



# De-emphasis Buffer Modeling Issues with IBIS

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# Agenda

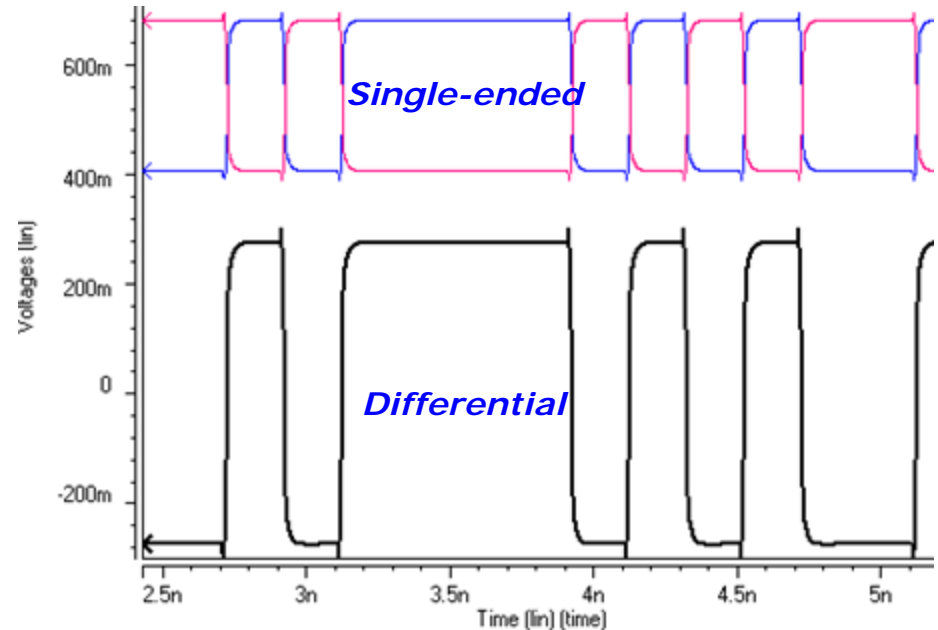
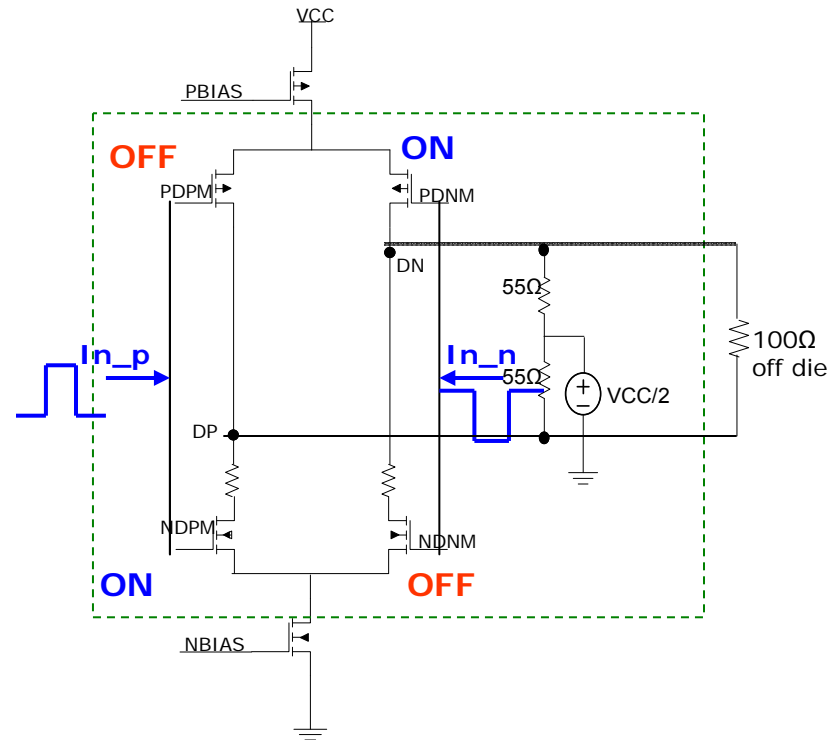
- Brief background
  - Differential buffer with de-emphasis
  - De-emphasis implementation in IBIS
- Different de-emphasis implementation
  - A different de-emphasis approach
  - Boost stimulus derivation
  - Example boost stimulus in SPICE
- Modeling the “new” boost
  - Issues with defining the boost
  - Single-ended or differential?
  - Verilog\* AMS approach
- Comments and future work

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# Differential Buffer

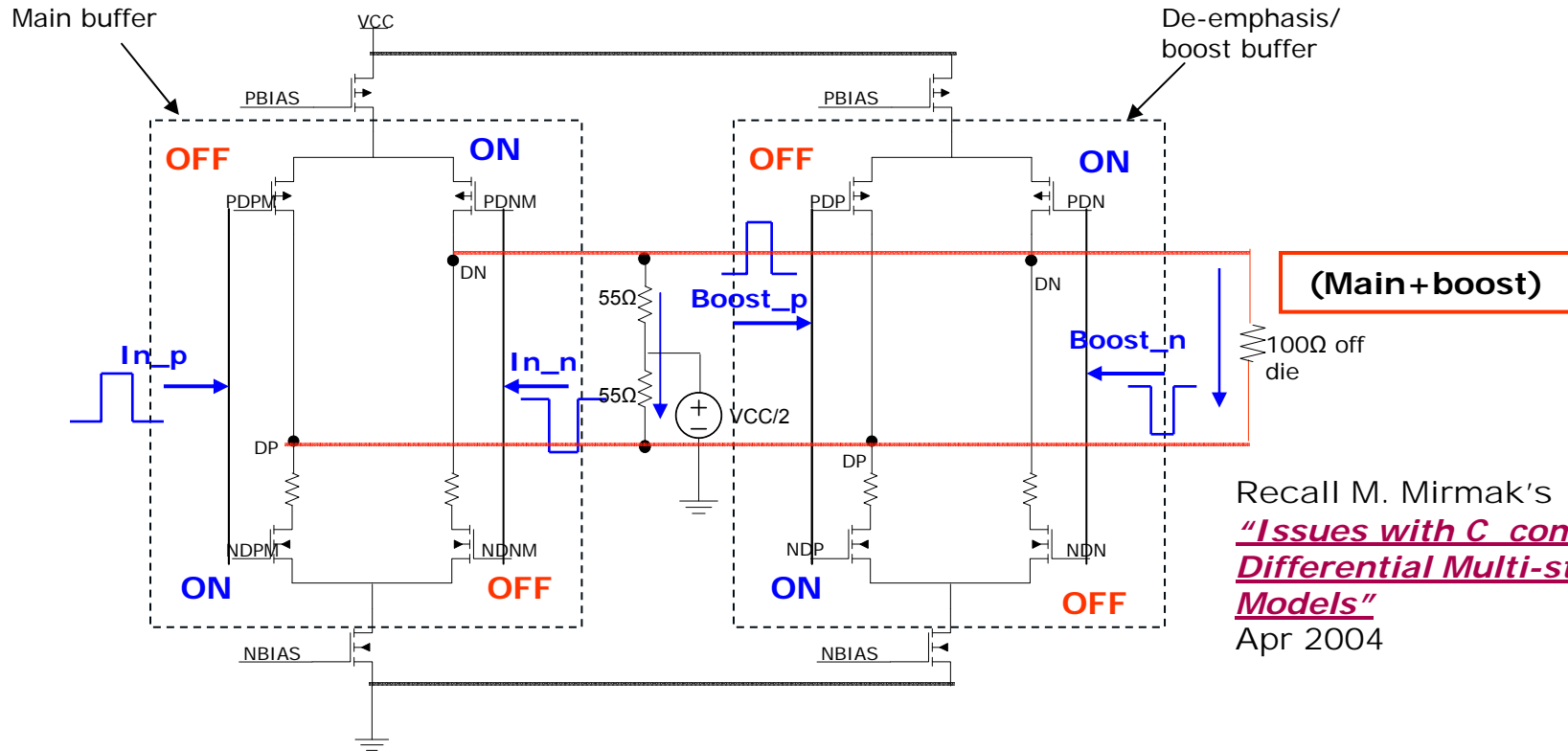
- PCI Express\* differential buffer example



**Note:** *NBIAS* and *PBIAS* are set to get 10mA from the driver

# Differential Buffer with De-emphasis

- Adding a second buffer (de-emphasis/boost)- WIRED-OR
- Boost adds to the main during full-swing (101010) operation

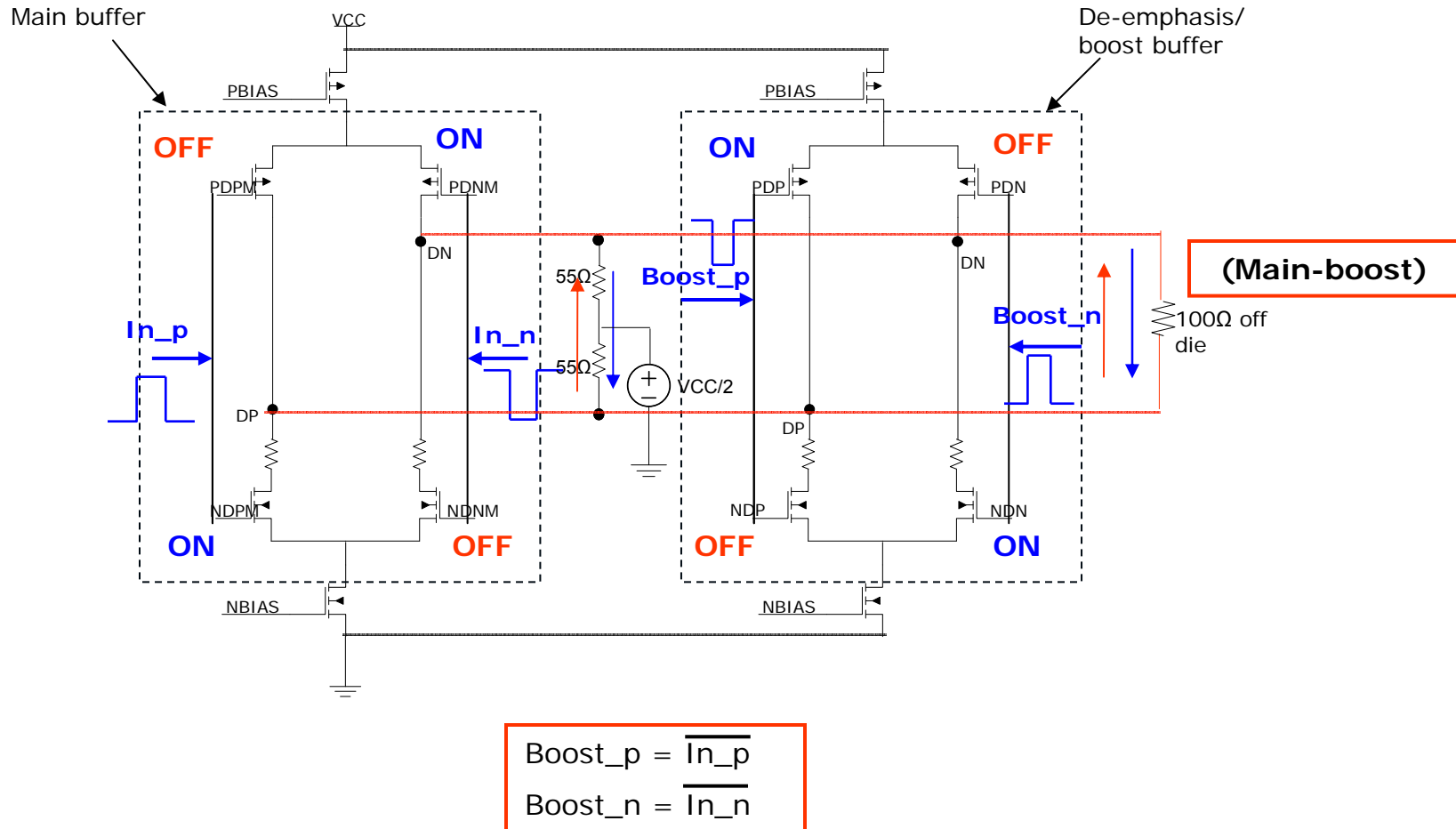


Recall M. Mirmak's  
*"Issues with C comp and  
Differential Multi-stage IBIS  
Models"*  
Apr 2004

$In_p$  and  $In_n$  are main stimulus patterns  
 $Boost_p = In_p$   
 $Boost_n = In_n$

# Differential Buffer with De-emphasis

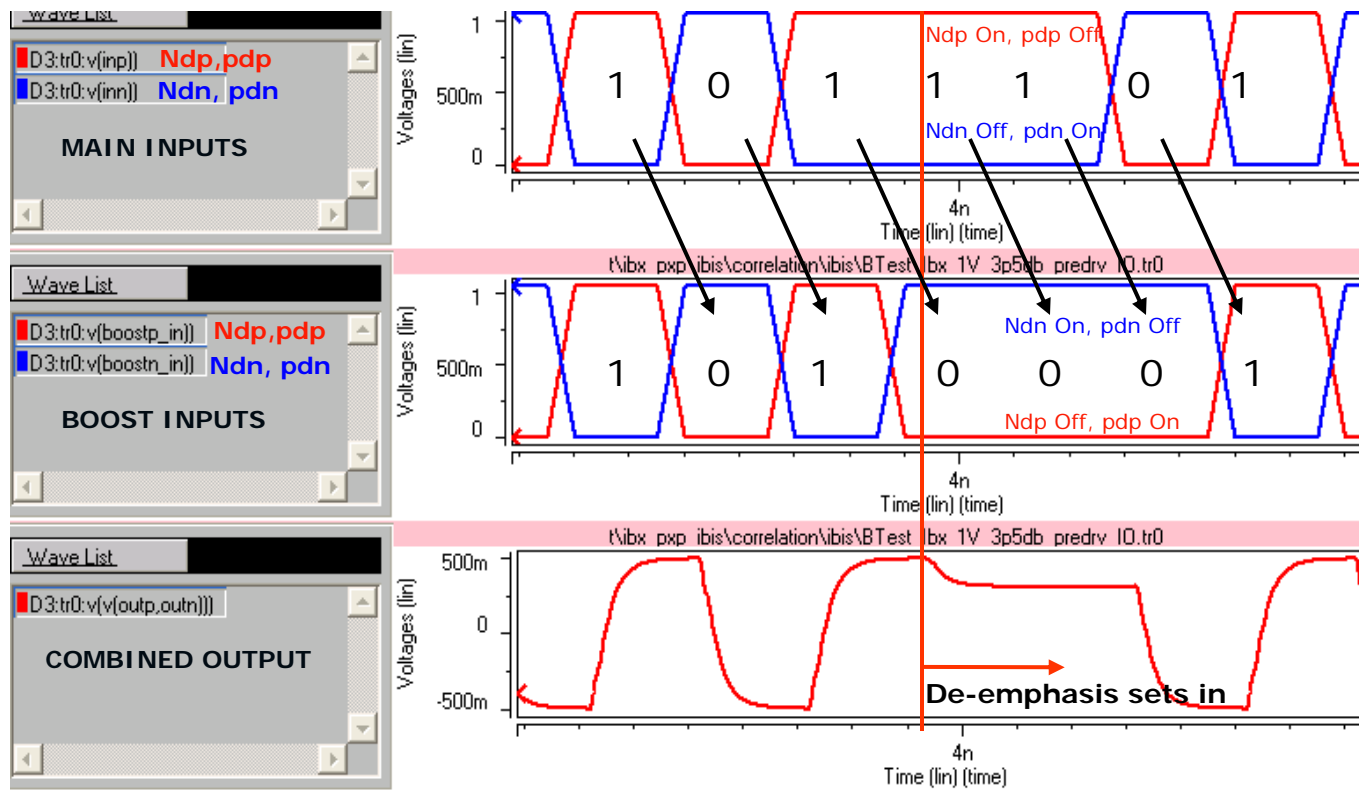
During de-emphasized operation (continuous ones/zeros), opposite legs of the buffer are switched on (one of the methodologies)



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# De-emphasis Implementation in IBIS

- Two differential buffers– main and boost are WIRED-OR
- Terminations and parasitics shouldn't be duplicated
- Boost is driven by a stimulus derived from the main pattern **depending on the de-emphasis logic**
- C\_comp is split between main and boost in the ratio of number of driver slices (one of the ways)

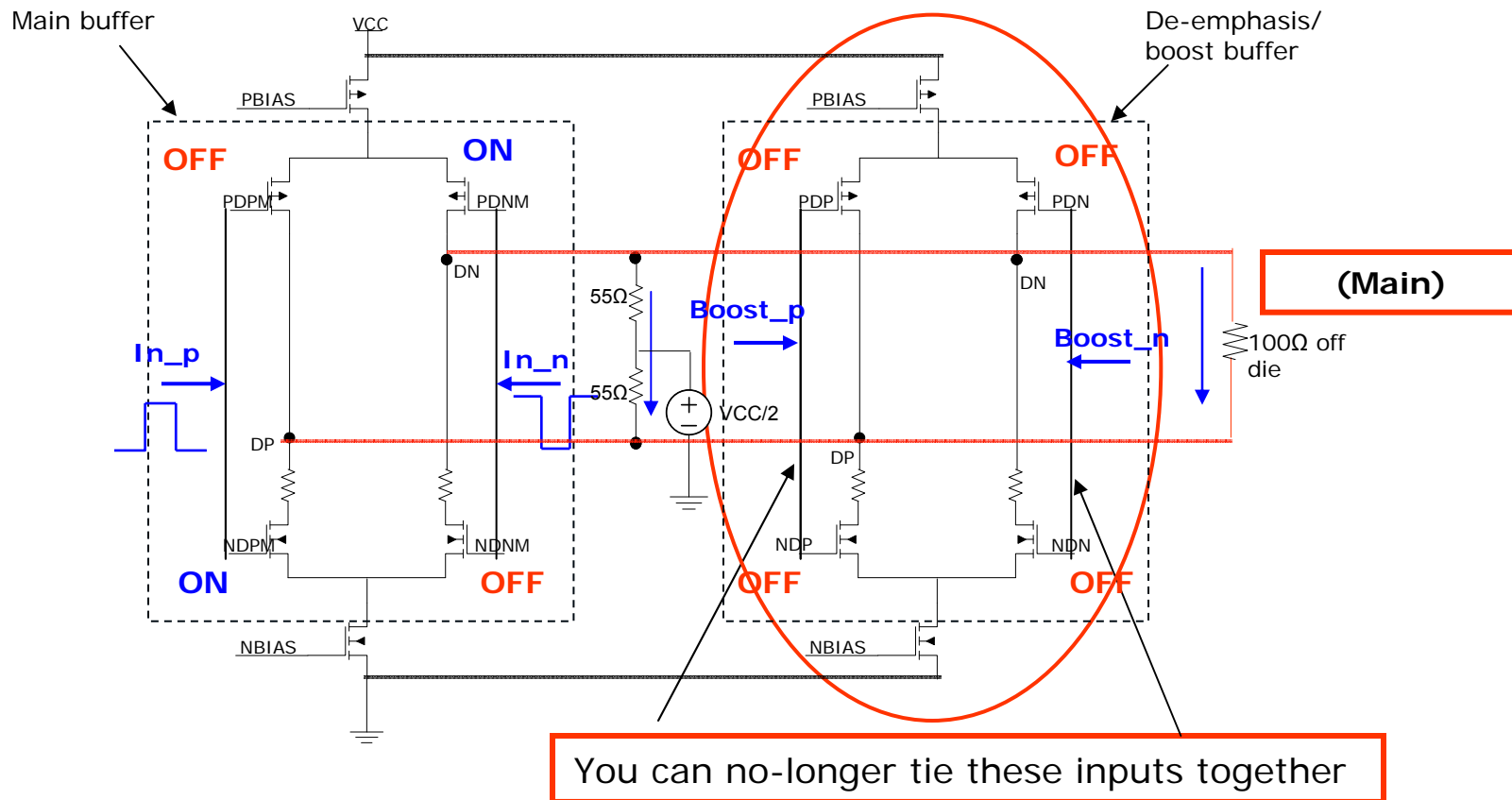


$$\text{Boost}(t) = \text{Inp}(t-1)$$

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# De-emphasis - Different Approach

- During de-emphasized operation, the boost buffer is completely **shut off**. Load sees only main





# Boost Stimulus... Some Derivations

Boost input stimulus will need to be different

Inp	1	0	1	0	1	1	1	1	0	0
Boost_NDP	1	0	1	0	1	OFF	OFF	OFF	0	OFF
Boost_PDP	1	0	1	0	1	1	1	1	0	1
						OFF	OFF	OFF		OFF

Inp(t-1)	Inp(t)	Boost_NDP	Boost_PDP
0	0	0	1
0	1	1	1
1	0	0	0
1	1	0	1

Similar logic applies for ndn and pdn, except that they will follow Inn

$$\text{Boost\_NDP} = \overline{\text{Inp}(t-1)} \cdot \text{Inp}(t)$$

$$\text{Boost\_PDP} = \text{Inp}(t-1) \cdot \overline{\text{Inp}(t)}$$

$$\text{Boost\_PDP} = \overline{\text{Boost\_PDP}}$$

$$\text{Boost\_NDN} = \overline{\text{Inn}(t-1)} \cdot \text{Inn}(t)$$

$$\text{Boost\_PDN} = \text{Inn}(t-1) \cdot \overline{\text{Inn}(t)}$$

$$\text{Boost\_PDN} = \overline{\text{Boost\_PDN}}$$

# Example Boost Stimulus in SPICE

```
***** Logic for Boost_NDP *****
E_inx      inpdelay 0 DELAY inp      0 TD='period/2'      ****Delay
E_intn     in2       0          vol='inV-V(inpdelay)'      **Inversion of the delay
**AND inp and in2
Gswitch Boost_NDP inp VCR PWL(1) inp 0 0v,1e-6 vcc,10m
Gswitch1 Boost_NDP in2 VCR PWL(1) in2 0 0v,1e-6 vcc,10m

Rxxx Boost_NDP 0 1E6      *** OUTPUT LOAD

***** Logic for Boost_PDP *****
E_inx1     inpdelay1 0 DELAY  inp 0 TD='period/2'      **Delay
E_inn1     inpbar    0 vol='inV-V(inp)'      **Inversion

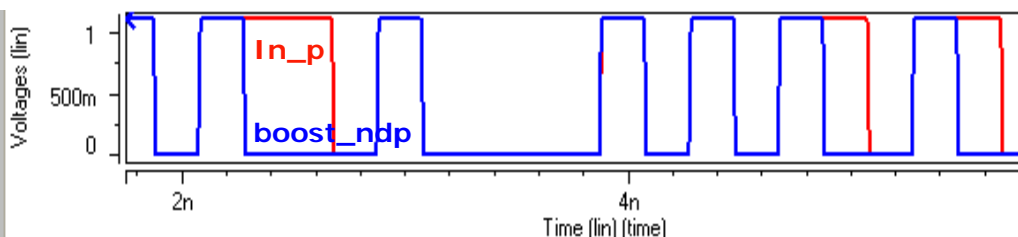
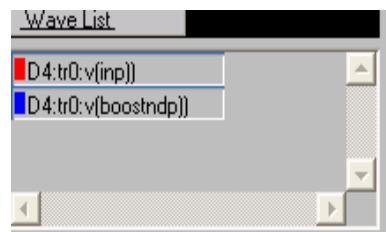
Gswitch2 bpbar inpbar VCR PWL(1) inpbar 0 0v,1e-6 vcc,10m
Gswitch3 bpbar inpdelay1 VCR PWL(1) inpdelay1 0 0v,1e-6 vcc,10m

E_boostp Boost_PDP 0 vol='inV-V(bpbar)'      **Inversion

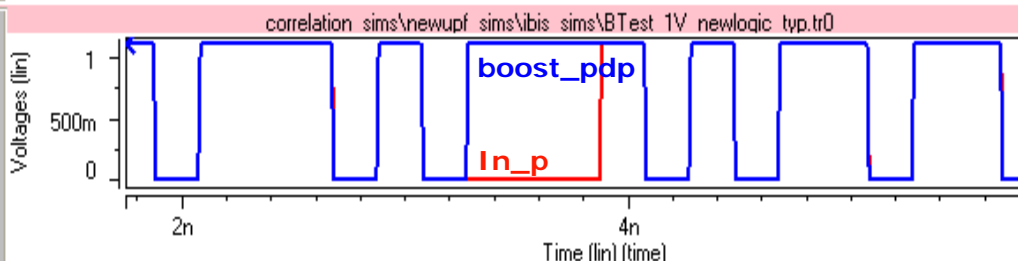
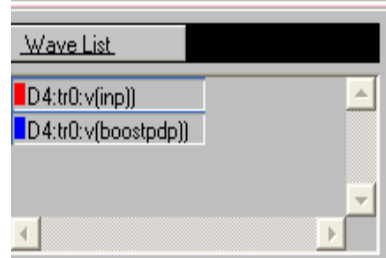
Rxxx1 Boost_PDP 0 1E6      *** OUTPUT LOAD
```

Similarly for NDN and PDN

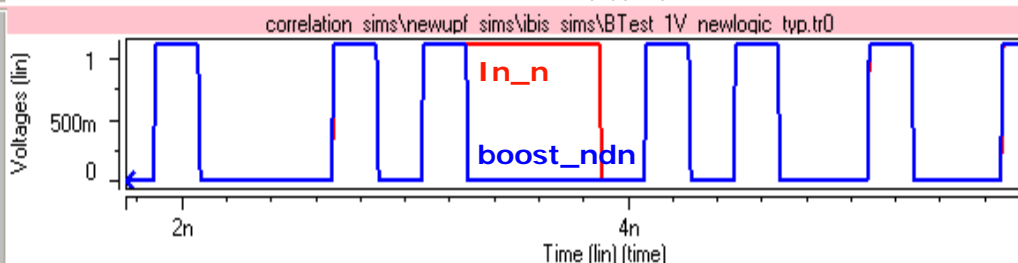
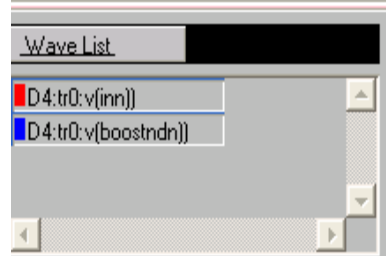
# The 'Working' Stimulus



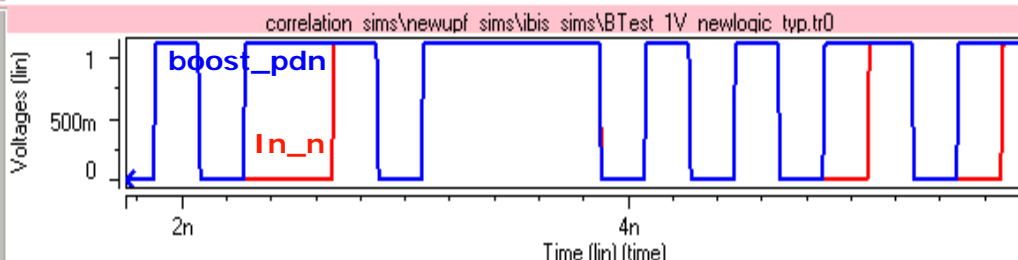
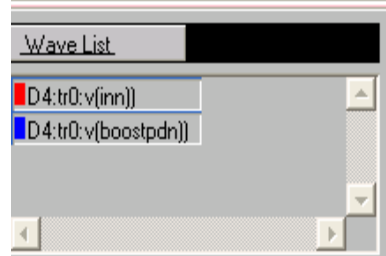
**NDP=0 (OFF) during de-emphasis**  
**N follows i/p during normal mode**



**PDP=1 (OFF) during de-emphasis**  
**P follows i/p during normal mode**



**NDN=0 (OFF) during de-emphasis**  
**N follows i/p during normal mode**



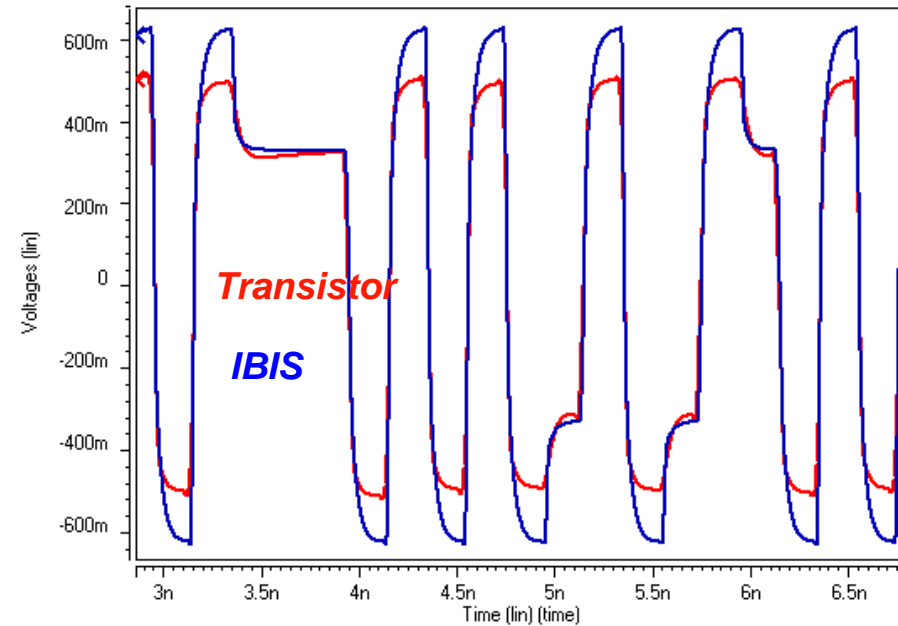
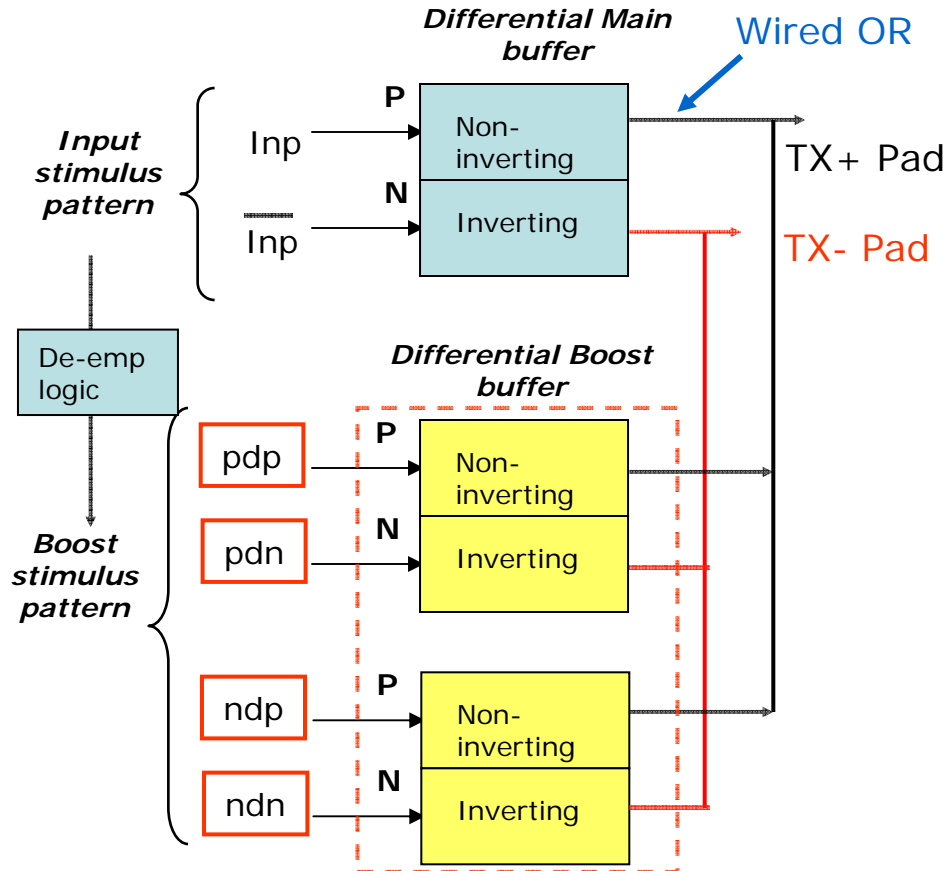
**PDN=1 (OFF) during de-emphasis**  
**P follows i/p during normal mode**

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# Modeling the 'New' Boost

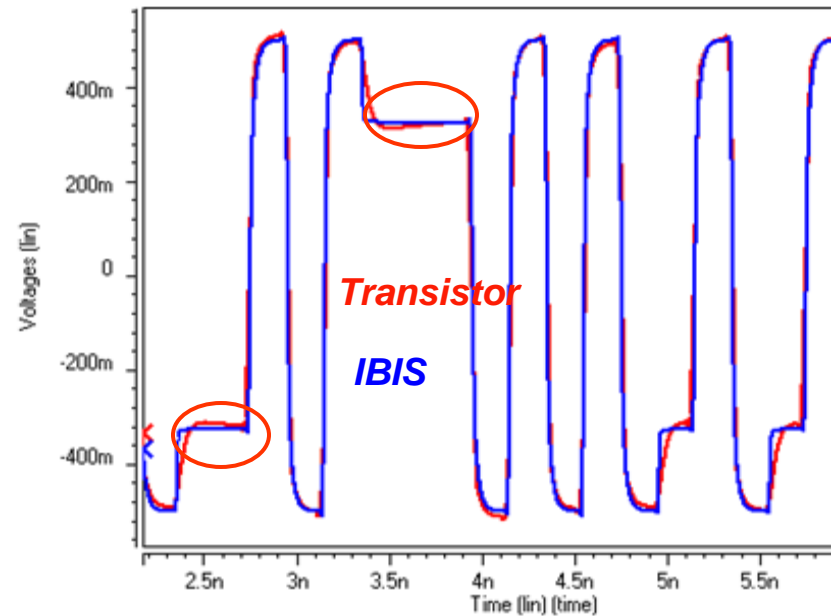
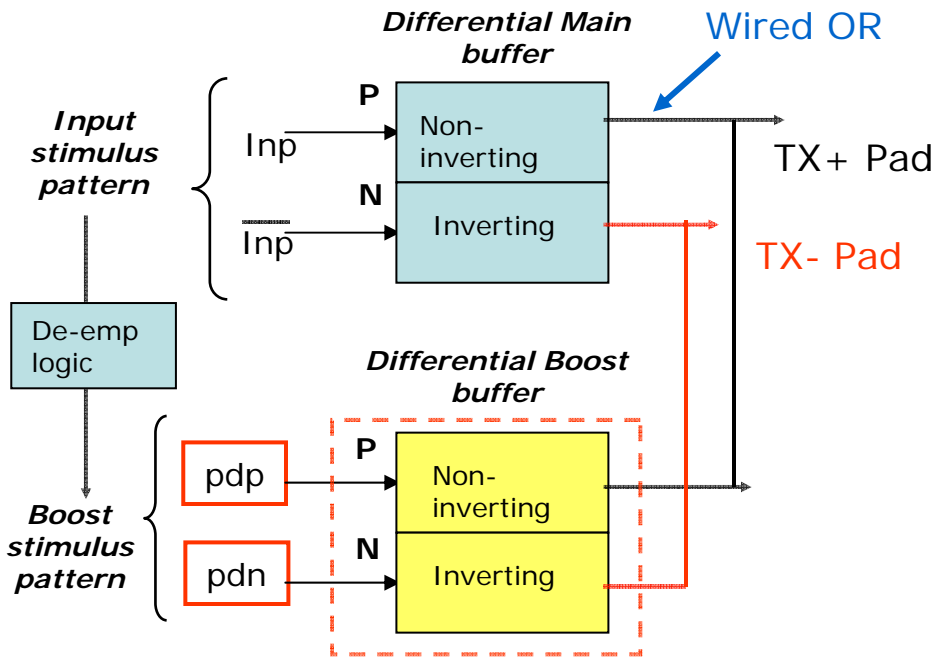
- Approach 1: Define 2 B-elements for main and 1 B-element for each of pdn, pdp, ndp and ndn (modeled as differential buffer)



**Doesn't work as  
Boost == 2 differential  
buffers**

# Modeling the 'New' Boost

- Approach 2: Define either pdp and pdn or ndp and ndn (modeled as differential buffer)

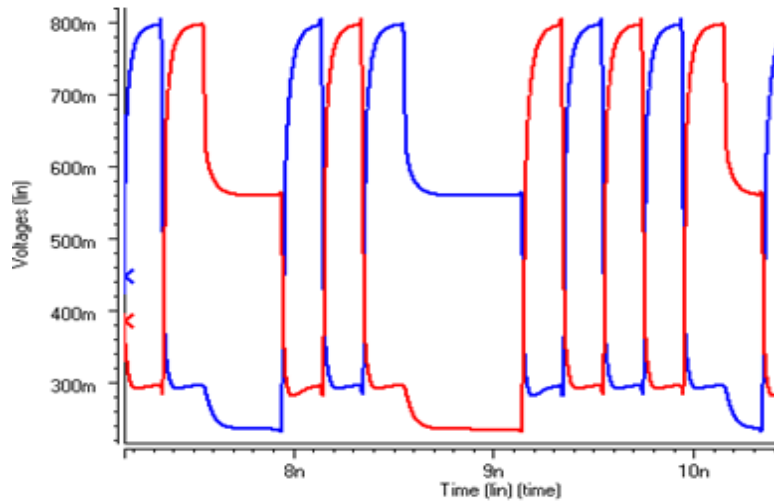


- Differential swing correlates well
- Mismatch on de-emphasis transition
- C\_comp distribution gets tricky

Recall A.Muranyi's  
**"Data Dependent Buffer  
Characteristics"**

Jan 2003

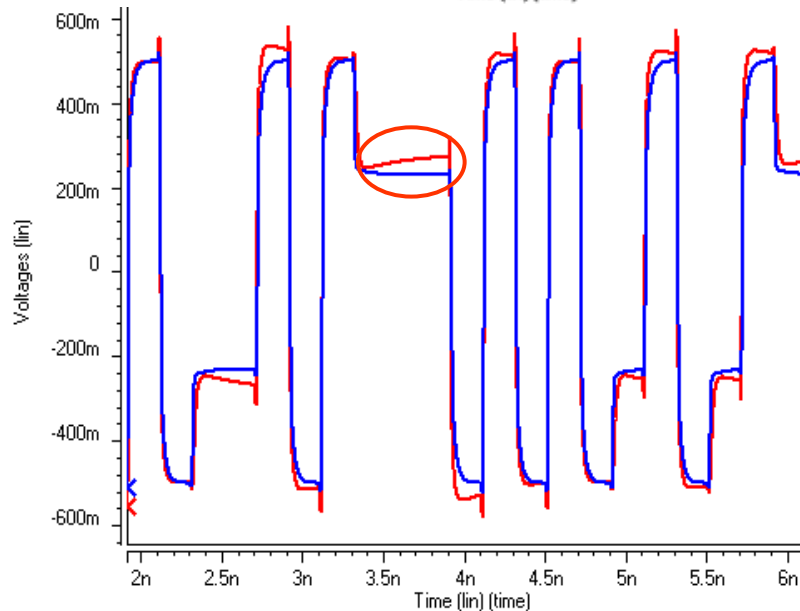
# A Further Issue



However, single ended signals are incorrect as we ignored ndn and ndp

*Transistor*

*IBIS*



6-dB De-emphasis

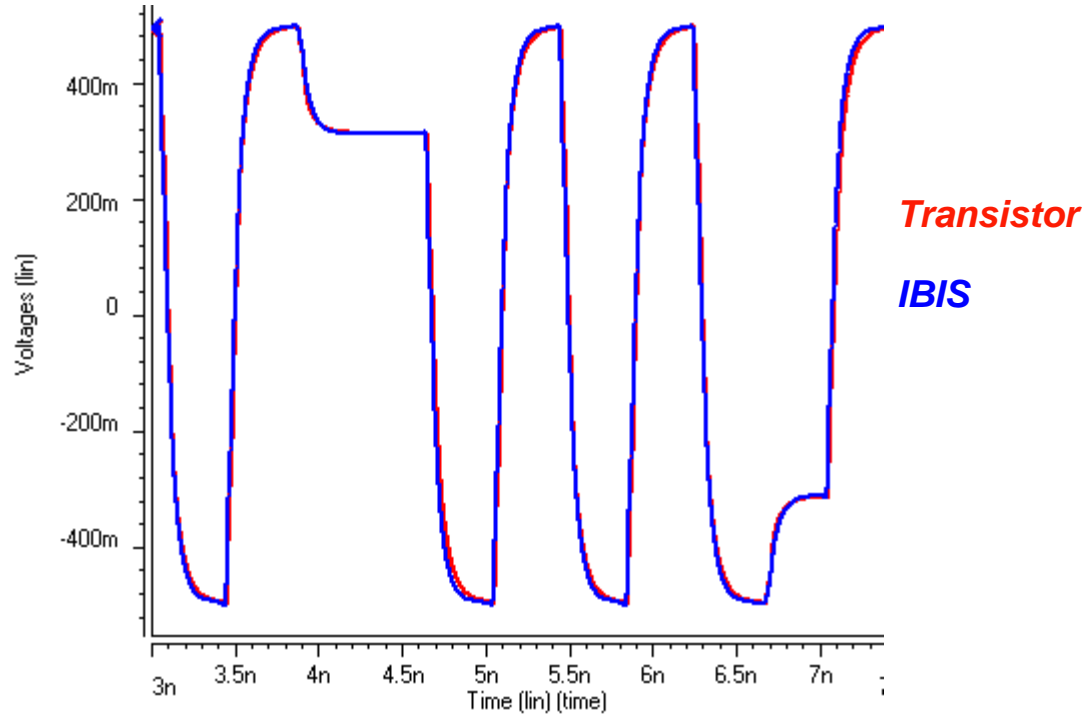
- Half the driver is switched off during switch from transition to non-transition ==> Odd behavior in transistor
- Table-based IBIS cannot mimic this behavior

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# Earlier De-emp Approach

Current reverses through boost buffer during de-emphasis

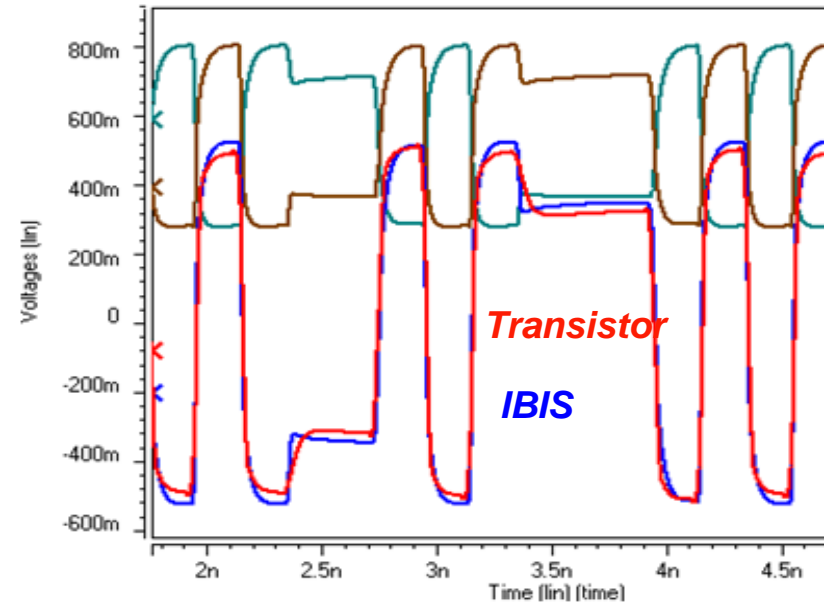
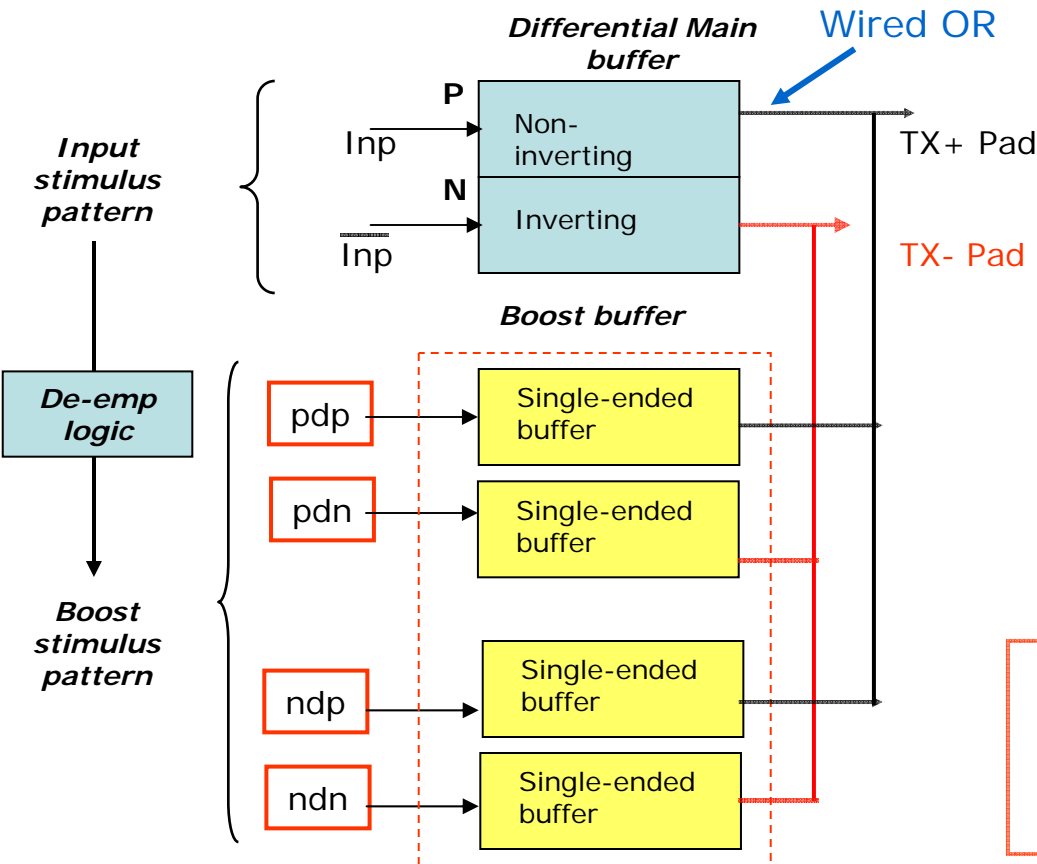


Miscorrelation was not observed with the previous de-emp methodology

Fairly good C\_comp distribution

# Modeling the 'New' Boost

- Approach 3:
  - Model boost as single-ended buffer instead of differential
  - Define 4 B-elements- with pdp, pdn, ndp and ndn stimulus



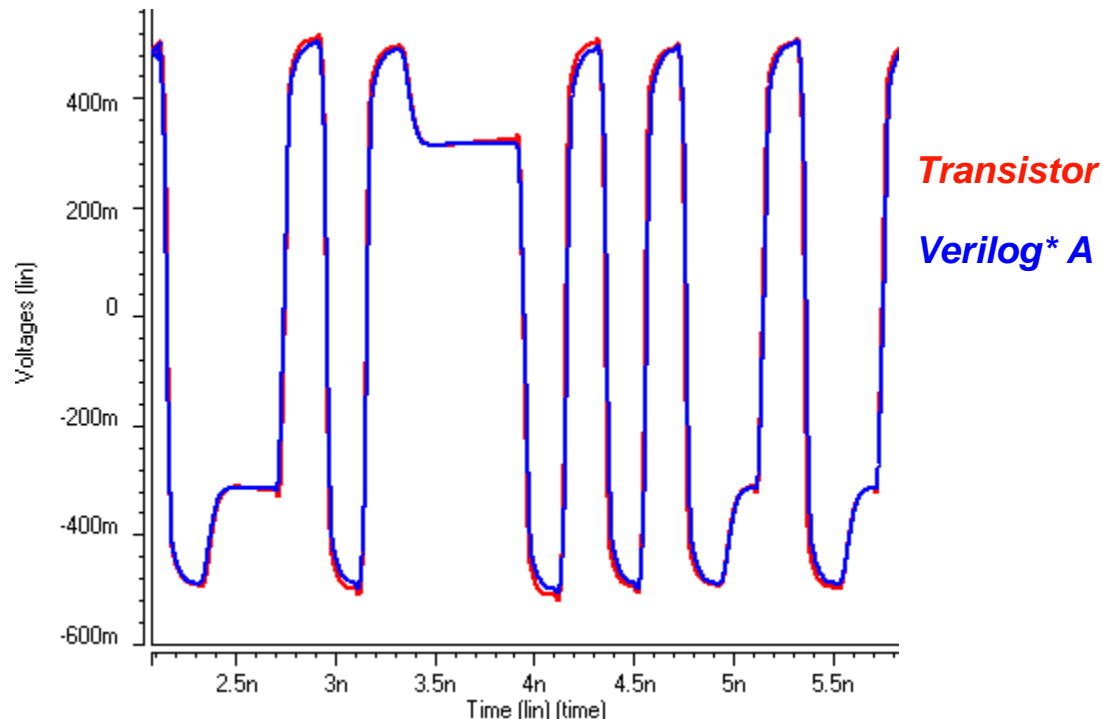
Issue with weird single ended signals resolved

But miscorrelation in differential swing!



# Verilog\* AMS Model

- Approach 4:
  - Create equation based Verilog\*-AMS model for the differential buffer
  - Shows good correlation



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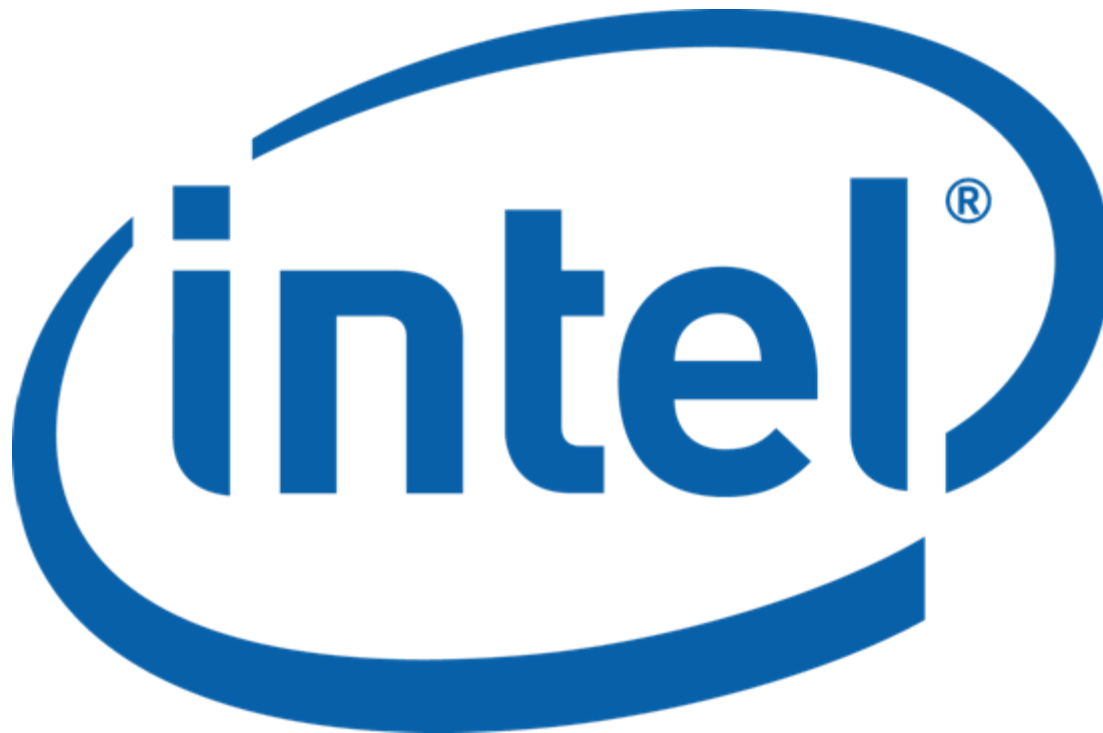


# Comments and Future Work

- Different de-emphasis implementations will need different boost stimulus logic
- Correlation issues observed while modeling the new de-emphasis buffer using table-based ibis
  - Manual fine tuning could fix this, but tedious and not the best approach
- Verilog\* AMS approach provides good correlation
- Alternatives for investigation:
  - Driver schedule
  - AMS approach

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