Subject: SerDesDesign.com TxCTLE_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 Tx CTLE IBIS-AMI model from circuit data. **Perfect = IBIS-AMI model exactly agrees with Spice simulations**.

Overview

Be sure to read these two documents first:

READ_ME_FIRST_-_License_Agreement.pdf

READ_ME_SECOND_-_Instructions.pdf See this file for instructions on installing this tool and its directory structure.

This Tx Tool has this directory structure:

C:/AMI_CTLE/TxAMI_Solution_SerDes_CTLE - SerDesDesign.com IBIS-AMI build directory.
C:/AMI_CTLE/TxCTLE_SS_Modeling_Tool - Tx CTLE Modeling Tool.
C:/AMI_CTLE/TxWaveformSmallSignalData – directory for the circuit data files.

Circuit Data Collection

The circuit is assumed to be for a SerDes receiver (Tx) continuous time linear equalizer (CTLE) with differential outputs that interface with a differential SerDes channel.

The data to be collected is:

- The Tx circuit output differential impedance versus frequency.
- The Tx circuit CTLE output waveform for each CTLE state.

For detail instruction on this required circuit data see the report:
Modeling_an_LTI_TxSerDes_CTLE_wih_TimeData.pdf

Place this circuit data into the directory C:\AMI_CTLE\TxWaveformSmallSignalData.

Within that directory create the file InputFileNameList.txt which is to contain a list of all the CTLE waveform files in the desired order.

Setting up the TxCTLE Modeling Tool

The TxCTLE Modeling tool is in the directory C:\AMI_CTLE\TxCTLE_SS_Modeling_Tool.

Within that directory, the file DataFiles\TxCTLE_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.

Line 2: TxCTLE_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_CTLE\TxWaveformSmallSignalData.

<s2p_filename>: Name of the s2p data file.

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

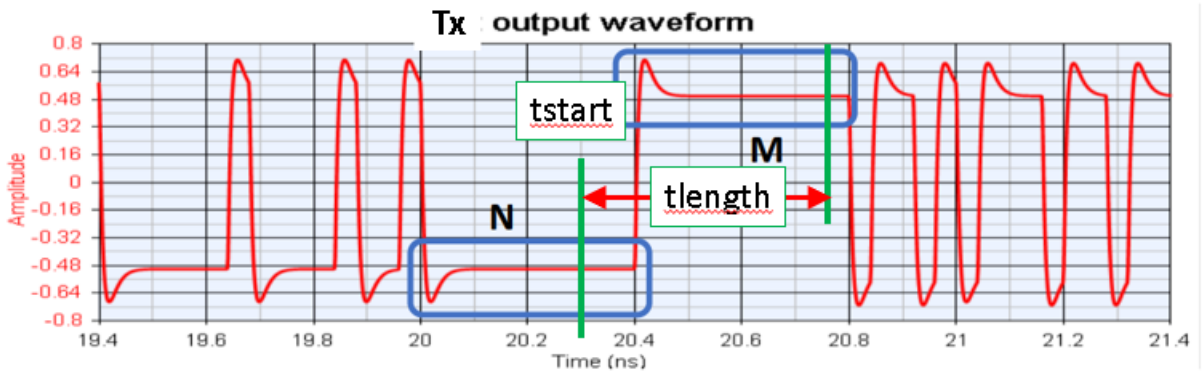
<extraction_tstart>: the time stamp in the waveform file use to start waveform extraction.

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

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 TxCTLE Modeling Tool

The TxCTLE Modeling tool is run by selectin the batch file C:\AMI_CTLE\TxCTLE_SS_Modeling_Tool\TxCTLE_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.

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

*** Starting TxCTLE_Modeling_Tool
BitRate = 2.57812e+10
SamplesPerBit = 32
NumStepResp = 8
*** Completed Analysis Setup.
DirName = C:\AMI_CTLE\TxWaveformSmallSignalData
IBIS_SParamFile = TxSerDes_CTLE.s2p
SkipLines = 4
ExtractionTStart = 5.05e-08
ExtractionTLength = 1.4e-09
*** Completed TxCTLE_Modeling_Tool Setup.
```

```
Exiting TxCTLE_Modeling_Tool with success.

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

The process produces its log files in the TxWaveformSmallSignalData directory: Log_TxCTLE_Modeling_Tool.log.

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

Step 1: Combine the circuit waveform files.

```
*** Starting TxCTLE_ResampleWaveform
    Running TxCTLE_ResampleWaveform Sweep
    Running TxCTLE_ResampleWaveform CreateOutFile
    For detail log, see file:  C:\AMI_CTLE\TxWaveformSmallSignalData\Log_ResampleWaveformData.log
    Generated file:  C:\AMI_CTLE\TxWaveformSmallSignalData\Combined.csv
*** Completed TxCTLE_ResampleWaveform
```

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

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

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

```
*** Starting TxCTLE_ExtractStepResponseData
    Running TxCTLE_ExtractStepResponseData output step response extracted waveform.
    For detail log, see file:  C:\AMI_CTLE\TxWaveformSmallSignalData\Log_ExtractStepResponseData.log
    Generated files:
              C:\AMI_CTLE\TxWaveformSmallSignalData\Combined.OutputStepExtracted.csv
*** Completed TxCTLE_ExtractStepResponseData
```

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

```
*** Starting TxCTLE_DeembedInputResp
    Running Get OutputStepData.
    Running Get IBIS_ImpulseData.
    Running Generate Step for IBIS Impulse.
    Running Deembed IBIS from Output.
    For detail log, see file:  C:\AMI_CTLE\TxWaveformSmallSignalData\Log_DeembedInputResp.log
    Generated files:
              C:\AMI_CTLE\TxWaveformSmallSignalData\Combined.OutputStepExtracted.InputDeembedded.csv
*** Completed TxCTLE_DeembedInputResp
```

The log file, Log_DeembedInputResp.log, shows the test results.

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

Two files are used in creating the Tx CTLE IBIS-AMI model:

- TxSerDes_CTLE.s2p.s4p (rename your *.s2p.s4p file to this name).
- Combined.OutputStepExtracted.WithIBISDeembedded.csv

Generating the TxCTLE IBIS-AMI Model

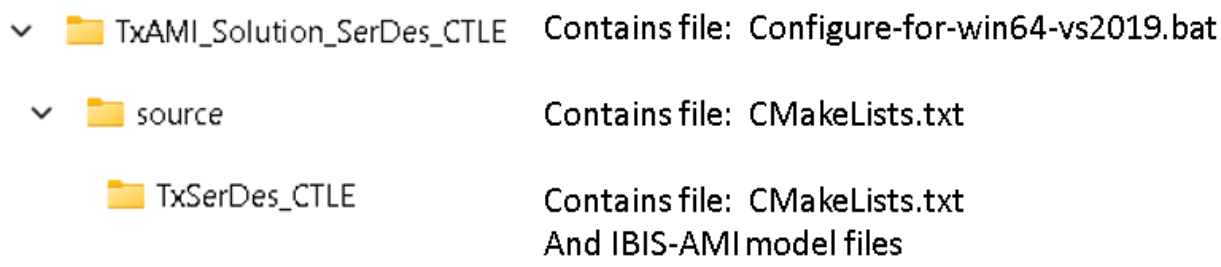
This section provides instructions on building the IBIS-AMI models – only with the instructions needed to be successful. This section does not include detail discussion of these steps, the reasons for these steps, the structure of the files generated, or other such detail. That detail is available in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

The full product, 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 TxAMI_Solution_SerDes_CTLE directory is used for building the IBIS-AMI model. It has this structure:



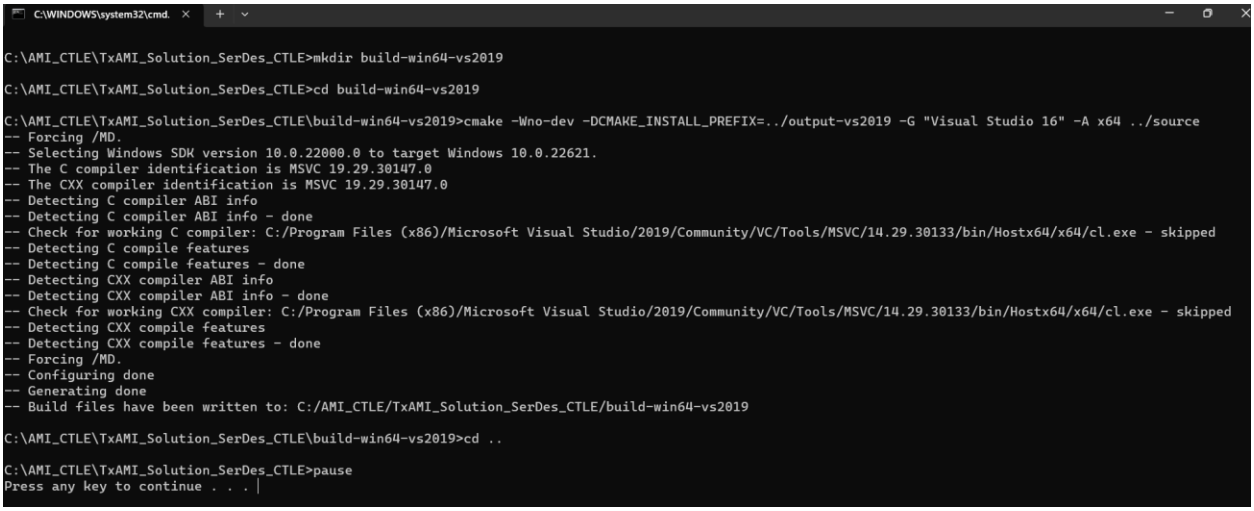
As identified in the prior section, two files from the prior section are used in creating the Tx CTLE IBIS-AMI model:

- TxSerDes_CTLE.s2p.s4p (rename your *.s2p.s4p file to this name).
- Combined.OutputStepExtracted.WithIBISDeembedded.csv

Copy these files to the TxSerDes_CTLE directory.

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.

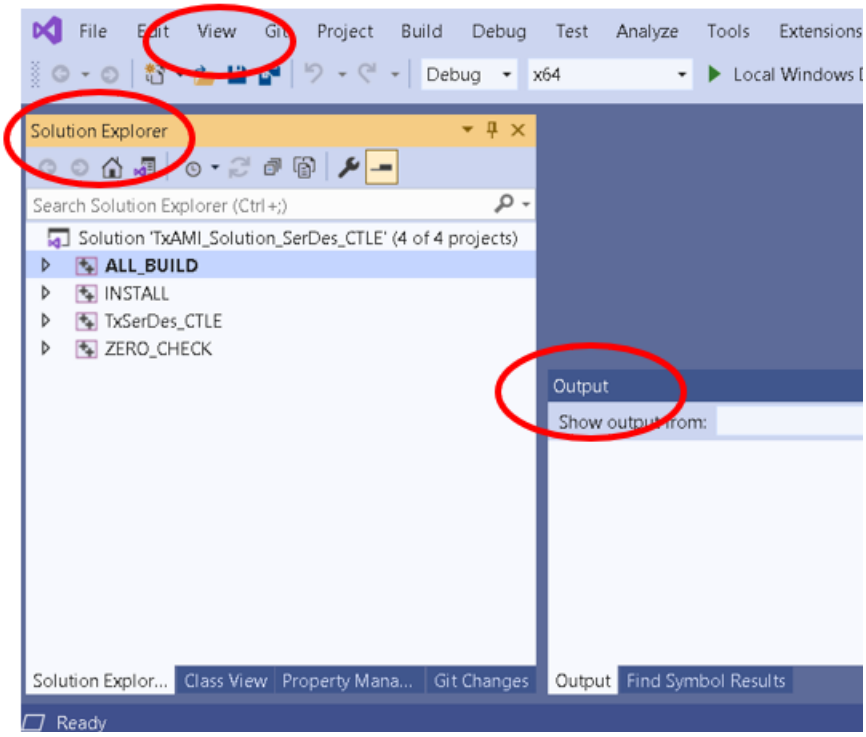


Press any key to continue. You will see the directory build-win64-vs2019 within TxAMI_Solution_SerDes_CTLE.

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

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

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

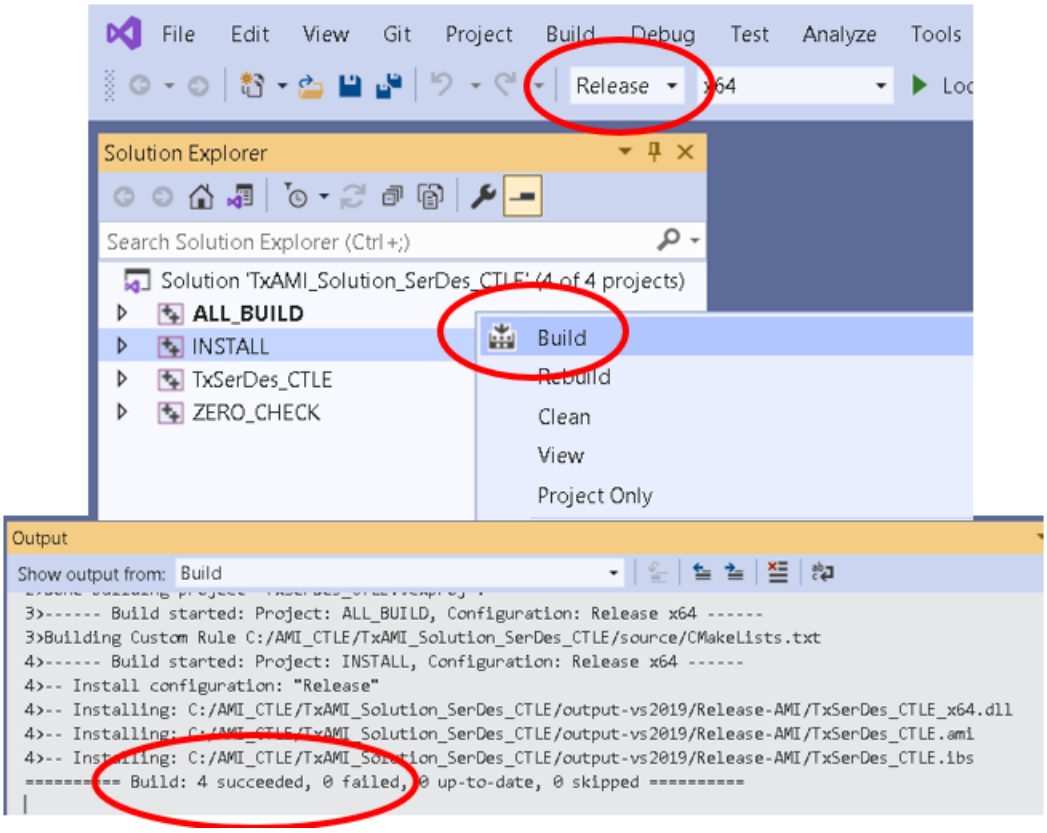


Observe the display for the '**Solution Explorer**' and '**Output**' windows.

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

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

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



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

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

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 TxAMI_Solution_SerDes_CTLE 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**.

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

Example Tool Process with the Included Circuit Data Files

The example circuit data files are in the TxWaveformSmallSignalData directory.

These files are:

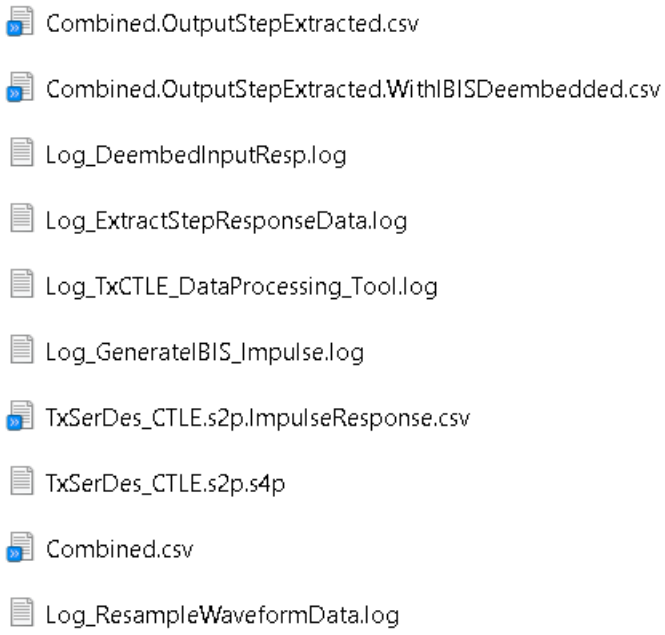
- TxSerDes_CTLE.s2p - the Tx circuit differential input S-parameters.
- CTLE_<n>.tim – the 8 waveform files (n=1 to 8) for the 8 CTLE states. These files were generated using the Keysight ADS Spice circuit simulator and use the ADS text file *.tim format. The top four lines contain header information 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 8 lines listing the 8 CTLE waveform file names.

The example setup for the TxCTLE Modeling Tool is defined in the file TxCTLE_Modeling.txt in the TxCTLE_SS_Modeling_Tool\DataFiles directory. This file has these two lines:

- SetupAnalysis BitRate 25.78125e9 SamplesPerBit 32 NumStepResp 8
- TxCTLE_SS_Modeling DirName C:\AMI_CTLE\TxWaveformSmallSignalData IBIS_SParamFile TxSerDes_CTLE.s2p SkipLines 4 ExtractionTStart 5.0500e-08 ExtractionTLength 1.4000e-09

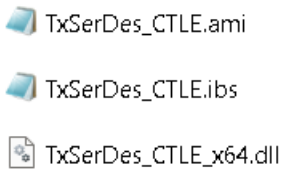
Notice the value provided in these two lines that are specific for this set of example circuit data files.

The TxCTLE Modeling Tool is run by double clicking on the batch file TxCTLE_Modeling.bat in the TxCTLE_SS_Modeling_Tool directory and results in these generated files in the TxWaveformSmallSignalData directory.



The two files TxSerDes_CTLE.s2p.s4p and Combined.OutputStepExtracted.WithIBISDeembedded.csv are copied to the TxAMI_Solution_SerDes_CTLE\source\TxSerDes_CTLE directory.

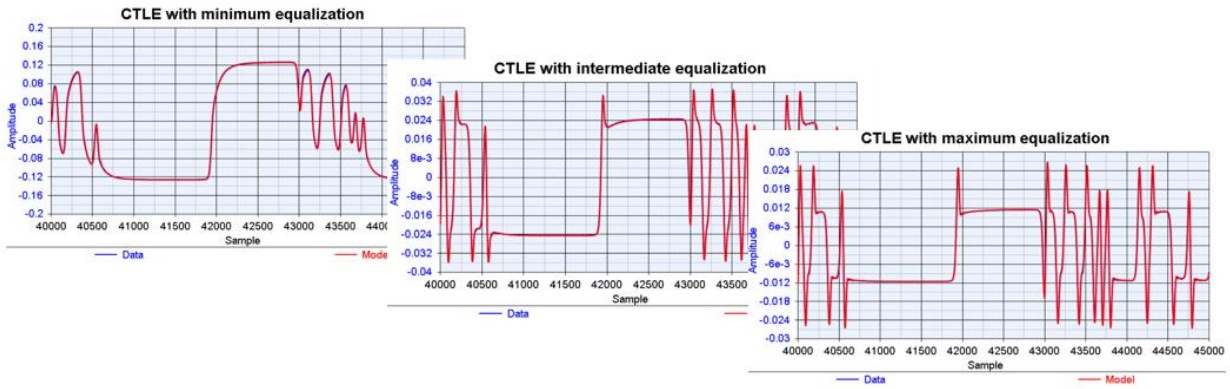
When the Visual Studio solution is generated and the Visual Studio build process is run, these files are generated in the AMI_Solution_TxSerDes_CTLE\output-vs2019\Release-AMI directory.



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

This example TxSerDes_CTLE IBIS-AMI model will provide perfect agreement with the circuit waveform output data when used with the same circuit input waveform data.

Here is a display for the CTLE with min, intermediate and max equalization. In all cases, the Model waveform response is equal to the Data waveform response.



Topics for Further Consideration

Additional SerDesDesign.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

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

- **Guarantee;** Premium Tool – SerDes IBIS-AMI Rx CTLE with Nonlinearity Modeling Tool; includes the SerDes IBIS-AMI Rx/Tx CTLE Modeling Tool.

Terms and Conditions

See terms and conditions for IBIS-AMI Modeling are at this link: **Terms & Conditions | Privacy Policy**