate model. Support using only 3 files was introduced to minimize the data collection process with some loss in accuracy for the other 29 CTLE states. When only 3 CTLE states are used, their derived nonlinear compensation factors are interpolated to generate nonlinear compensation factors for all 32 states.
- LS_InputFileNameList.txt – the text file listing all large signal files.
  - In our case, this file has 15 lines.
  - If the large signal data was provided for all 32 states, then this file would have 160 lines.
- If only 3 CTLE states were used for the large signal data, then one additional file is required: LS_With_SS_DataList.csv. This has three lines that map the large signal data to the small signal states using index CTLE-1. Thus, in our example case, using CTLE_1, CTLE_8 and CTLE_31, this file has three lines: 0, 7 and 31.

The example setup for the RxCTLE_SS Modeling Tool is defined in the file RxCTLE_SS_Modeling.txt in the RxCTLE_SS_Modeling_Tool\DataFiles directory. This file has these two lines:

- SetupAnalysis BitRate 25.78125e9 SamplesPerBit 32 NumStepResp 32
- RxCTLE_Modeling DirName C:\AMI\AFE\RxWaveformSmallSignalData IBIS_SParamFile RxSerDes_CTLE.s2p SkipLines 4 ExtractionTStart 5.0500e-08 ExtractionTLength 1.4000e-09

Note: The value provided in these two lines that are specific for this set of example circuit data files.

The example setup for the RxAFE_NL Modeling Tool is defined in the file RxAFE_NL_Modeling.txt in the RxAFE_NL_Modeling_Tool\DataFiles directory. This file has these three lines:

- SetupAnalysis BitRate 25.78125e9 SamplesPerBit 32 Num_SS_StepResp 32 Num_LS_Resp 3 Num_LS_Levels 5
- RxAFE_LS_Modeling SS_DirName C:\AMI\AFE\RxWaveformSmallSignalData LS_DirName C:\AMI\AFE\RxWaveformLargeSignalData IBIS_SParamFile RxSerDes_CTLE.s2p SkipLines 4 ExtractionTStart 5.0500e-08 ExtractionTLength 1.4000e-09

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- RxAFE_NonlinearityModeling NumResamplesPerVolt 100 NonlinearityDirName C:\AMI\AFE\RxNonlinearityData SkipLines 4

Note: The value provided in these three lines that are specific for this set of example circuit data files.

The RxCTLE Modeling Tool is run by double clicking on the batch file RxCTLE_Modeling.bat in the RxCTLE_SS_Modeling_Tool directory and results in these two generated files in the RxWaveformSmallSignalData directory that will be used in the IBIS-AMI models.

- RxSerDes_CTLE.s2p.s4p
    - Note: This name is specific to the example file. It will be based on the name the user sets for the S2P file.
- Combined.OutputStepExtracted.InputWithIBISDeembedded.csv

The RxAFE_NL Modeling Tool is run by double clicking on the batch file RxAFE_NL_Modeling.bat in the RxAFE_NL_Modeling_Tool directory and results in these six generated files in the RxWaveformLargeSignalData directory that will be used in the IBIS-AMI models.

- RxSerDes_CTLE.s2p.s4p
    - Note: This name should be the same as was used for the RxCTLE_SS tool.
- Combined.csv
- Combined.InputStepExtracted.WithIBIS_Impulse.InputStepLevels.csv
- Combined.OutputStepExtracted.InputWithIBISDeembedded.GainFactors.csv
- Combined.OutputStepExtracted.InputWithIBISDeembedded.GainSplitFactors.csv
- Combined.OutputStepExtracted.InputWithIBISDeembedded.RootValues.csv
- Nonlinearity_Combined.csv

When the Visual Studio solution is generated and the Visual Studio build process is run, these files are generated in the RxAMI_Solution_SerDes_AFE_NL\output-vs2019\Release-AMI directory.

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RxSerDes_AFE_NL.ami

RxSerDes_AFE_NL_Test.ami

RxSerDes_AFE_NL_TestWaveform.ami

RxSerDes_AFE_NL_TestWaveformOut.ami

RxSerDes_AFE_NL_TestWaveform_x64.dll

RxSerDes_AFE_NL_x64.dll

RxSerDes_AFE_NL.ibs

RxSerDes_AFE_NL_Test.ibs

RxSerDes_AFE_NL_TestWaveform.ibs

RxSerDes_AFE_NL_TestWaveformOut.ibs

These files along with the RxSerDes_CTLE.s2p.s4p files can be used in any Channel Simulator on the Windows PC that supports the IBIS 7.0 specification or later.

Use of these IBIS-AMI files a channel simulator is discussed in the separate document RxSerDes_AFE_NL_Use_In_SerDesDesign_on_Windows.pdf.

Topics for Further Consideration

Additional SerDesDesin.com Premium Tools are available with local download and installation on a user's Windows 64-bit PC.

For details see the links:

https://www.serdesdesign.com/home/web_documents/SerDes_Design_Premium_Tool.pdf

https://www.serdesdesign.com/home/store/

See these store options:

- **Description; Guarantee; Webinar;** Premium Tool – SerDes_System_Tool

- **Guarantee**; Premium Tool – SerDes_IBIS-AMI_Model_Generation_Tool
- This an add-on to the SerDes System Tool and includes the SerDesDesign.com IBIS-AMI Model Development Environment for Windows/Linux.

- **Guarantee**; Premium Tool – SerDes IBIS-AMI TxFFE Modeling Tool

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- **Description**; **Guarantee**; **Webinar**; Premium Tool – SerDes IBIS-AMI Rx/Tx CTLE Modeling Tool

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