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Bridging the gap: correlating IBIS-AMI simulations with post-silicon measurements for a 6.25 Gbps transmitter

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Agenda

Introduction

Full Custom PHY Interface IPs

- An Integral part of modern applications
- **PHY IP design challenges**
  - Stringent electrical specification
  - Non-standard & custom test compliances
  - Complete system performance analysis
- **System level design challenges**
  - Cost vs Performance
    - Tune the package and PCB
  - IP sourcing from multiple suppliers
    - Integration
    - CAD Models compatibility
  - Time to market
    - Pre-silicon design correlation

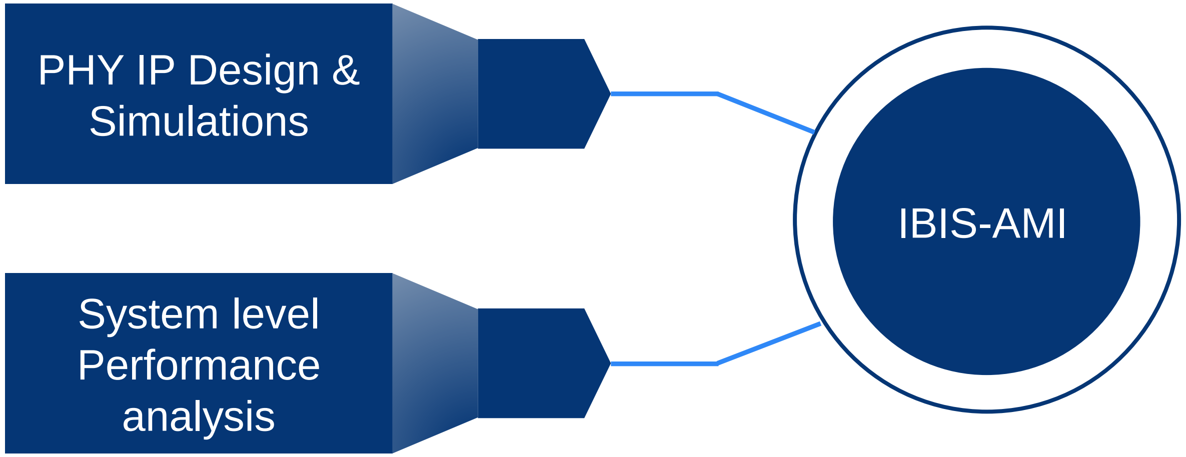
Spice: More accurate **but** non-universal & practically impossible to perform the giga-bit channel simulation

Simplified: Ideal & Simple model (source & impedances) **but** very less accurate

IBIS: Universal, Fast, Protects proprietary **but** not accurate for higher data rate

IBIS-AMI: All IBIS advantages, **also** well able to capture the complex high-speed serial interfaces.

Model scope

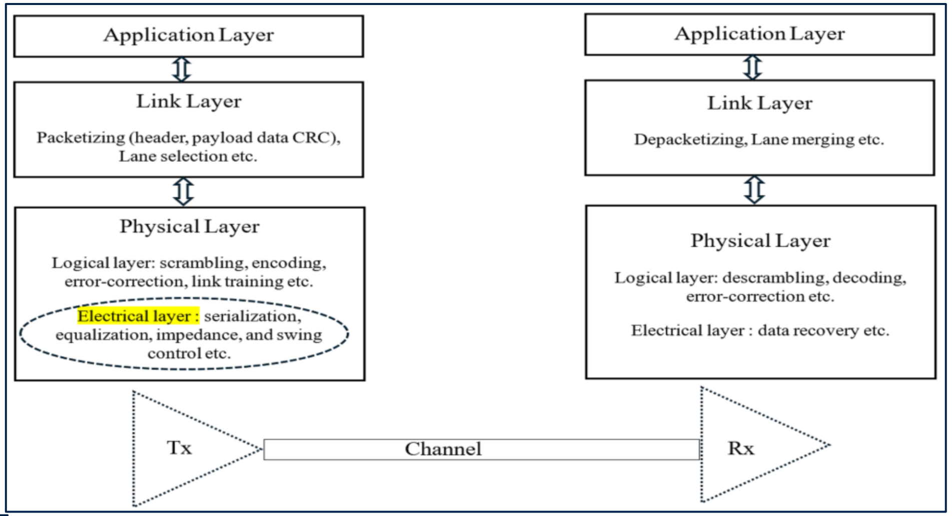


Solution: robust, accurate, universal & **qualified** CAD model

Design & IBIS-AMI model brief

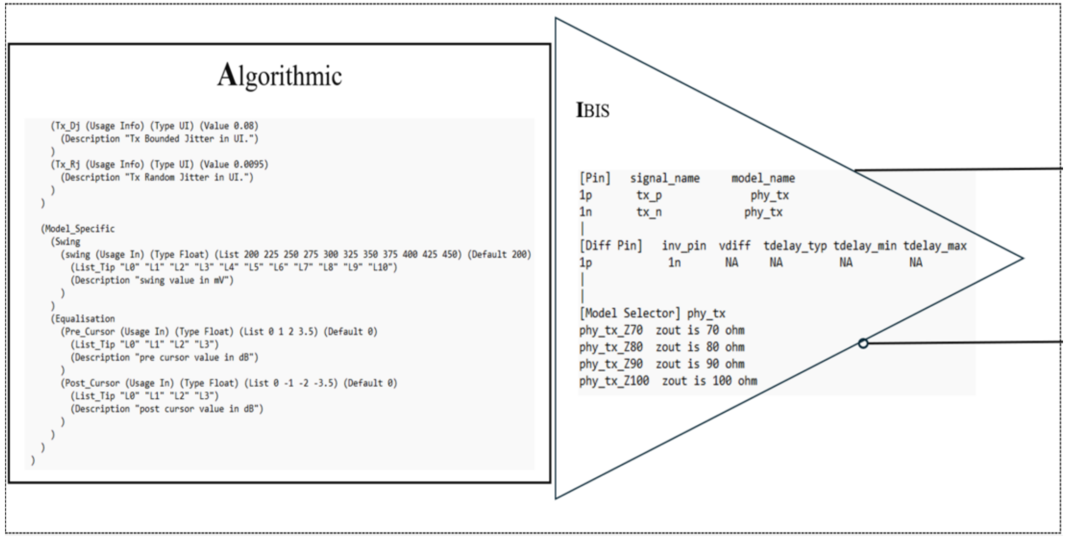
Design

- PHY transmitter
  - Supports data rates up to 6.25 Gbps
  - 11 levels of swing from 200 mV to 450 mV
  - 4 level of Pre-cursor and Post-cursor
  - 4 level of output impedance



IBIS-AMI model

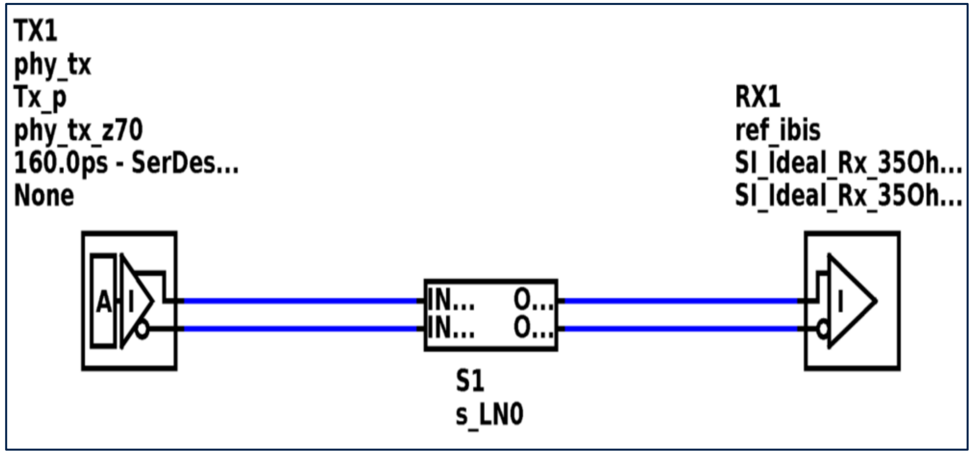
- Model specific parameter
  - Swing: to select Tx output swing
  - Pre_Cursor: to select pre-cursor gain level
  - Post_Cursor: to select post-cursor gain level
- IBIS model of PHY Tx



IBIS-AMI simulations 1/2

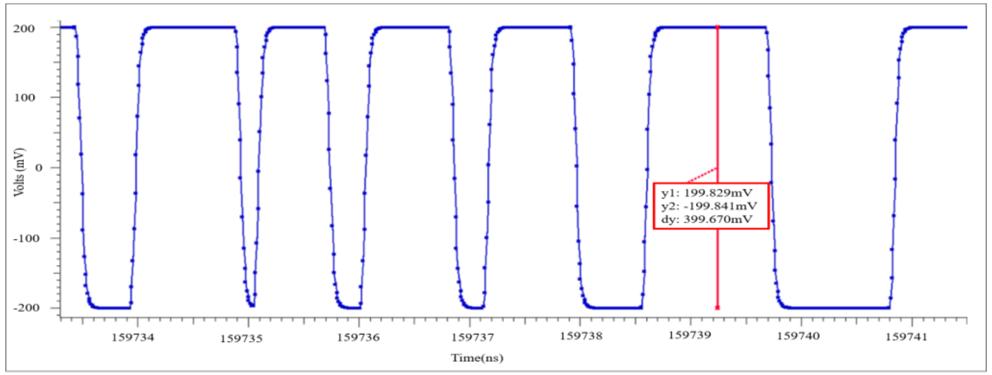
Simulation setup

- PVT: TYP, 1.0V, 27C
- Model
  - Tx: IBIS-AMI model
  - Channel: Actual s4p
  - Rx: IBIS Model



Swing extraction

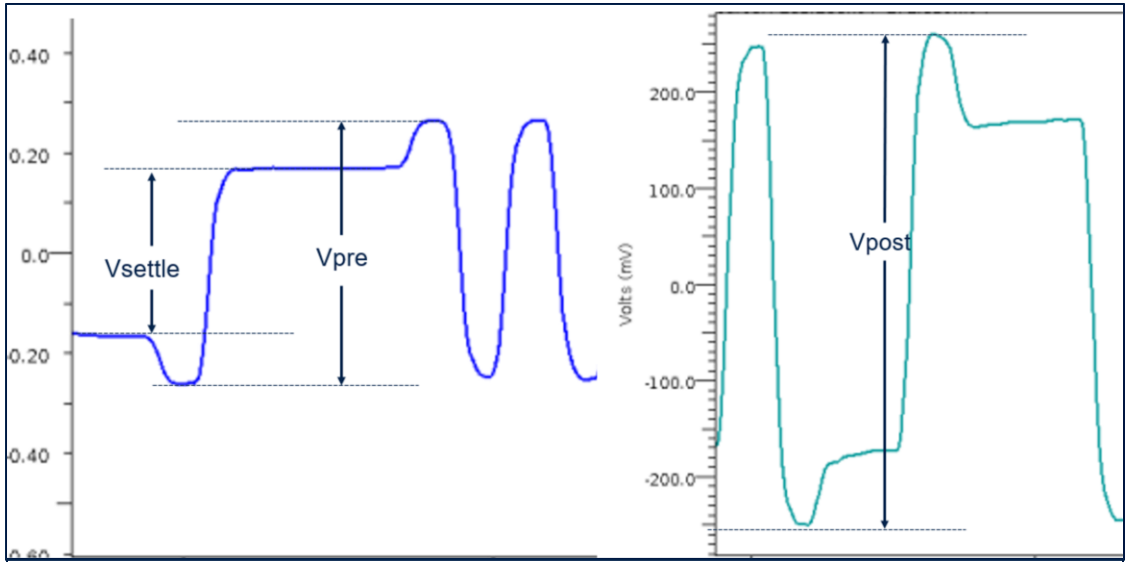
- Bit stream
  - Alternating pattern of 64 1’s & 0’s with 160ps UI
- AMI parameter
  - Swing = L0 & L10 (200 mV & 450 mV)
  - Pre_Curosr = L0   (0 dB)
  - Post_Cursor = L0 (0 dB)
- IBIS model: phy_tx_z70 & phy_tx_z90
- Channel simulations: 4 run



IBIS-AMI Simulations 2/2

Pre & post cursor gain extraction

- Bit stream
  - Alternating pattern of 64 1's and 0's each with 160ps
- AMI Parameter
  - Swing = L0 & L10 (200 mV & 450 mV)
  - Pre_Cursor = L1, L2, L3 (1 dB, 2 dB, 3.5 dB)
  - Post_Cursor = L1, L2, L3 (-1 dB, -2 dB, -3.5 dB)
- IBIS Model selector
  - phy_tx_z70 & phy_tx_z90
- Channel simulations : 24 run



$$\text{post cursor gain} = 20\log\left(\frac{Vsettle}{Vpost}\right)$$

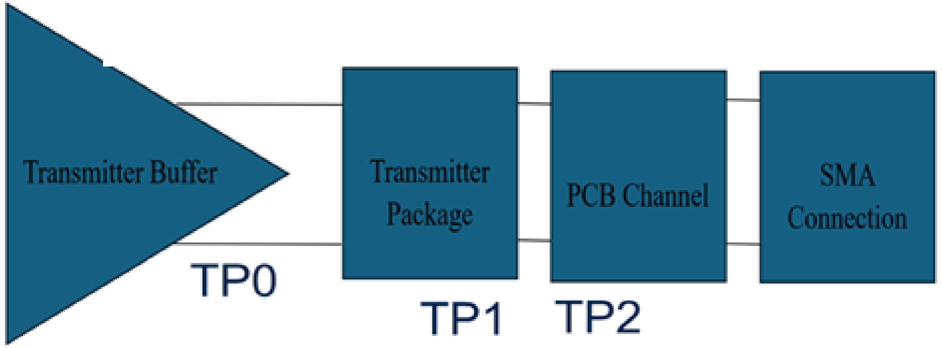
$$\text{pre cursor gain} = 20\log\left(\frac{Vpre}{Vsettle}\right)$$

Vsettle: This is measured by keeping the pre-cursor and post-cursor gain is equal to zero
Vpre: This is defined as the average voltages over bits 57 to 62 by keeping the postcursor gain equal to zero
Vpost: This is defined as the average voltages over bits 57 to 62 by keeping the precursor gain equal to zero

Silicon measurements 1/2

Measurement setup & criteria

- All electrical measurements need to done for Tx at die (TP0)
- Direct probing at Tx pin (TP1) is not possible
- Measurements done at channel breakout (TP2)
  - It includes the losses of fixture (Package, Socket & PCB)
- De-embedding Methodology
  - Fixture effect removed
- Tools
  - Keysight
    - Oscilloscope, Digital Power Supplies, Arbitrary Waveform Generator, VNA, Matched Pair SMA Cable
  - Tektronix
    - TDR
  - Agilent
    - Digital Multimeter



Silicon Measurements 2/2

Post cursor measurement

- **Step1: Configure DUT**
  - Swing with no deemphasis (Pre=0 dB Post=0dB)
  - Alternating 64 1's and 64 0's are transmitted
  - Measure $V_b = (V_H - V_L)$
    - V_H = Histogram Mean of [57UI to 62UI]
    - V_L = Histogram Mean of [121UI to 126UI]
- **Step2: Enable post cursor only**
  - (Pre=0dB)
  - Alternating 64 1's and 64 0's are transmitted
  - Measure Va = $(V_H - V_L)$
    - V_H = Histogram Mean of [57UI to 62UI] ;
    - V_L = Histogram Mean of [121UI to 126UI]
- **Step3: Gain Calculation**

$$\text{post cursor gain} = 20\log\left(\frac{V_b}{V_a}\right)$$

- **Pre- cursor measurement**
  - Enable pre cursor only (Post=0dB)
    - Alternating 64 1's and 64 0's are transmitted
    - Measure $V_c = (V_H - V_L)$
      - V_H = Histogram Mean of [57UI to 62UI]
      - V_L = Histogram Mean of [121UI to 126UI]

$$\text{pre cursor gain} = 20\log\left(\frac{V_c}{V_b}\right)$$

- **Swing measurement**

$$V_{p\_p} = VH - VL$$

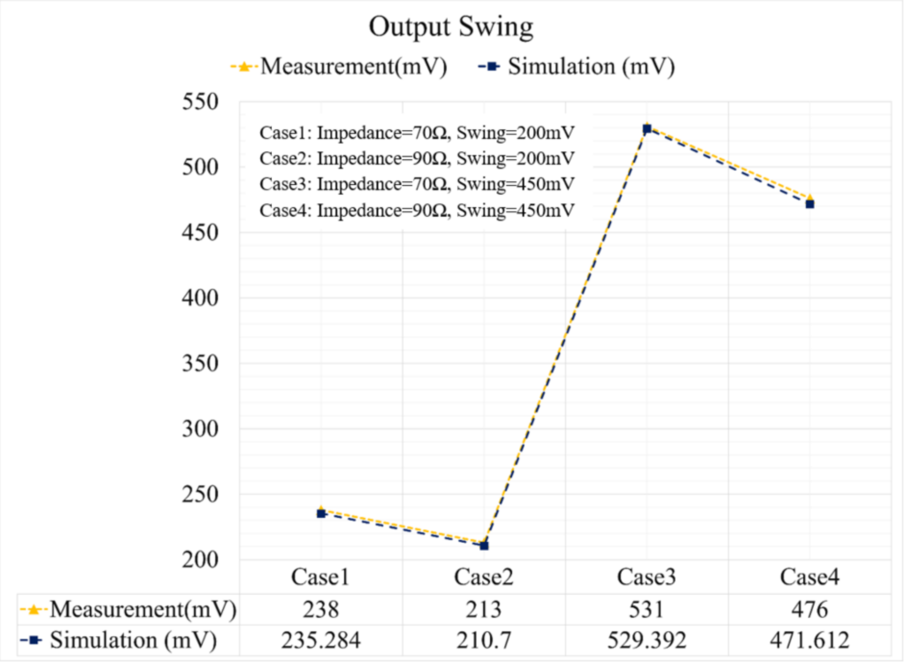
V_H = Histogram Mean of 111111 [6 continuous 1's]

V_L = Histogram Mean of 000000 [6 continuous 0's]

Results 1/2

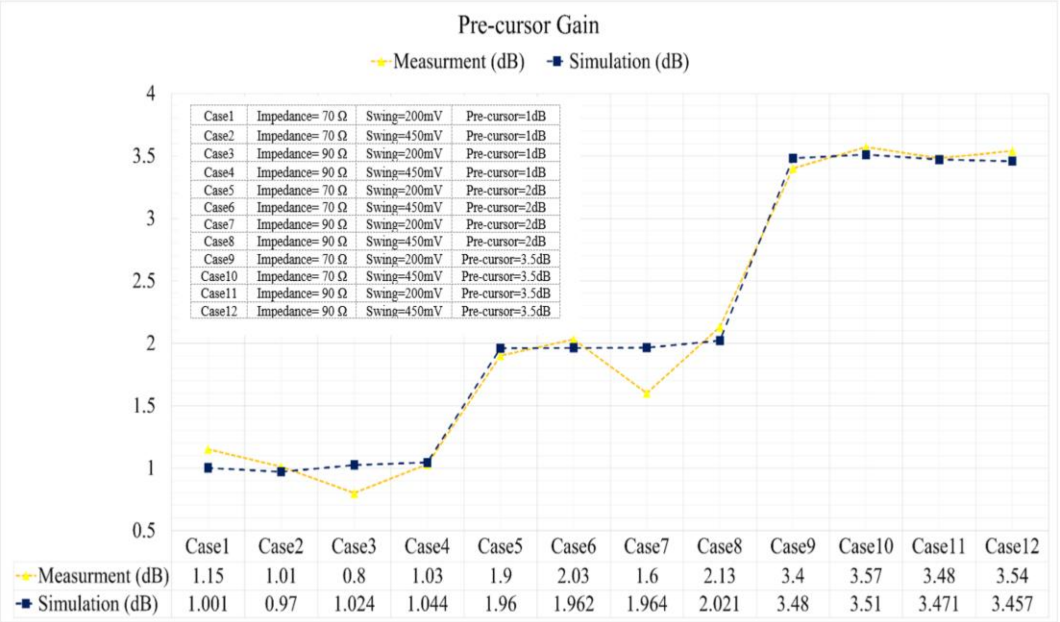
Swing Comparison

- 4 transmitter configurations
  - Tx Impedances : 70 Ohm and 90 Ohm
  - Tx Swing : 200 mV and 450 mV
  - De-emphasis disabled (Pre/post-cursor = 0dB)



Pre-cursor gain Comparison

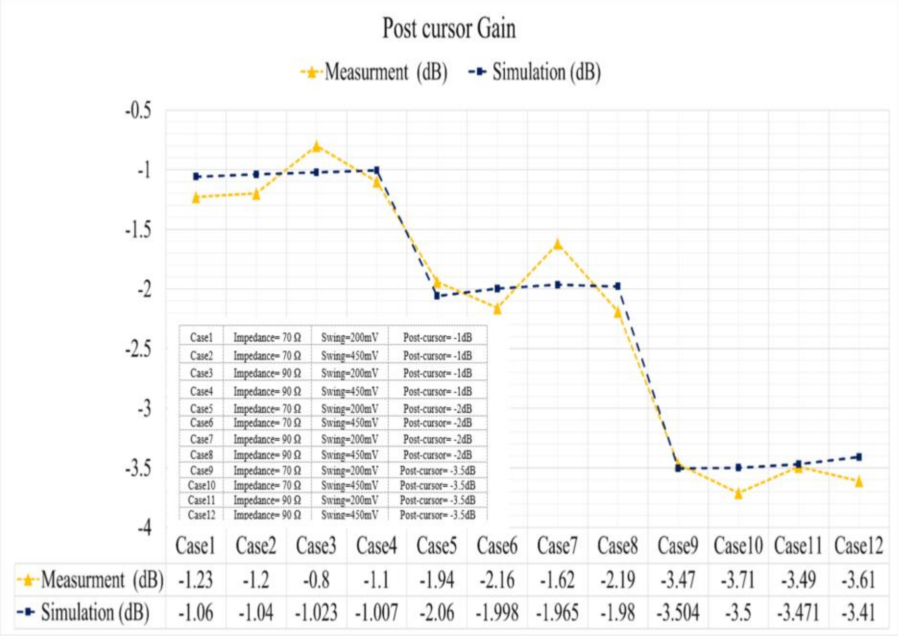
- 12 transmitter configurations
  - Tx Impedances : 70 Ohm and 90 Ohm
  - Tx Swing : 200 mV and 450 mV
  - Pre-cursor = 1dB, 2dB, 3.5dB;
  - Post-cursor = 0dB



Results 2/2

Post cursor

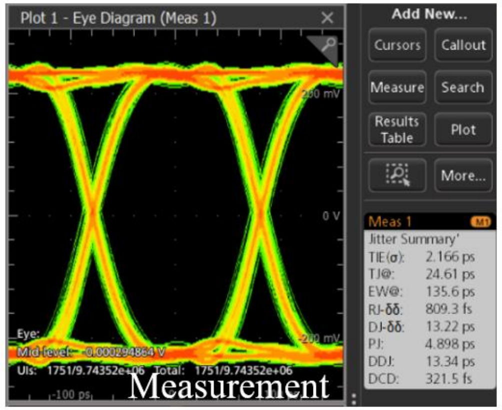
- 12 transmitter configurations
  - Tx Impedances : 70 Ohm and 90 Ohm
  - Tx Swing : 200 mV and 450 mV
  - Post-cursor = -1dB, -2dB, -3.5dB
  - Pre-cursor = 0dB

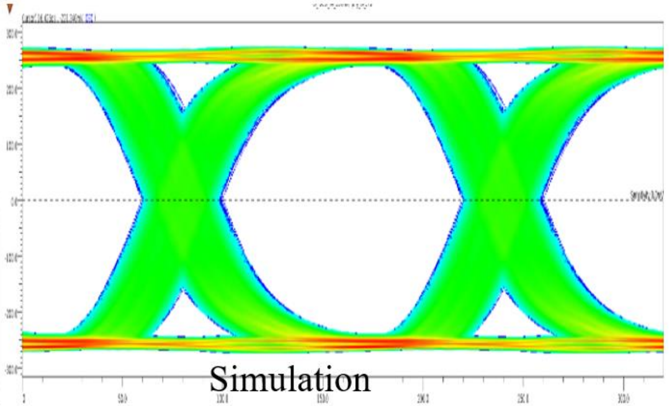


Eye comparison

- Eye Width

Tx configuration	0.2V & 70Ohm	0.2V & 90Ohm	0.45V & 70Ohm	0.45V & 90Ohm
Measurement	141.7ps	141.6ps	139.36ps	140ps
Simulation	135.6ps	132.5 ps	135.ps	132.5ps
% Error	4.287	6.42	2.68	5.35





Conclusion

Fidelity of IBIS-AMI Model

- Demonstrated through comparison of main electrical parameters
- Electrical Parameters Comparison: Swing, pre-cursor, and post-cursor gain
  - Swing Mismatch: Less than 1%
  - Pre-cursor and Post-cursor Gains: Within 5%, with some outliers

Comprehensive Analysis

- Reliability: Validates the IBIS-AMI model for successive system design iterations
- Acceleration: Speeds up milestones for next-generation products
- Early-Stage Design: Reliable with an error margin of less than 2%
- Simulation Speed: Faster simulations
- Parameter Handling: Capable of managing major parameters

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