User's Guide
DS100KRxxx IBIS-AMI Model

Version 3
April 2014

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1 Document Revision History

Revision	Editor	Comment	Date
1	Casey Morrison [cmorrison@ti.com]	Initial creation of User's Guide.	23-Feb-2012
2	Casey Morrison [cmorrison@ti.com]	Update to include LTI (statistical) mode.	11-March-2014
3	Casey Morrison [cmorrison@ti.com]	Update to include s-parameter based termination.	02-April-2014

2 Overview

This document is a User's Guide for the DS100KRxxx Buffer Repeater. Table 1 below lists pertinent information related to the delivered model.

Table 1: Model information

<table>
<tr><th>Item</th><th>Value/Comment</th></tr>
<tr><td>TI device models included</td><td>DS100KR210, DS100KR401, and DS100KR800 Buffer Repeaters</td></tr>
<tr><td>IBIS version</td><td>Compliant to IBIS version 5.1.</td></tr>
<tr><td>Supported platforms</td><td>32-bit Windows
64-bit Windows
64-bit Linux</td></tr>
<tr><td>Release package files</td><td><pre>
TI_DS100KRxxx_IBIS_AMI_v2
     |
     +-- Example_Projects
     | |
     | +-- TI_DS100KRxxx_ADS_Project_Quick_Guide.pdf
     | +-- Agilent_ADS_2013.06.7zads
     |
     +-- Model
             |
             +-- TI_DS100KRxxx_IBIS_AMI_User_Guide.pdf
             +-- DS100KRXXX.ibs
             +-- DS100KRxxx_Tx_03_2014.ami
             +-- DS100KRxxx_Rx_03_2014.ami
             +-- DS100KRxxx_Tx_03_2014.dll
             +-- DS100KRxxx_Rx_03_2014.dll
             +-- DS100KRxxx_Tx_03_2014_x64.dll
             +-- DS100KRxxx_Rx_03_2014_x64.dll
             +-- DS100KRxxx_Tx_03_2014_x64.s0
             +-- DS100KRxxx_Rx_03_2014_x64.so
             +-- repeater_pkg.s4p
</pre></td></tr>
</table>

3 Receiver Model Parameters

The DS100KRxxx receiver model includes the following model-specific parameters:

1. **EQ_Level**: This parameter sets the Repeater's input equalization setting. Refer to Table 2 of the device datasheet (copied below for convenience).

Table 2. Equalizer Settings

Model EQ_Level setting	Level	EQA1 EQB1	EQA0 EQB0	EQ – 8 bits [7:0]	dB at 1.0 GHz	dB at 3.0 GHz	dB at 5.0 GHz	Suggested Use
0	1	0	0	0000 0000 = 0x00	1.7	4.2	5.3	FR4 < 5 inch trace
1	2	0	R	0000 0001 = 0x01	2.8	6.6	8.7	FR4 5 inch 5–mil trace
2	3	0	Float	0000 0010 = 0x02	4.1	8.6	10.6	FR4 5 inch 4–mil trace
3	4	0	1	0000 0011 = 0x03	5.1	9.8	11.7	FR4 10 inch 5–mil trace
4	5	R	0	0000 0111 = 0x07	6.2	12.4	15.6	FR4 10 inch 4–mil trace
5	6	R	R	0001 0101 = 0x15	5.1	12.0	16.6	FR4 15 inch 4–mil trace
6	7	R	Float	0000 1011 = 0x0B	7.7	15.0	18.3	FR4 20 inch 4–mil trace
7	8	R	1	0000 1111 = 0x0F	8.8	16.5	19.7	FR4 25 to 30 inch 4–mil trace
8	9	Float	0	0101 0101 = 0x55	6.3	14.8	20.3	FR4 30 inch 4–mil trace
9	10	Float	R	0001 1111 = 0x1F	9.9	19.2	23.6	FR4 35 inch 4–mil trace
10	11	Float	Float	0010 1111 = 0x2F	11.3	21.7	25.8	10m, 30awg cable
11	12	Float	1	0011 1111 = 0x3F	12.4	23.2	27.0	10m – 12m cable
12	13	1	0	1010 1010 = 0xAA	11.9	24.1	29.1	
13	14	1	R	0111 1111 = 0x7F	13.6	26.0	30.7	
14	15	1	Float	1011 1111 = 0xBF	15.1	28.3	32.7	
15	16	1	1	1111 1111 = 0xFF	16.1	29.7	33.8	

2. **Limit**: This parameter puts the device into a limiting or non-limiting mode.

Model Limit setting	Description
0	In this mode the model operates in non-limiting mode. The peak-to-peak output voltage depends on the peak-to-peak input voltage. *This mode is required for applications which require link training (i.e. 8Gbps PCIe-Gen3 and 10.3125Gbps 10GBASE-KR).*
1	In this mode the model operates in limiting mode. An additional gain of 40dB is included and thus the output peak-to-peak voltage will only depend on the limiting amplitude and not the input peak-to-peak voltage. *This mode should be used for applications which do not require link training.*

3. **LTI_mode**: This parameter determines whether the model's AMI_Init() function returns a modified impulse response (for LTI simulations) or an unmodified impulse response (for non-LTI simulations). Regardless, the model has GetWave_Exists=True and therefore all behavior (LTI and non-LTI) will be represented in time domain simulations.

Note: Not all EDA tools support pure statistical simulations for Redrivers/Retimers. Nevertheless, LTI mode can still be used.

Model LTI_mode	Description
0	Non-linear-time-invariant (non-LTI) mode. Useful for pure time domain simulations. The AMI_Init() function does not modify the impulse response.
1 (default)	Linear time-invariant (LTI) mode. Useful for statistical simulations. The AMI_Init() function does modify the impulse response based on the LTI approximation of the TX model's equalization.

4. **Tstonefile**: On-die termination s-parameter file. This should not be modified by the user.

5. **Rx_R:** Monitor for port termination impedance. Debug only.

6. **Supporting_Files:** List of supporting files used by the model. This should not be modified by the user.

4 Transmitter Model Parameters

The DS100KRxxx transmitter model includes the following model-specific parameters:

1. **VOD_Level**: This parameter sets the driver output voltage setting. There are eight VOD settings as shown in the table below. Note that in non-limiting mode (Limit=0), the output peak-to-peak amplitude will depend on the input peak-to-peak amplitude, so the output amplitude may not match the values shown in this table. In limiting model (Limit=1) the output peak-to-peak amplitude is directly controllable with the VOD_Level setting.

Model VOD_Level setting	De-emphasis value
0	700 mVp-p
1	800 mVp-p
2	900 mVp-p
3	1000 mVp-p
4	1100 mVp-p
5	1200 mVp-p
6	1300 mVp-p
7	1400 mVp-p

2. **DE_Level**: This parameter sets the driver de-emphasis level setting. There are eight de-emphasis settings as shown in the table below.

Model DE_Level setting	De-emphasis value
0	0 dB
1	-1.5 dB
2	-3.5 dB
3	-5.0 dB
4	-6.0 dB
5	-8.0 dB
6	-9.0 dB
7	-12.0 dB

3. **LTI_mode**: This parameter determines whether the model's AMI_Init() function returns a modified impulse response (for LTI simulations) or an unmodified impulse response (for non-LTI simulations). Regardless, the model has

GetWave_Exists=True and therefore all behavior (LTI and non-LTI) will be represented in time domain simulations.

Note: Not all EDA tools support pure statistical simulations for Redrivers/Retimers. Nevertheless, LTI mode can still be used.

Model LTI_mode	Description
0	Non-linear-time-invariant (non-LTI) mode. Useful for pure time domain simulations. The AMI_Init() function does not modify the impulse response.
1 (default)	Linear time-invariant (LTI) mode. Useful for statistical simulations. The AMI_Init() function does modify the impulse response based on the LTI approximation of the TX model's equalization.

4. **Gain_debugonly**: This parameter takes on the value of 0.55 and should not be changed by the user. It is included for debug purposes only.
5. **Tstonefile**: On-die termination s-parameter file. This should not be modified by the user.
6. **Tx_R:** Monitor for on-die supply series resistance. Debug only.
7. **Supporting_Files:** List of supporting files used by the model. This should not be modified by the user.

5 Model Usage Tips

1. ***How to set the samples per UI in the simulator***. Samples per UI should be chosen such that the sample time (UI divided by samples per UI) should be less than 10E-12 for accurate results. Typical recommended values for different bit rates are as follows:

Bit rate	Recommended samples per UI setting
≥ 1 Gbps	≥ 128 samples per UI
≥ 4 Gbps	≥ 64 samples per UI
≥ 8 Gbps	≥ 32 samples per UI

2. ***Note on [Repeater Pin]***. The [Repeater Pin] key word in the IBIS file is used to define the Rx input pin and Tx output pin pairs which form repeaters. At the time this document was written, this was not yet part of the official IBIS standard and hence the IBIS parser throws an 'Invalid Keyword' error upon encountering the [Repeater Pin] keyword. Please ignore this error as the model runs fine in most EDA tools (SiSoft QCD and Agilent ADS to name a few). In fact, the [Repeater Pin] definition is necessary to simulate 'Repeater' models in SiSoft QCD. If the model needs to be run in other tools which do not support this keyword (like Mentor Graphics Hyperlynx), the [Repeater Pin] definition can be deleted without any change in the functionality of the model.

6 Model Verification

To verify the functionality and accuracy of the model, comparisons were made between IBIS-AMI model simulations and Cadence transistor-level simulations at different data rates and for different channel media.

6.1 Receiver test #1

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 10 meter, 30 AWG copper cable
DS100KRxxx EQ_Level: 10
DS100KRxxx Limit: 0
Measurement point: Receiver output

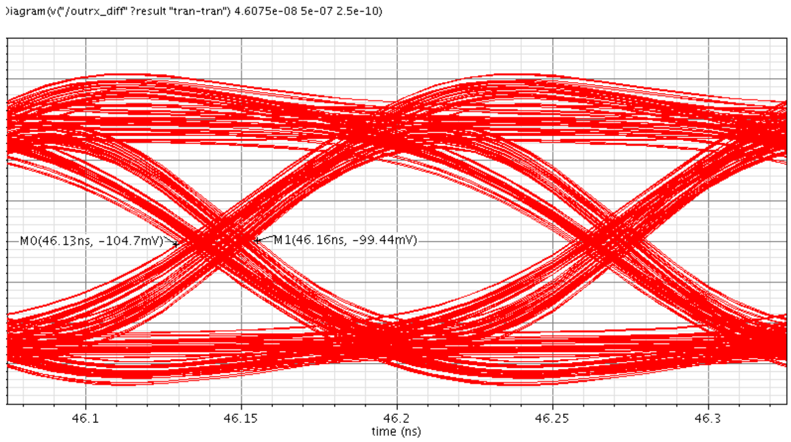
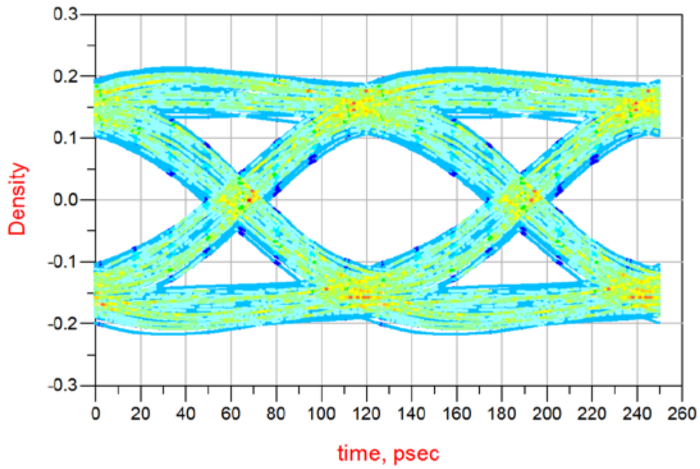


Figure 1: Cadence simulation (Jitter = 30 ps p-p)



measurement	Summary
Level1	0.150
Level0	-0.149
LevelMean	1.710E-4
Amplitude	0.299
Height	0.174
Width	9.625E-11
RiseTime	5.949E-11
FallTime	6.067E-11
JitterPP	2.875E-11
JitterRMS	7.109E-12
WidthAtBER	9.813E-11
HeightAtBER	0.214

Figure 2: IBIS-AMI simulation (Jitter = 29 ps p-p)

6.2 Receiver test #2

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 10 inches, 4 mil stripline
DS100KRxxx EQ_Level: 6*
DS100KRxxx Limit: 0
Measurement point: Receiver output
**This test case is to deliberately show over-equalization, hence the misshapen eye.*

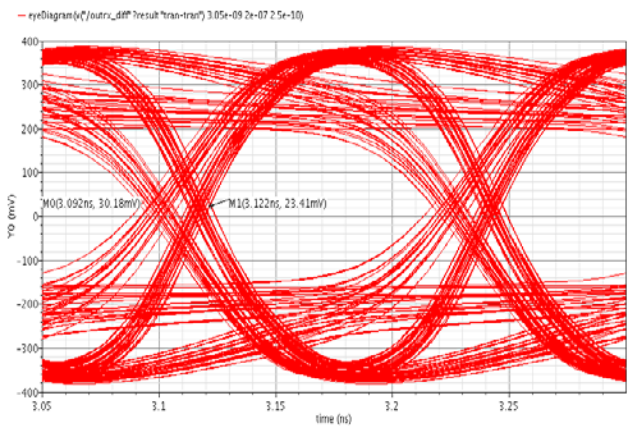
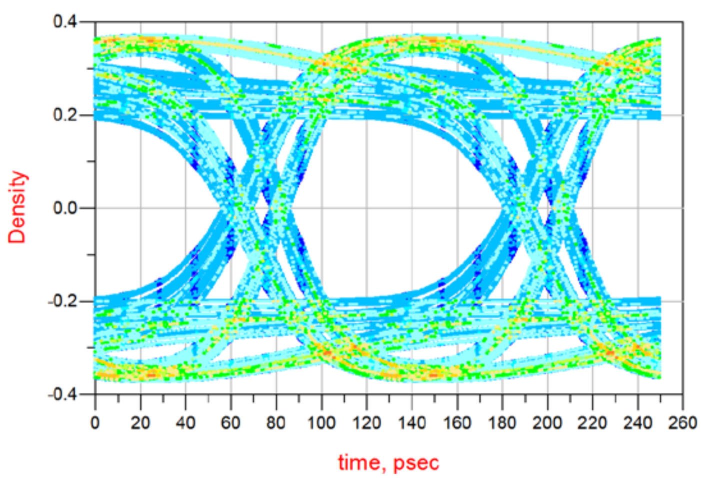


Figure 3: Cadence simulation (Jitter = 30 ps p-p)



measurement	Summary
Level1	0.300
Level0	-0.301
LevelMean	-3.958E-4
Amplitude	0.600
Height	0.347
Width	9.625E-11
RiseTime	4.745E-11
FallTime	5.028E-11
JitterPP	2.875E-11
JitterRMS	9.840E-12
WidthAtBER	9.500E-11
HeightAtBER	0.390

Figure 4: IBIS-AMI simulation (Jitter = 29 ps p-p)

6.3 Receiver test #3

Signal source: 10.3125 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 20 inches, 4 mil stripline
DS100KRxxx EQ_Level: 6
DS100KRxxx Limit: 0
Measurement point: Receiver output

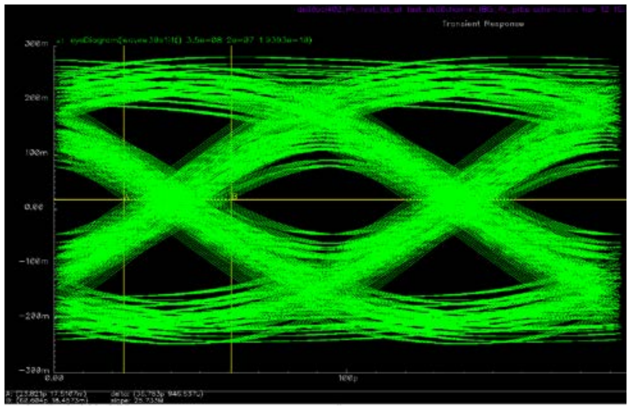
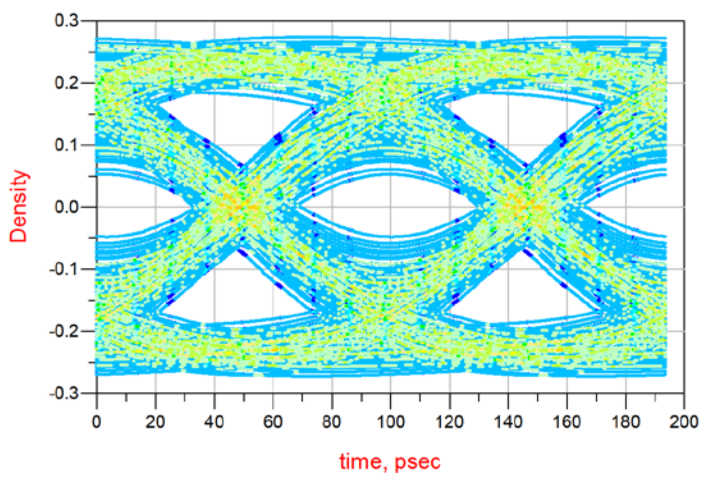


Figure 5: Cadence simulation (Jitter = 37 ps p-p)



measurement	Summary
Level1	0.173
Level0	-0.173
LevelMean	6.445E-5
Amplitude	0.345
Height	0.082
Width	6.061E-11
RiseTime	6.491E-11
FallTime	6.304E-11
JitterPP	3.636E-11
JitterRMS	7.848E-12
WidthAtBER	6.158E-11
HeightAtBER	0.099

Figure 6: IBIS-AMI simulation (Jitter = 36 ps p-p)

6.4 Transmitter test #1

Signal source: 8.0 Gbps, 0.6 V peak-to-peak differential, 0 dB de-emphasis
Channel: 15 inches, 4 mil stripline
DS100KRxxx DE_Level: 4
DS100KRxxx VOD_Level: 6
Measurement point: Far-end channel output

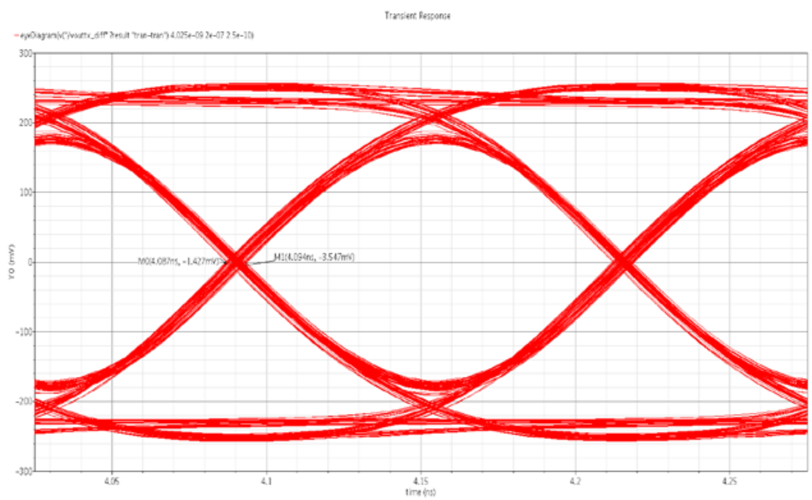
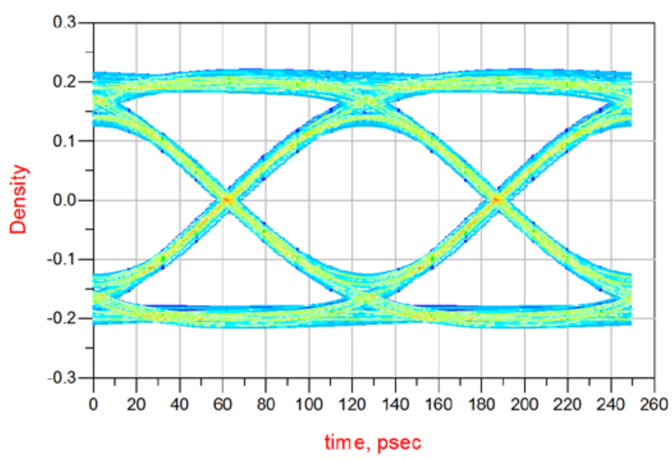


Figure 7: Cadence simulation (Jitter = 7 ps p-p)



measurement	Summary
Level1	0.166
Level0	-0.166
Amplitude	0.332
Height	0.234
HeightDB	-6.308
Width	1.144E-10
RiseTime	6.359E-11
FallTime	6.356E-11
JitterPP	1.054E-11
JitterRMS	2.108E-12
WidthAtBER	1.144E-10
HeightAtBER	0.250
CrossingLevel	0.000

Figure 8: IBIS-AMI simulation (Jitter = 10 ps p-p)

6.5 Full channel test #1

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
RX channel: 20 inches, 4 mil stripline
TX channel: 10 inches, 4 mil stripline
DS100KRxxx EQ_Level: 4
DS100KRxxx Limit: 0
DS100KRxxx DE_Level: 2
DS100KRxxx VOD_Level: 7
Measurement points: Receiver output and far-end channel output

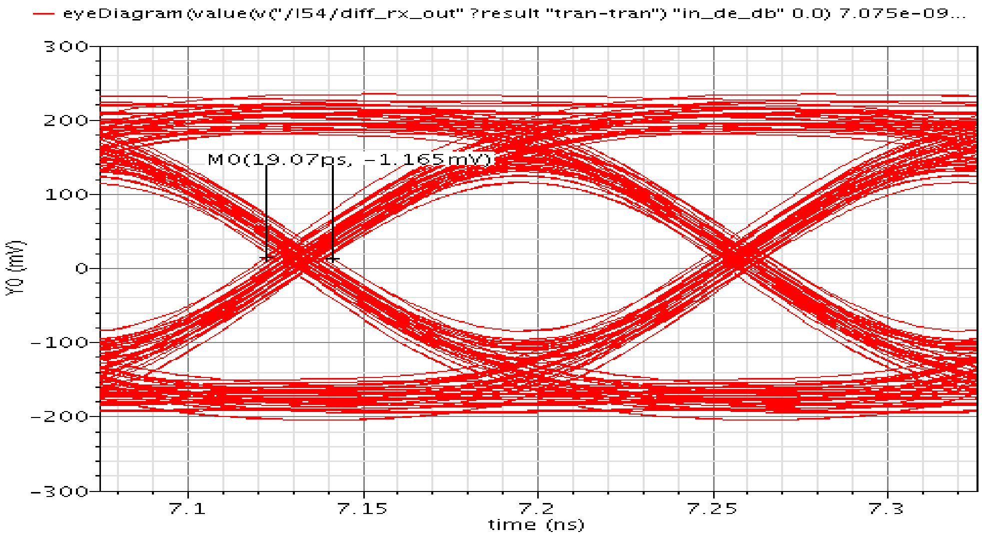


Figure 9: Cadence simulation, RX output (Jitter = 19 ps p-p)

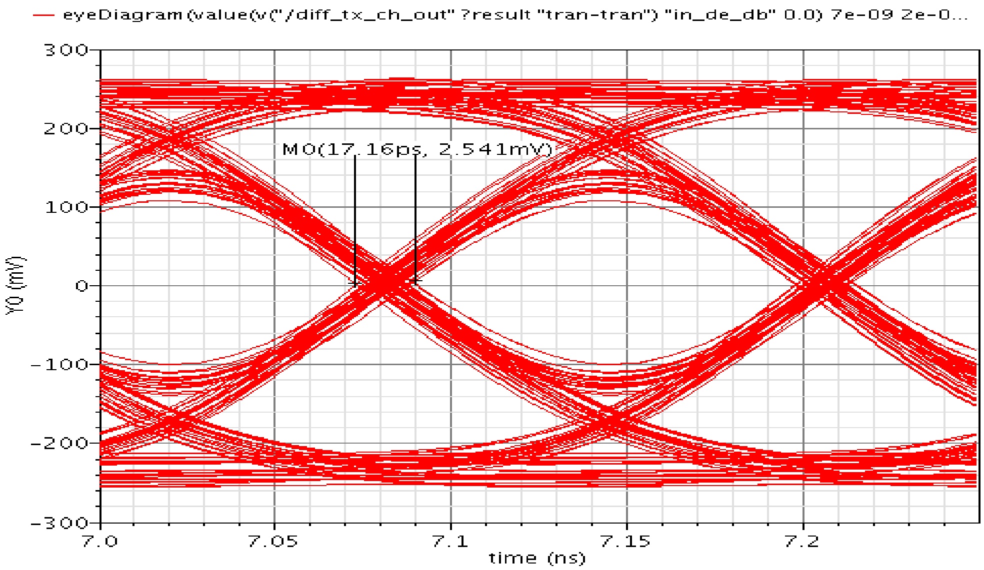
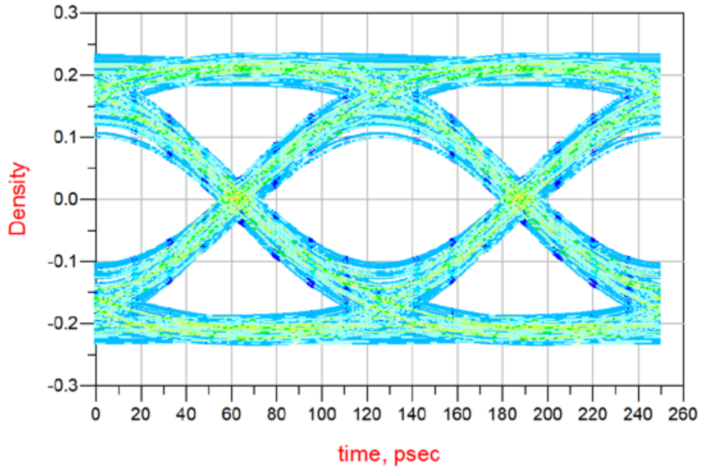
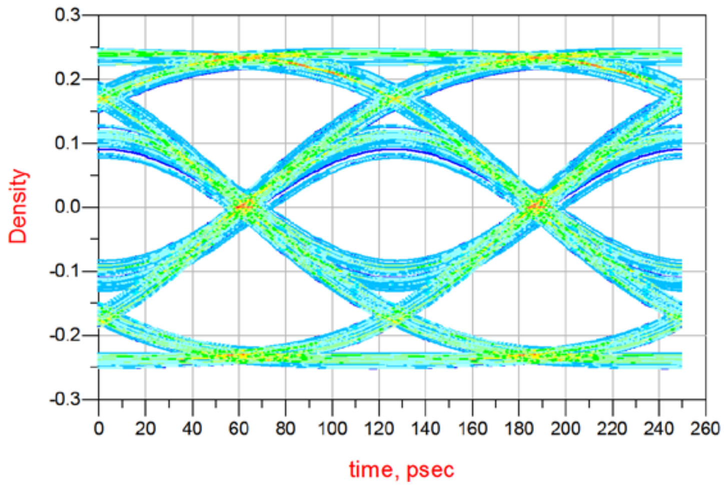


Figure 10: Cadence simulation, far-end channel output (Jitter = 17 ps p-p)



measurement	Summary
Level1	0.171
Level0	-0.171
LevelMean	1.023E-4
Amplitude	0.342
Height	0.187
Width	1.044E-10
RiseTime	7.287E-11
FallTime	7.068E-11
JitterPP	2.063E-11
JitterRMS	4.799E-12
WidthAtBER	1.063E-10
HeightAtBER	0.201

Figure 11: IBIS-AMI simulation, RX output (Jitter = 21 ps p-p)



measurement	Summary
Level1	0.171
Level0	-0.170
Amplitude	0.341
Height	0.146
HeightDB	-8.356
Width	1.044E-10
RiseTime	8.332E-11
FallTime	8.338E-11
JitterPP	2.063E-11
JitterRMS	4.160E-12
WidthAtBER	1.056E-10
HeightAtBER	0.160
CrossingLevel	0.000

Figure 12: IBIS-AMI simulation, far-end channel output (Jitter = 21 ps p-p)

6.6 Full channel test #2

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 9 dB de-emphasis*
RX channel: 20 inches, 4 mil stripline
TX channel: 10 inches, 4 mil stripline
DS100KRxxx EQ_Level: 4
DS100KRxxx Limit: 0
DS100KRxxx DE_Level: 2
DS100KRxxx VOD_Level: 7
Measurement points: Receiver output and far-end channel output
This test case is deliberately over-equalized to show how source de-emphasis passes through the repeater.

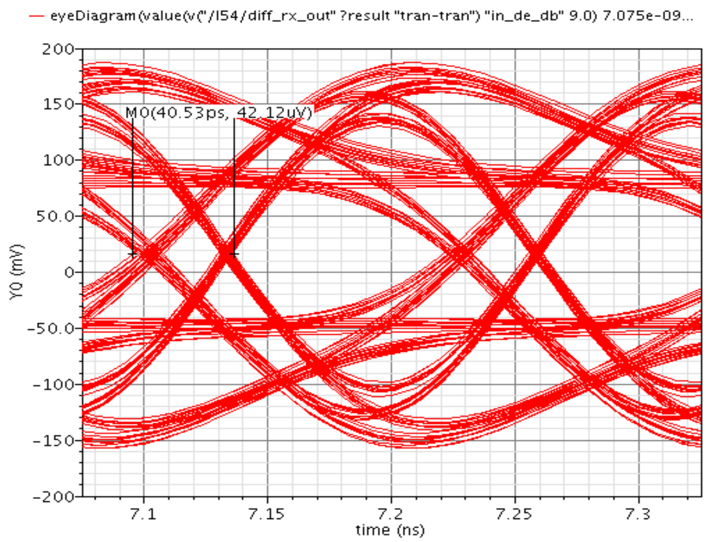


Figure 13: Cadence simulation, RX output (Jitter = 41 ps p-p)

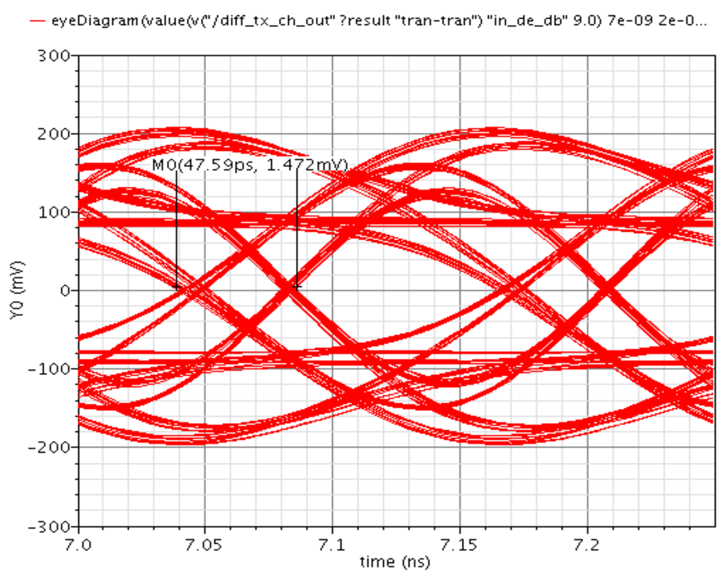
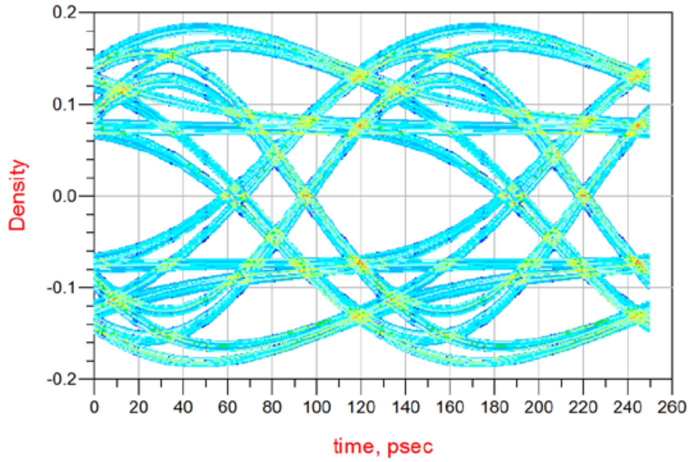
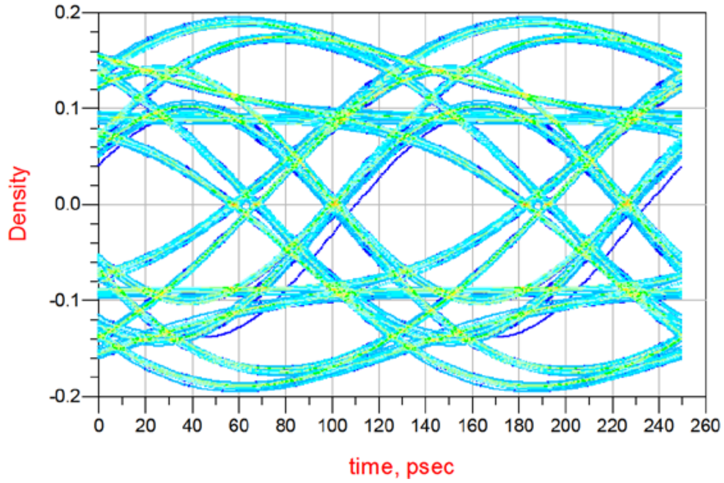


Figure 14: Cadence simulation, far-end channel output (Jitter = 48 ps p-p)



measurement	Summary
Level1	0.114
Level0	-0.114
LevelMean	-1.298E-4
Amplitude	0.228
Height	0.056
Width	8.188E-11
RiseTime	5.164E-11
FallTime	6.587E-11
JitterPP	4.313E-11
JitterRMS	1.664E-11
WidthAtBER	8.188E-11
HeightAtBER	0.127

Figure 15: IBIS-AMI simulation, RX output (Jitter = 43 ps p-p)



measurement	Summary
Level1	0.112
Level0	-0.112
Amplitude	0.224
Height	0.082
HeightDB	-10.862
Width	7.063E-11
RiseTime	6.753E-11
FallTime	6.763E-11
JitterPP	5.438E-11
JitterRMS	1.970E-11
WidthAtBER	7.250E-11
HeightAtBER	0.123
CrossingLevel	-0.005

Figure 16: IBIS-AMI simulation, far-end channel output (Jitter = 54 ps p-p)

6.7 Statistical versus Time Domain: RX test

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 20 inches, 4 mil stripline
DS100KRxxx EQ_Level: 8
DS100KRxxx Limit: 0
Measurement point: Receiver output

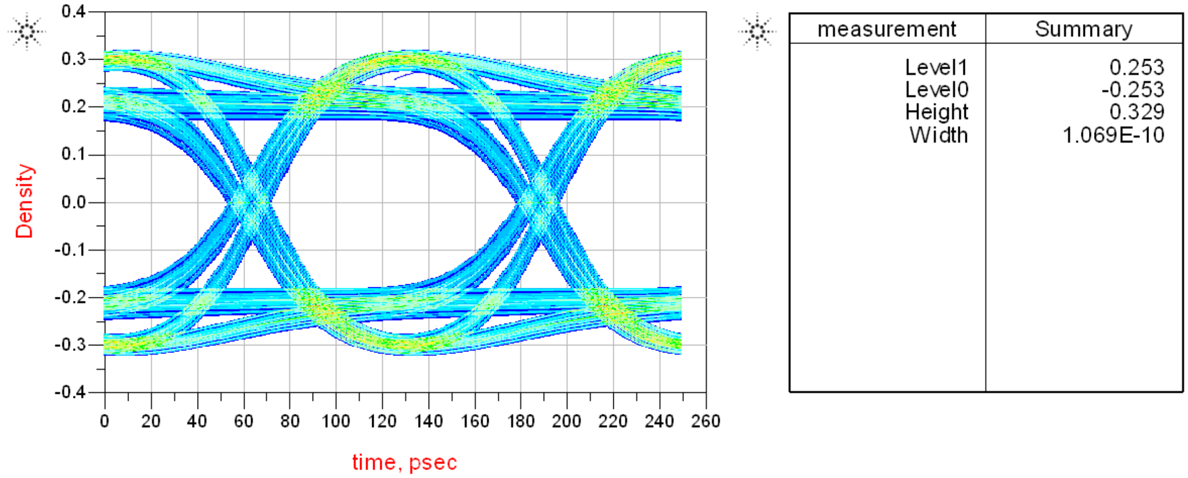


Figure 17: Time domain (bit-by-bit) simulation result

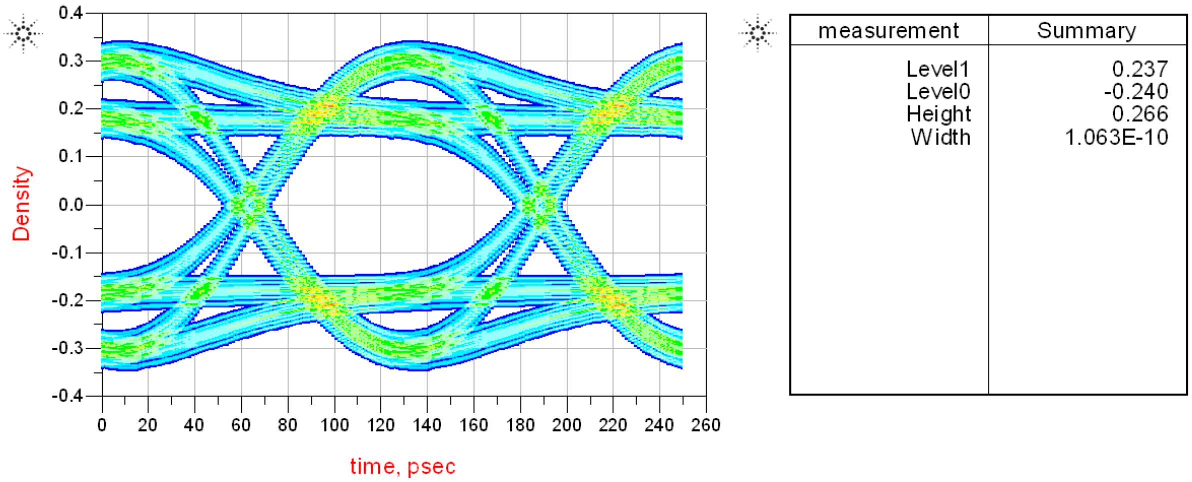


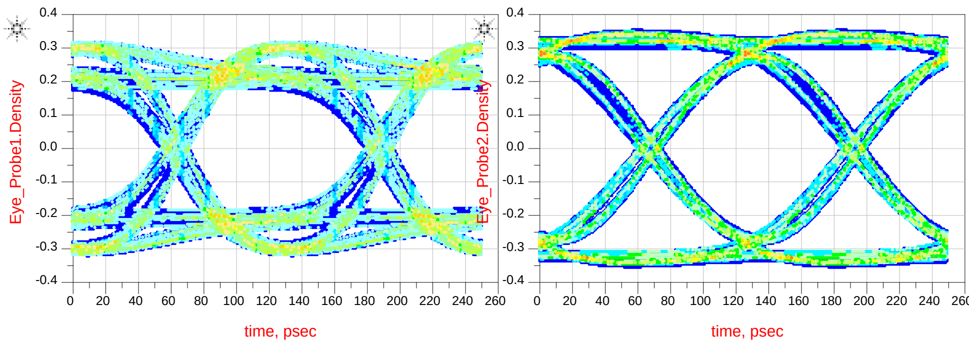
Figure 18: Statistical simulation result

6.8 Statistical versus Time Domain: Full Link test

Note: Some tools do not support pure statistical simulations for Redrivers/Retimers, so the results shown below are for two time domain simulations, one executed with init-only processing (i.e. GetWave_Exists=False), and one executed with GetWave-only processing (i.e. LTI_mode=0).

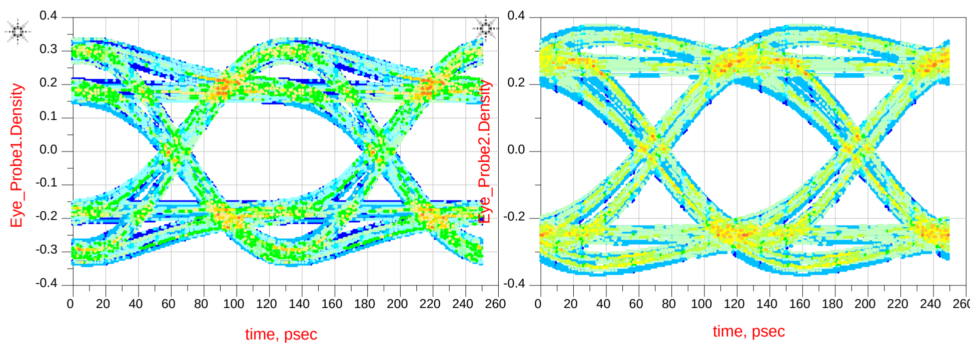
Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
RX Channel: 20 inches, 4 mil stripline
DS100KRxxx RX EQ_Level: 8
DS100KRxxx RX Limit: 0
TX Channel: 10 inches, 4 mil stripline
DS100KRxxx RX DE_Level: 1

Measurement points: Redriver RX and TX outputs



measurement	Eye_Probe1.Summary	Eye_Probe2.Summary
Level1 Level0 Height Width	0.253 -0.254 0.335 1.094E-10	0.289 -0.289 0.446 1.106E-10

Figure 19: Time domain simulation result; GetWave_Exists=True, LTI_mode=0



measurement	Eye_Probe1.Summary	Eye_Probe2.Summary
Level1 Level0 Height Width	0.238 -0.239 0.275 1.088E-10	0.262 -0.263 0.334 1.056E-10

Figure 20: Time domain simulation result; GetWave_Exists=False, LTI_mode=1