User's Guide
Linear EQ 12G IBIS-AMI Model

Version 4
April 2024

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1 Document Revision History

Revision	Comment	Date
1	Initial creation of User's Guide.	
2	Updated correlation data	12-Sept-2014
3	Added description information for S parameter files	9-Oct-2015
4	Updated for public release.	29-April-2024

2 Overview

This document is a User's Guide for the Linear EQ 12G IBIS-AMI model, which covers multiple TI products spanning multiple max data rates. Table 1 below lists pertinent information related to the model.

Table 1: Model information

Item	Value/Comment
TI devices included in this model	The Linear EQ 12G model can be used to evaluate the performance of the following TI devices: • DS80PCI810 Linear Repeater • DS125BR401A Linear Repeater (A-side channels only) • DS125BR820 Linear Repeater • DS125BR111 Linear Repeater
IBIS version	Compliant to IBIS version 5.1.
Supported platforms	• 32-bit Windows • 64-bit Windows • 64-bit Linux
Release package files	TI_Linear_EQ_12G_IBIS_AMI_v2 | +-- Example_Projects | | | +-- TI_Linear_EQ_12G_ADS_Project_Quick_Guide.pdf | +-- Agilent_ADS_2013.06.7zads | +-- Model | +-- TI_Linear_EQ_12G_IBIS_AMI_User_Guide.pdf +-- Linear_EQ_12G.ibs +-- Linear_EQ_12G_tx.ami +-- Linear_EQ_12G_rx.ami +-- Linear_EQ_12G_tx.dll +-- Linear_EQ_12G_rx.dll +-- Linear_EQ_12G_tx_x64.dll +-- Linear_EQ_12G_rx_x64.dll +-- Linear_EQ_12G_tx_x64.so +-- Linear_EQ_12G_rx_x64.so +-- WQFN54_rx.s4p(1->3,2->4) +-- WQFN54_tx.s4p(1->3,2->4) +-- WQFN24_rx.s4p(1->2,3->4) +-- WQFN24_tx.s4p(1->2,3->4) +-- rxterm.s4p(1->3,2->4) +-- txterm.s4p(1->3,2->4) ***The WQFN54_*.s4p package models are applicable to the DS80PCI810, DS125BR401A, and DS125BR820.***

	The WQFN24_*.s4p package models are applicable to the DS125BR111.

3 Receiver Model Parameters

The Linear_EQ_12G receiver model includes the following model-specific parameters:

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

Model BST setting
0
1
2
3

EQUALIZATION BOOST RELATIVE TO DC							
Level	EQA EQB	EQ – 8 bits [7:0]	dB at 1.5 GHz	dB at 2.5 GHz	dB at 4 GHz	dB at 5 GHz	dB at 6 GHz
1	0	xxxx xx00 = 0x00	2.1	2.5	2.7	2.9	3.0
2	R	xxxx xx01 = 0x01	4.0	5.1	6.4	6.8	7.4
3	F	xxxx xx10 = 0x02	5.5	7.0	8.3	8.6	8.9
4	1	xxxx xx11 = 0x03	6.8	8.3	9.5	9.6	9.8

(1) Optimal EQ setting should be determined via simulation and prototype verification.
(2) Equalization boost values are inclusive of package loss.

2. **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 Transmitter Model Parameters

The Linear_EQ_12G transmitter model includes the following model-specific parameters:

1. **VOD**: This parameter sets the driver output voltage setting. There are eight VOD settings as shown in the table below. ***Note that the exact output peak-to-peak amplitude will depend on the input peak-to-peak amplitude***.

Model VOD setting
0
1
2
3
4
5
6
7

Level	VODA1 VODB1	VODA0 VODB0	VOD - 3 bits [2:0]	VOD_DB - 3 bits [2:0]	VID Vp-p	VOD/VID Ratio (1)
--	--	--	000'b	000'b	1.2	0.57 (2)
1	0	0	001'b	000'b	1.2	0.65
2	0	R	010'b	000'b	1.2	0.71
3	0	1	011'b	000'b	1.2	0.77
4	R	F	100'b	000'b	1.2	0.83
5	F	R	101'b	000'b	1.2	0.90
6	1	0	110'b	000'b	1.2	1.00
--	--	--	111'b	000'b	1.2	1.04 (2)(3)

(1) For 40G-CR4/KR4/SAS/SATA/PCIe operation, it is important to keep the output amplitude and dynamic range as large as possible. When operating in Pin Mode, it is recommended to use VODA[1:0] = VODB[1:0] = Level 6. In SMBus Mode, it is also recommended to use Level 6 (that is, VOD = 110'b and VOD_DB = 000'b).
(2) These VOD settings are only accessible via SMBus modes.
(3) VOD = 111'b setting in SMBus mode is not recommended.

2. **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.

5 Tstonefiles

1. **txterm.s4p, rxterm.s4p:** These files represent the transmitter termination and receiver termination. Port sequence is 1→3; 2→4

2. **WQFN54_tx.s4p:** This is the TX package S parameter file for DS80PCI810, DS125BR401A, and DS125BR820.
   Port sequence is 1→3; 2→4
   Insertion loss is around 0.11dB@4GHz

3. **WQFN54_rx.s4p:** This is the RX package S parameter file for DS80PCI810, DS125BR401A, and DS125BR820.
   Port sequence is 1→3; 2→4
   Insertion loss is around 0.11dB@4GHz

4. **WQFN24_tx.s4p:** This is the TX package S parameter file for DS125BR111.
   Port sequence is 1→2; 3→4
   Insertion loss is around 0.06dB@4GHz

5. **WQFN24_rx.s4p:** This is the RX package S parameter file for DS125BR111.
   Port sequence is 1→2; 3→4
   Insertion loss is around 0.04dB@4GHz

6 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 Quantum Channel Designer 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.

7 Model Verification

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

7.1 8Gbps Receiver test #1

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 5 inches 5 mil FR4 trace
Linear_EQ_12G BST=1
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

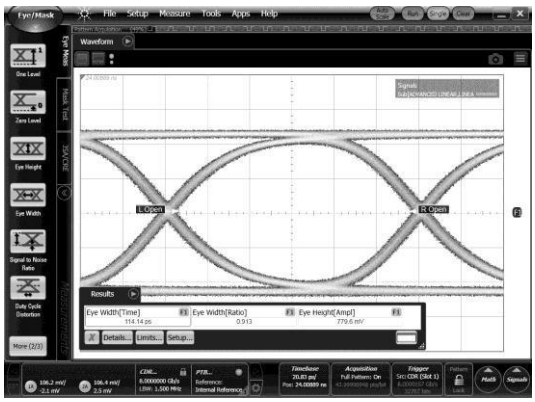
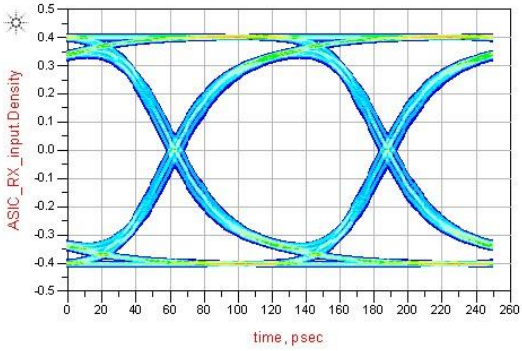


Figure 1: Measurement (TJ(1E-12) =13.6ps, Eye height=779mV)



measurement	...RX_input.Summary
Level1	0.369
Level0	-0.368
Height	0.592
Width	1.162E-10
WidthAtBER	1.150E-10
HeightAtBER	0.653

Figure 2: IBIS-AMI simulation (TJ(1E-12)=10ps, Eye height=653mV)

7.2 8Gbps Receiver test #2

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 10 inches 5 mil FR4 trace
Linear_EQ_12G BST=2
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

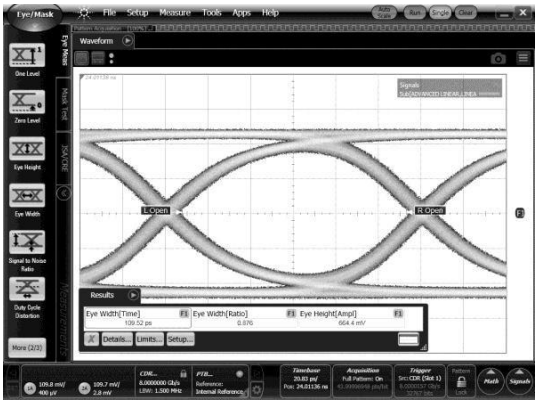
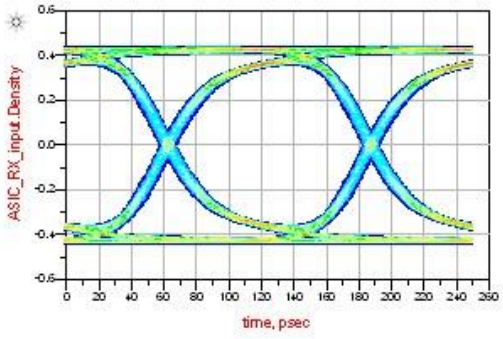


Figure 3: Measurement (TJ(1E-12) =18.1ps, Eye height=664mV)



measurement	...RX_input.Summary
Level1	0.393
Level0	-0.392
Height	0.656
Width	1.163E-10
WidthAtBER	1.150E-10
HeightAtBER	0.711

Figure 4: IBIS-AMI simulation ((TJ(1E-12) =10ps, Eye height=711mV)

7.3 8Gbps Receiver test #3

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 20 inches 5 mil FR4 trace
Linear_EQ_12G BST=3
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

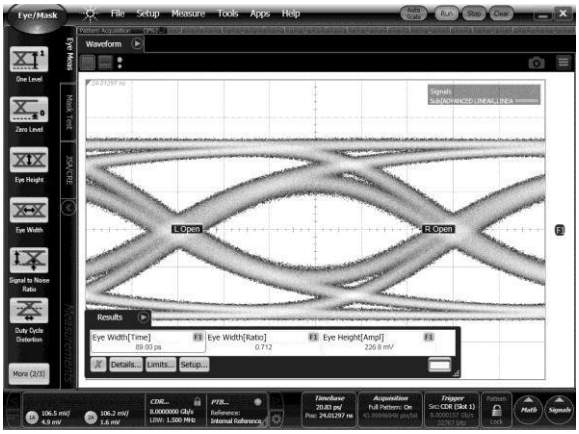
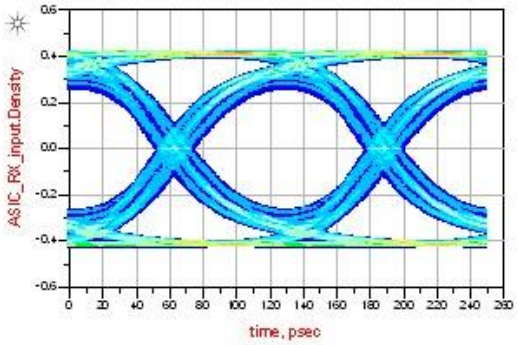


Figure 5: Measurement (TJ(1E-12) =35.5ps, Eye height=226mV)



measurement	...RX_input.Summary
Level1	0.362
Level0	-0.361
Height	0.473
Width	1.044E-10
WidthAtBER	1.031E-10
HeightAtBER	0.520

Figure 6: IBIS-AMI simulation ((TJ(1E-12) =22ps, Eye height=520mV)

7.4 10.3125Gbps Receiver test #4

Signal source: 10.3125 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 5 inches 5 mil FR4 trace
Linear_EQ_12G BST=1
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

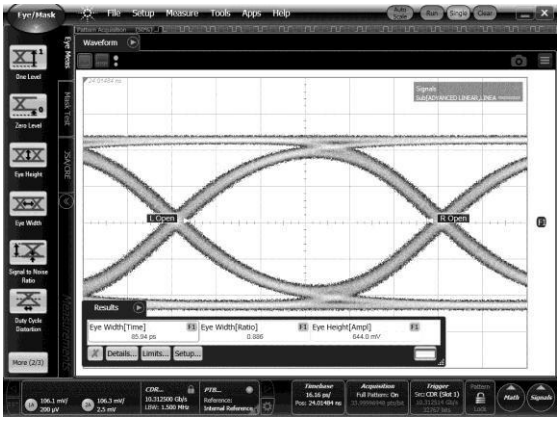
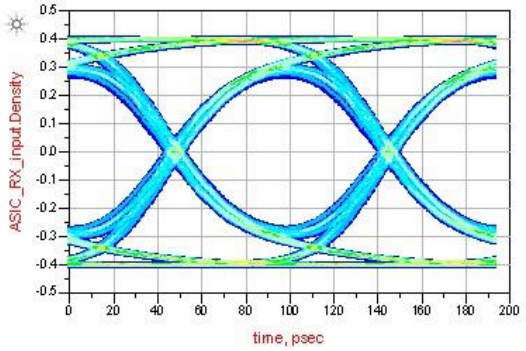


Figure 7: Measurement (TJ(1E-12) =14ps, Eye height=644mV)



measurement	...RX_input.Summary
Level1	0.344
Level0	-0.342
Height	0.492
Width	8.727E-11
WidthAtBER	8.679E-11
HeightAtBER	0.525

Figure 8: IBIS-AMI simulation ((TJ(1E-12) =10ps, Eye height=525mV)

7.5 10.3125Gbps Receiver test #5

Signal source: 10.3125 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 10 inches 5 mil FR4 trace
Linear_EQ_12G BST=2
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

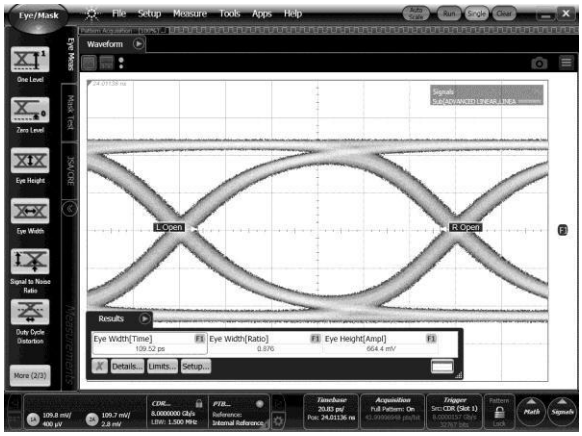
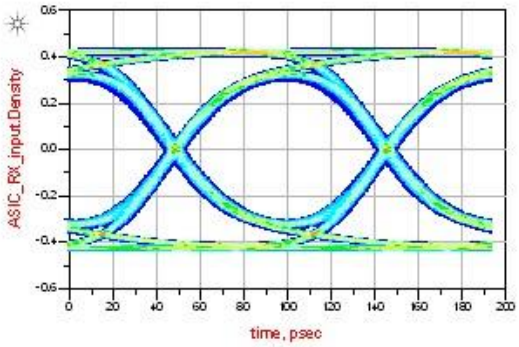


Figure 9: Measurement (TJ(1E-12) =18.7ps, Eye height=664mV)



measurement	...RX_input.Summary
Level1	0.371
Level0	-0.370
Height	0.560
Width	8.824E-11
WidthAtBER	8.824E-11
HeightAtBER	0.599

Figure 10: IBIS-AMI simulation ((TJ(1E-12) =8.8ps, Eye height=599mV)

7.6 10.3125Gbps Receiver test #6

Signal source: 10.3125 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 20 inches 5 mil FR4 trace
Linear_EQ_12G BST=3
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

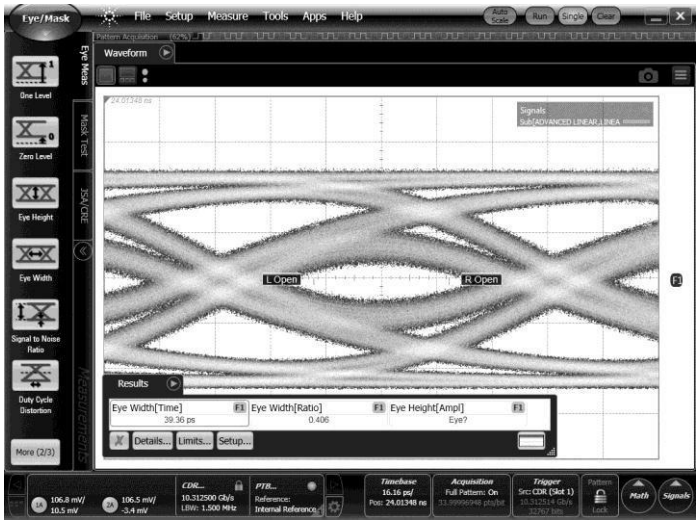


Figure 11: Measurement (TJ(1E-12) =49.1ps)

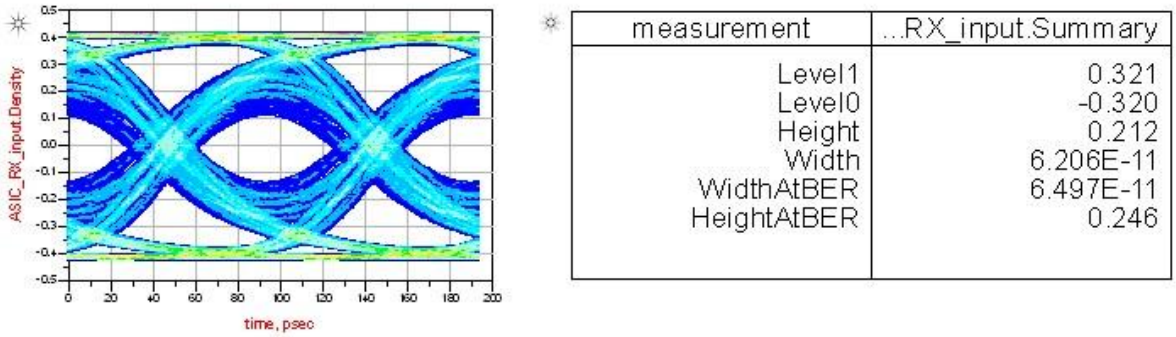


Figure 12: IBIS-AMI simulation ((TJ(1E-12) =32ps, Eye height=246mV)

7.7 12Gbps Receiver test #7

Signal source: 12 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 5 inches 5 mil FR4 trace
Linear_EQ_12G BST=1
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

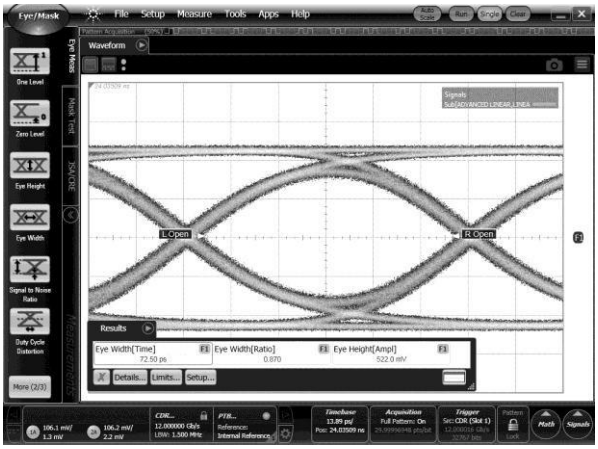
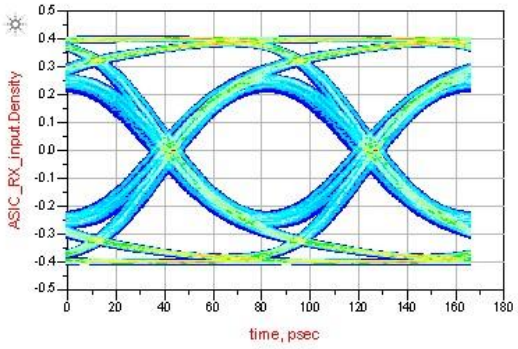


Figure 13: Measurement (TJ(1E-12) =13.1ps, Eye height=522mV)



measurement	...RX_input.Summary
Level1	0.325
Level0	-0.324
Height	0.398
Width	7.042E-11
WidthAtBER	7.000E-11
HeightAtBER	0.428

Figure 14: IBIS-AMI simulation ((TJ(1E-12) =13ps, Eye height=428mV)

7.8 12Gbps Receiver test #8

Signal source: 12 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
Channel: 10 inches 5 mil FR4 trace
Linear_EQ_12G BST=2
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6

Measurement point: Receiver output

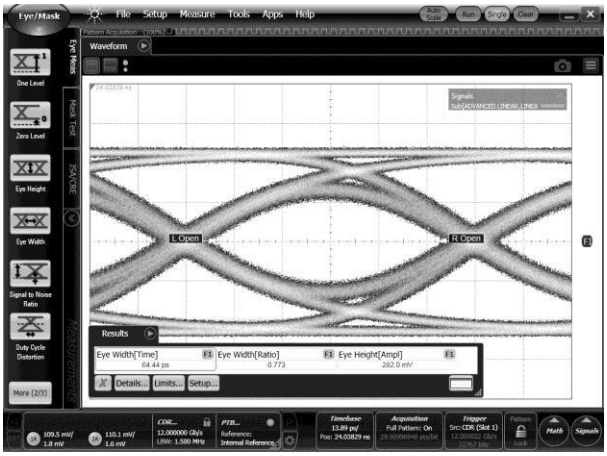
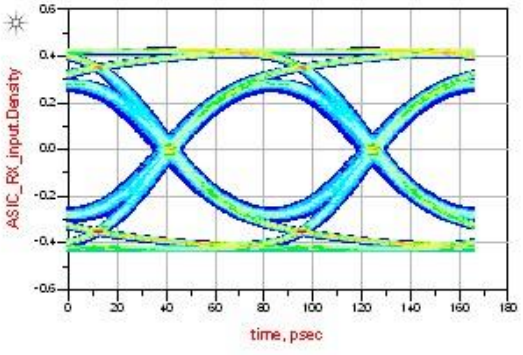


Figure 15: Measurement (TJ(1E-12) =20.1ps, Eye height=282mV)



measurement	...RX_input.Summary
Level1	0.354
Level0	-0.352
Height	0.466
Width	7.292E-11
WidthAtBER	7.250E-11
HeightAtBER	0.496

Figure 16: IBIS-AMI simulation ((TJ(1E-12) =10.5ps, Eye height=496mV)

7.9 8Gbps Full Link test

Signal source: 8.0 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
RX Channel: 15 inches, 5 mil FR4 trace
Linear_EQ_12G BST=3
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6
TX Channel: 10 inches, 5 mil FR4 trace
Measurement points: At the end of 10 inches FR4

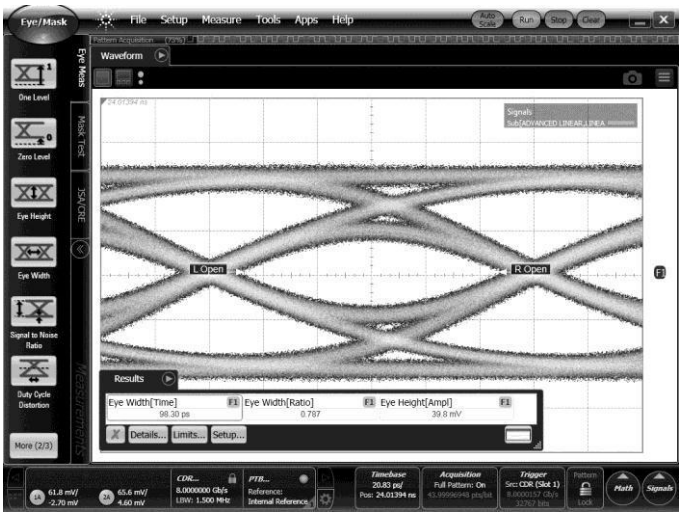


Figure 17: Measurement (TJ(1E-12) =33ps)

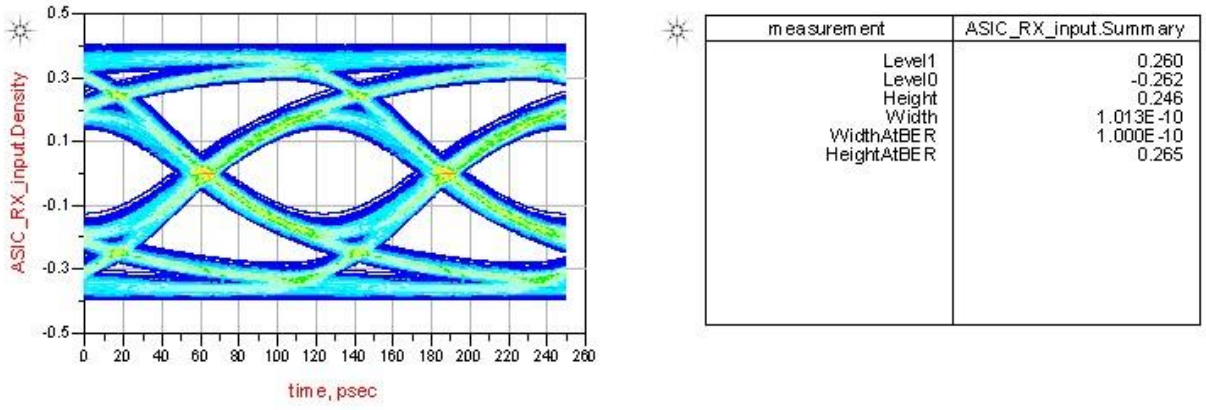


Figure 18: IBIS-AMI simulation ((TJ(1E-12) =25ps, Eye height=265mV)

7.10 10.3125Gbps Full Link test

Signal source: 10.3125 Gbps, 1 V peak-to-peak differential, 0 dB de-emphasis
RX Channel: 15 inches, 5 mil FR4 trace
Linear_EQ_12G BST=3
Linear_EQ_12G LTI_mode=1
Linear_EQ_12G VOD=6
TX Channel: 10 inches, 5 mil FR4 trace

Measurement points: At the end of 10 inches FR4

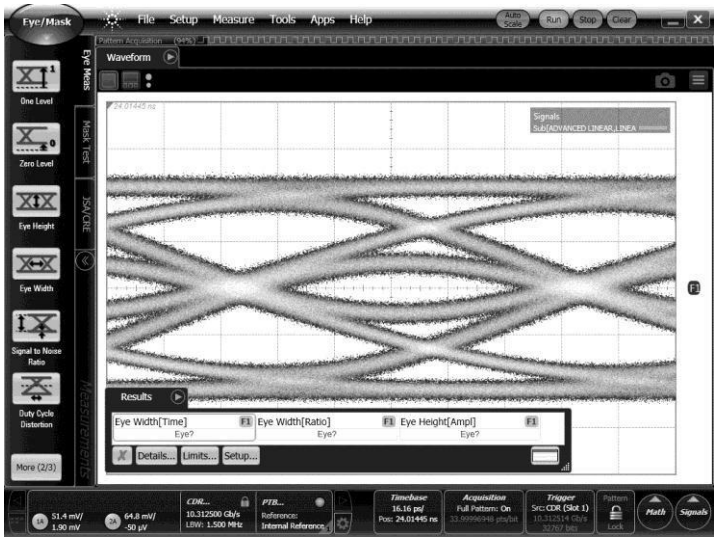


Figure 19: Measurement (TJ(1E-12) =47.9ps)

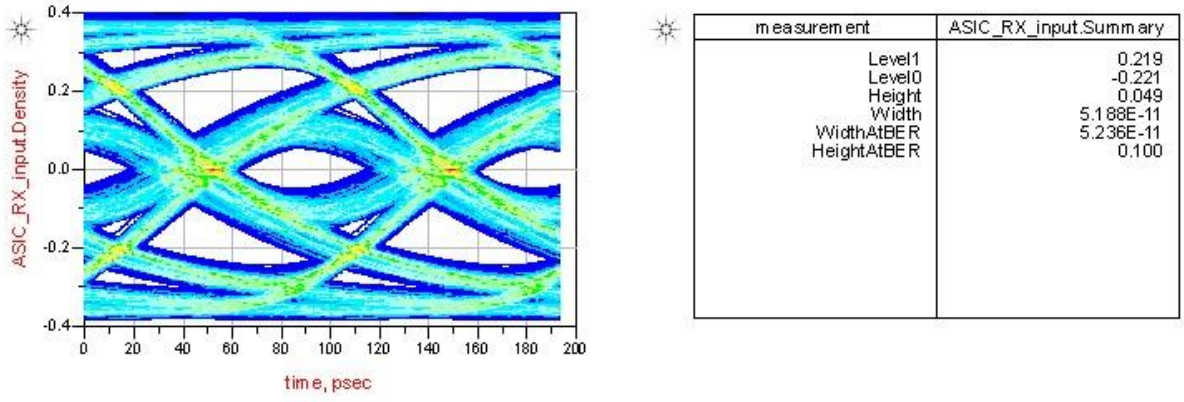


Figure 20: IBIS-AMI simulation ((TJ(1E-12) =44.7ps, Eye height=100mV)