

---

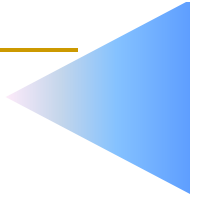
# More on C\_comp:

How to represent C\_comp in IBIS buffer model

---

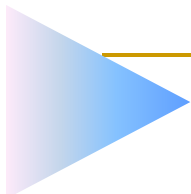
European IBIS Summit  
SPI 2010 - Hildesheim, Germany  
May 12, 2010

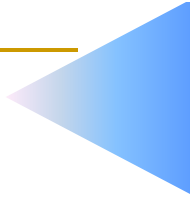




# Outline

- C\_comp extraction method
  - Review of last presentation in Asia IBIS Summits
- Methods for representing die-capacitance in IBIS buffer model
  - Test cases
- Conclusions and suggestions





# C\_comp extractions

- Review of last C\_comp presentation for extraction methods
  - Presented in Asia IBIS Summits (Japan and China) 2009
  - Links in IBIS Open Forum website
    - <http://www.vhdl.org/pub/ibis/summits/nov09b/wang.pdf>

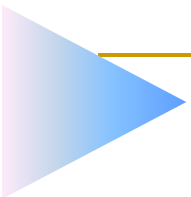
## C-comp extraction methods for High-Speed I/O buffers

Lance Wang  
(lwang@iometh.com)  
Asian IBIS Summit 2009  
JEITA, Tokyo, Japan  
November 6<sup>th</sup> 2009



Copyright © 2006-2008  
IO Methodology Inc.

Copyright © 2006-2010  
IO Methodology Inc.

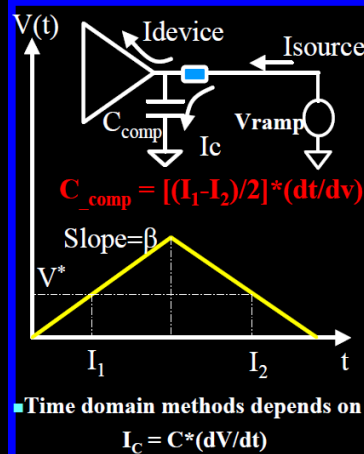


# Time and Frequency Domain methods



## Time Domain Methods

- Apply ramp voltage source ( $\beta \cdot t$ ) & measure the current.
- Subtract DC current in pull up/down device.
- $C(t) = (I_1 - I_2) / 2\beta = (I(t)_{Source} - I(t)_{Device}) / \beta$ .
- Ccomp varies with  $\beta$  !!!!

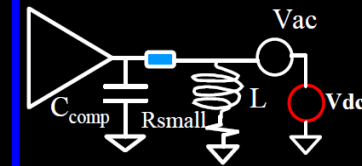
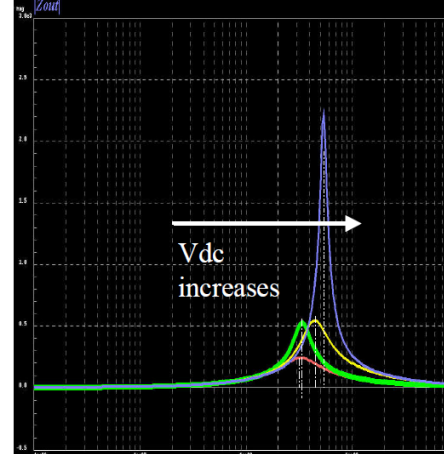


Mentor Graphics

4 Pad capacitance Extraction, Hazem Hegazy, IBIS Summit Meeting, June 13, 2002

Time Domain

## Voltage Dependence



$$\omega_o = 1/\text{Sqrt}(LC_{\text{comp}})$$

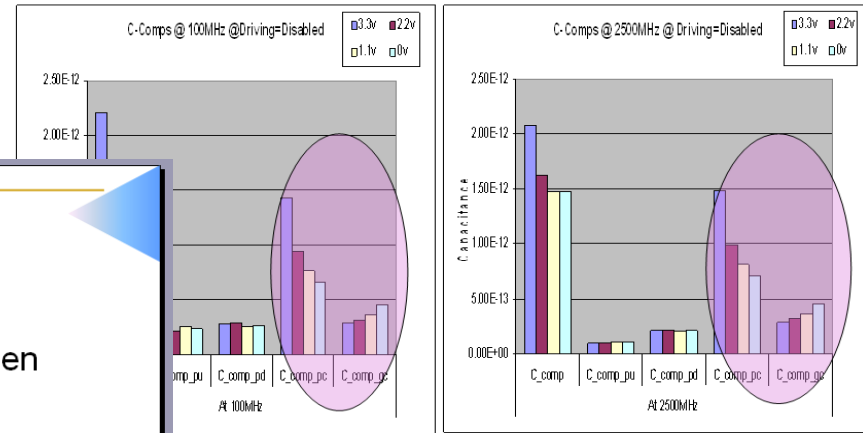
Mentor Graphics

10 Pad capacitance Extraction, Hazem Hegazy, IBIS Summit Meeting, June 13, 2002

Frequency Domain

# Non-driving / Receiving mode

## Non-driving mode @ 100MHz and 2500 MHz



### Non-driving mode summary

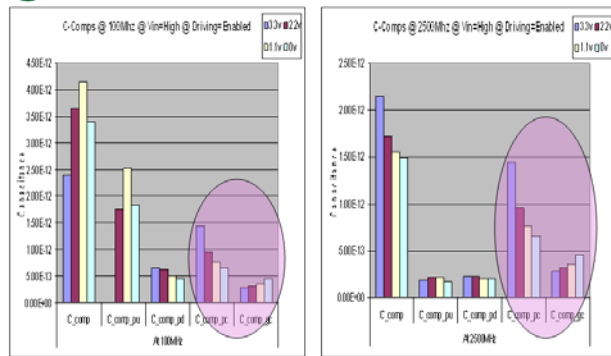
- Almost identical C-comp values for clamps when frequency changes
- Pad DC levels impact C-comp values for clamps
- For I/O buffers, C-comps values for Pullup and Pulldown may not be zero. They could change with frequency changes
- For I/O buffers, non-driving mode C-comp values are different than driving mode's. They could be big enough to affect your simulation analysis result

Copyright © 2006-2009  
IO Methodology Inc.

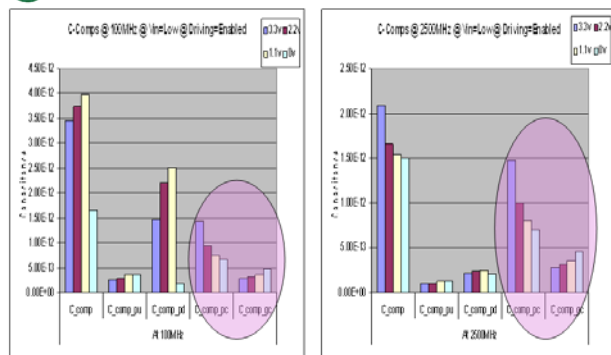
Copyright © 2006-2009  
IO Methodology Inc.

# Driving Mode

## Driving mode with Vin=High @ 100MHz and 2500MHz



## Driving mode with Vin=Low @ 100MHz and 2500 MHz



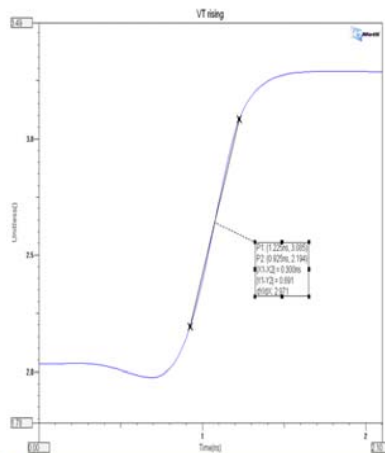
## Driving mode summary

- Identical C-comp values for clamps with frequency changes
- Pad DC levels impact C-comp values for clamps
- Pullup and Pulldown C-comp values vary with frequency changes. But it settles at a frequency point and up (being flat)
  - Input DC (level = High) impacts more on Pullup
  - Input DC (level = Low) impacts more on Pulldown

Copyright © 2006-2009  
IO Methodology Inc.

# Extract C\_comp with expected Frequency and Voltage

## Define frequency and voltages

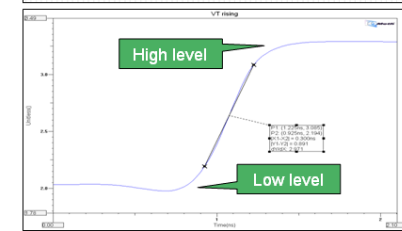
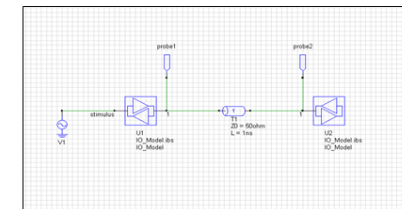


- Frequency
  - Use [Ramp] data as the reference
  - Buffer output frequency ( $F_{output}$ )  
 $F_{output} = 1 / (\text{Rising\_dt} + \text{Falling\_dt})$   
(for the most of high-speed buffer, the calculated output frequency point is in the settled region)
- Input buffer c-comp is not impacted much by output frequency changes. But suggest to use slightly higher frequency

Copyright © 2006-2009  
IO Methodology Inc.

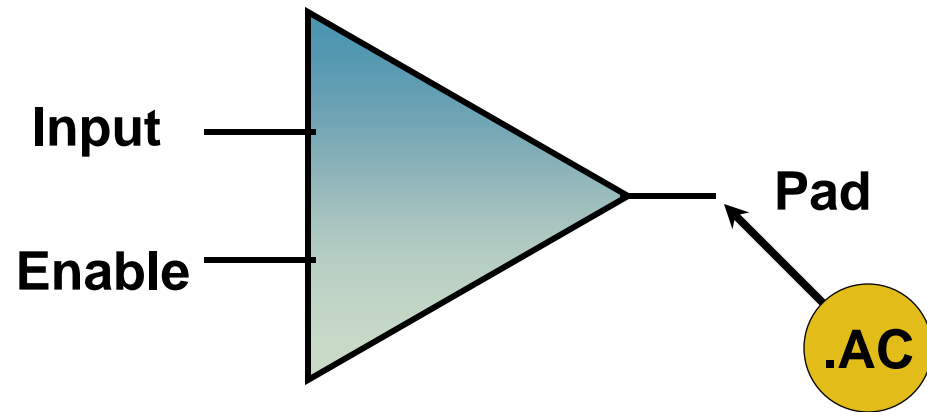
## Define frequency and voltages

- Voltages
  - Typical application settings
  - Operation voltage ranges
  - Using High and Low level DC settings
  - Averaging extracted C-comp values is a practical way for IBIS model
- Important to correctly define DC voltages



Copyright © 2006-2009  
IO Methodology Inc.

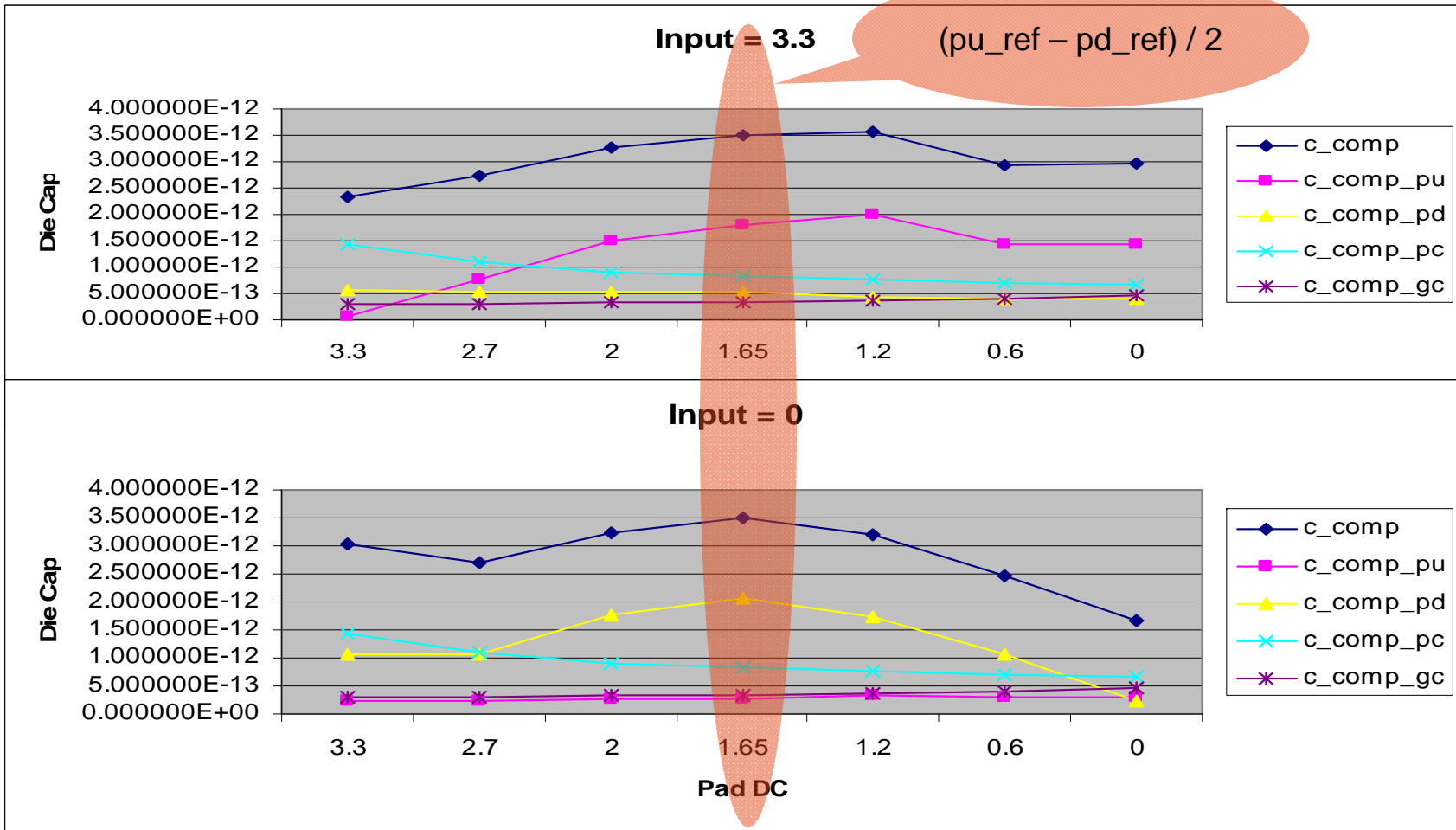
# Methods for representing die-capacitance in IBIS buffer model



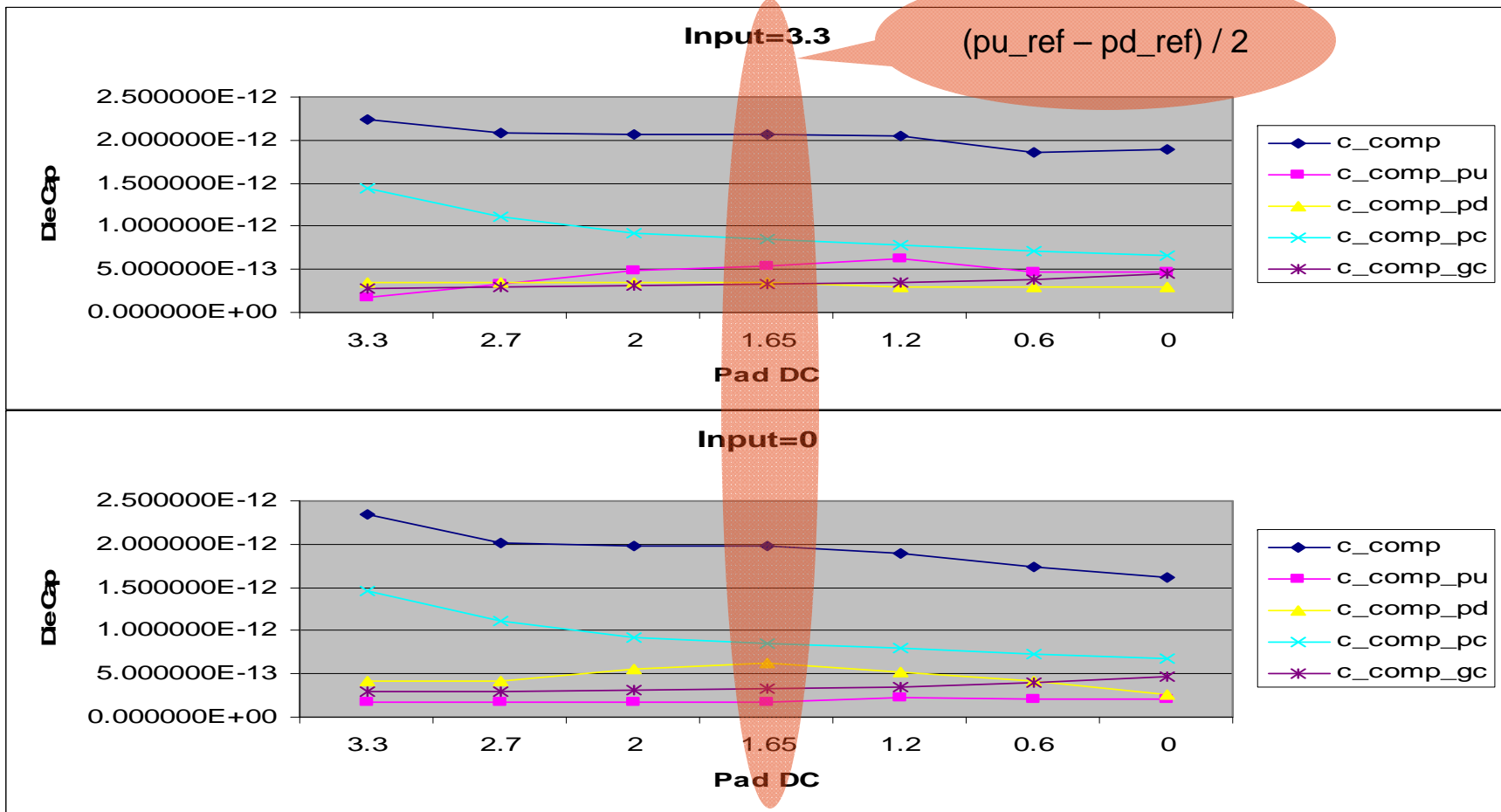
- A test case
  - Input=3.3
    - Pad DC=3.3, 2.7, 2, 1.65, 1.2, 0.6, 0
  - Input=0
    - Pad DC=3.3, 2.7, 2, 1.65, 1.2, 0.6, 0



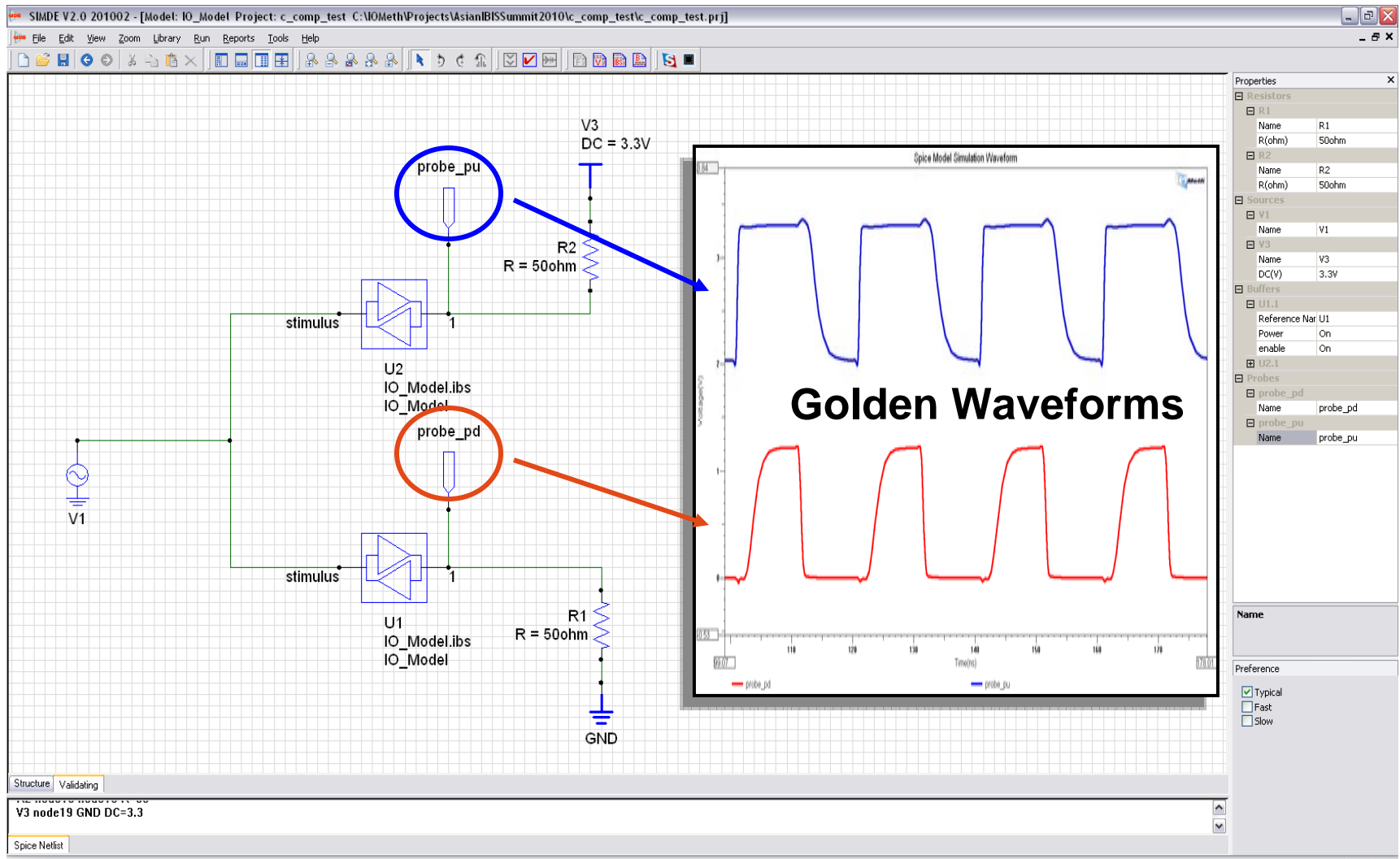
# Extracted C\_comp values for different Pad DC settings @ 180MHz

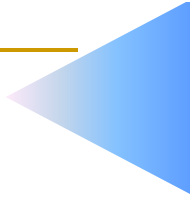


# Extracted C\_comp values for different Pad DC settings @579MHz



# Test Topologies



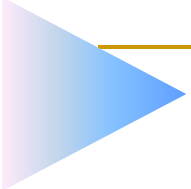


# Simulation result accuracy fact sheet for different setting C\_comp values

Frequency: 579MHz		probe_pd		probe_pu	
Input (V)	Pad DC (V)	DAI (%)	DPI (%)	DAI (%)	DPI (%)
3.3	1.65	0.29	4.02	0.57	24.18
3.3	2.7	0.3	4.02	0.58	25.65
3.3	0.6	0.3	3.98	0.6	26.99
0	1.65	0.27	4	0.48	17.3
0	2.7	0.27	4.01	0.47	17.38
0	0.6	0.29	3.83	0.61	28.39

**Using C\_comp not C\_comp\_xxx**

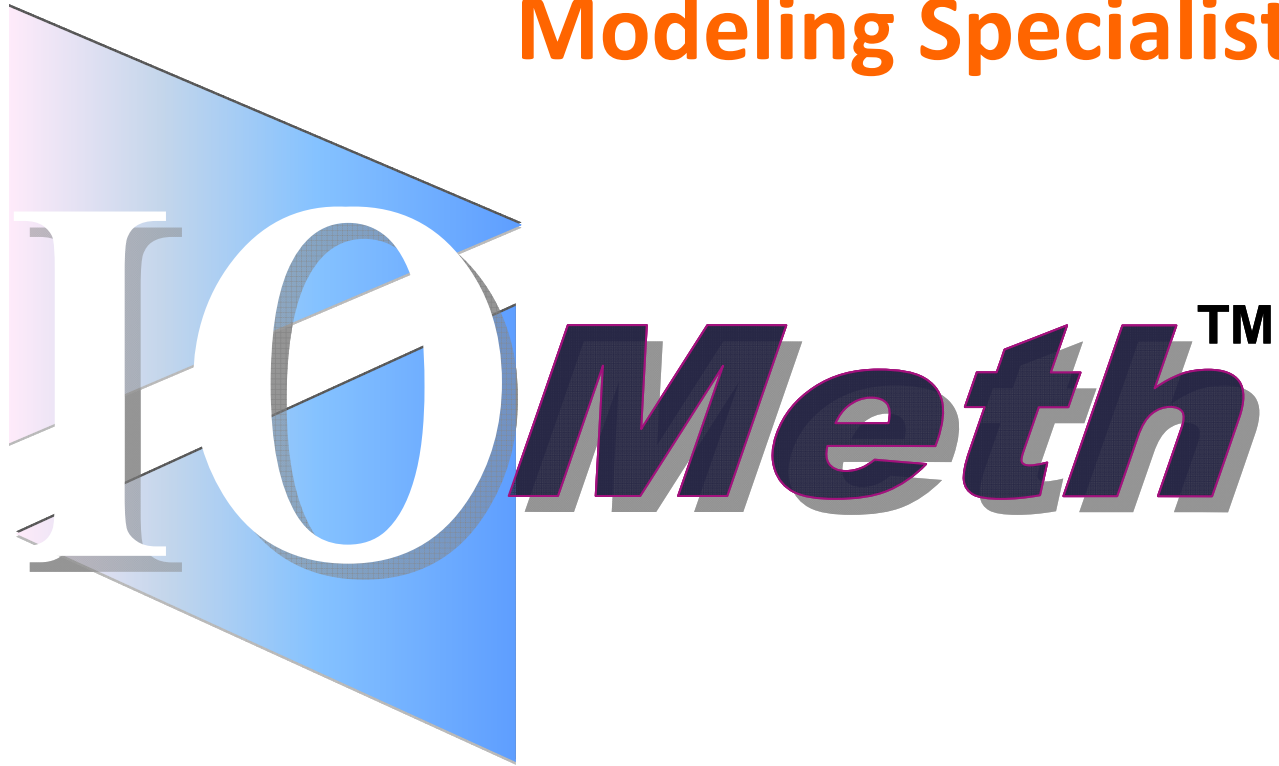
DAI – Differential Average Index, DPI – Differential Peak Index



# Conclusions

- C\_comp (reference to global GND) may not be enough for all the cases
  - C\_comp\_\*\*\* are more accurate representing die capacitance for the buffer
  - Bad news is that not all simulators handles or correctly handles C\_comp\_\*\*\*
- Be careful to pick C\_comp and C\_comp\_\*\*\* values depending on your applications.
  - Medium supply voltage is practical for extractions
- Depends on the application, sometimes, with only C\_comp could represent die capacitance accurately in the simulations
  - Termination to GND cases
- C\_comp\_\*\*\* could help correctly handling Driving / Receiving
  - Need a test

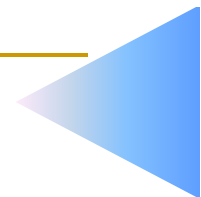
**Modeling Specialist**



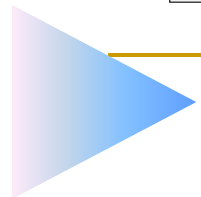
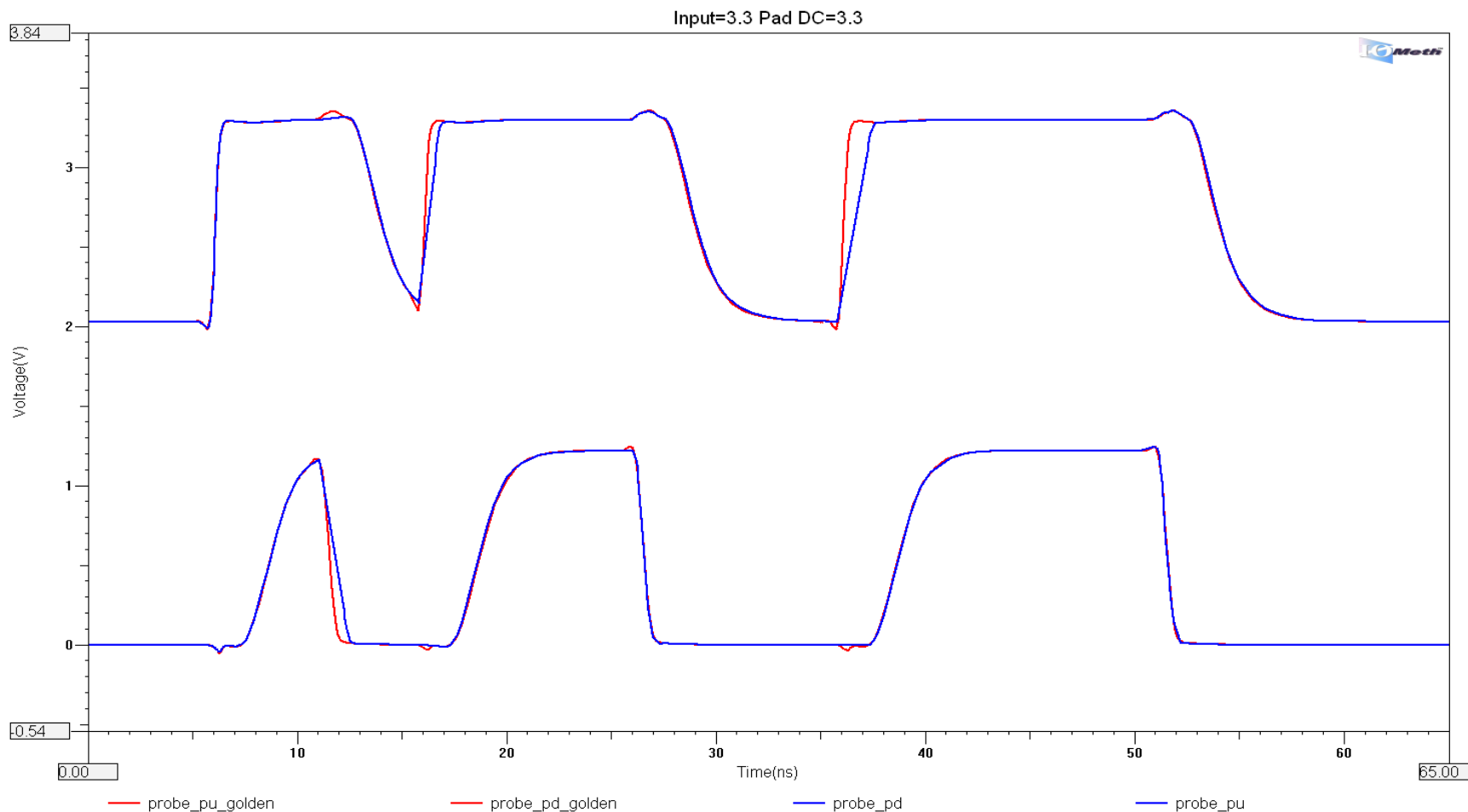


---

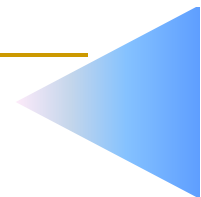
# Back-up Slides



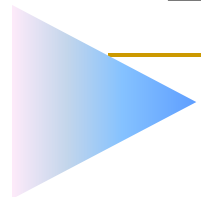
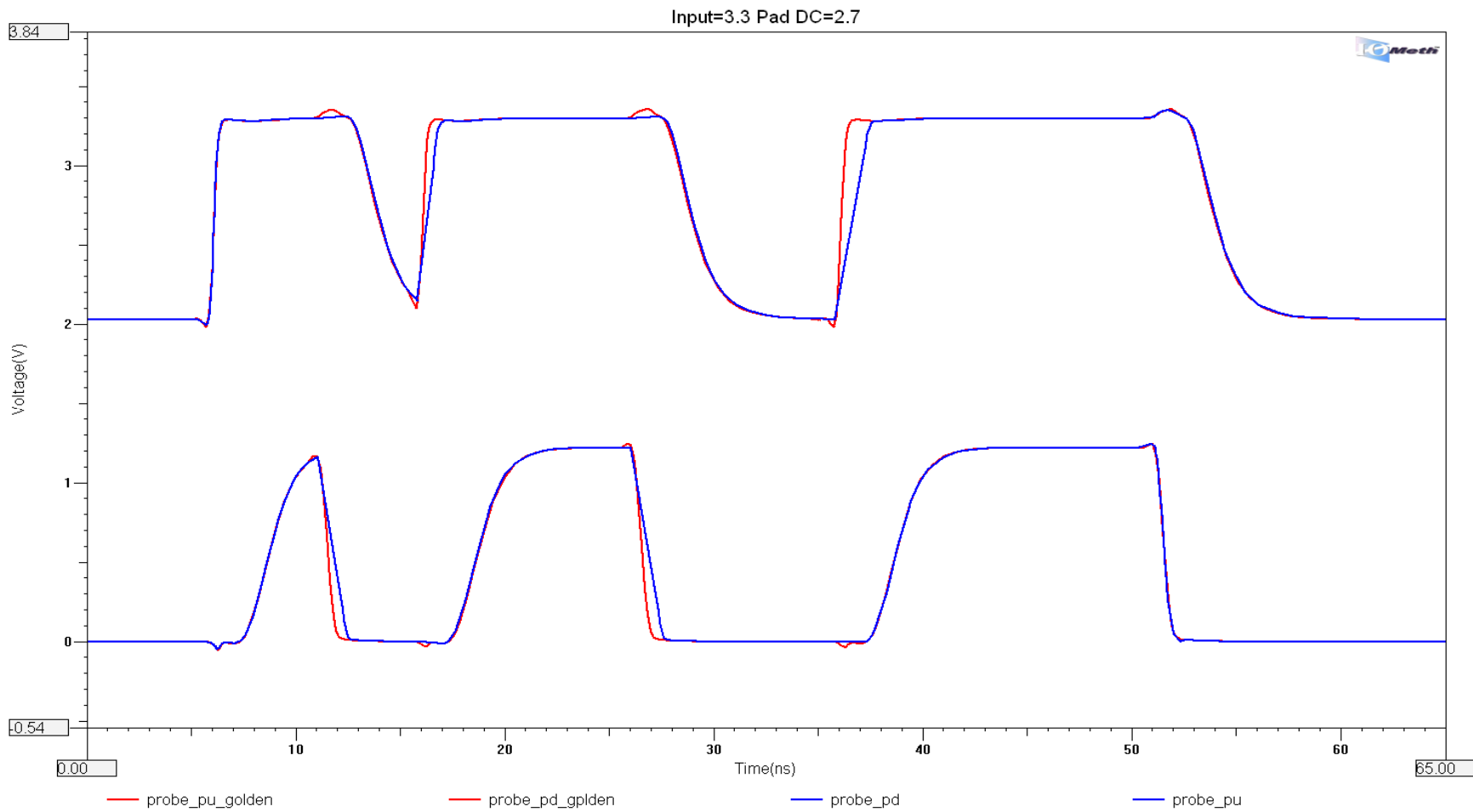
probe\_pd:           DAI = 0.62%(DA = 0.01),   DPI = 30.25%(DP = 0.39)  
probe\_pu:           DAI = 1.50%(DA = 0.02),   DPI = 54.23%(DP = 0.75)

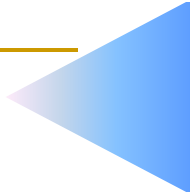




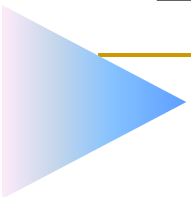
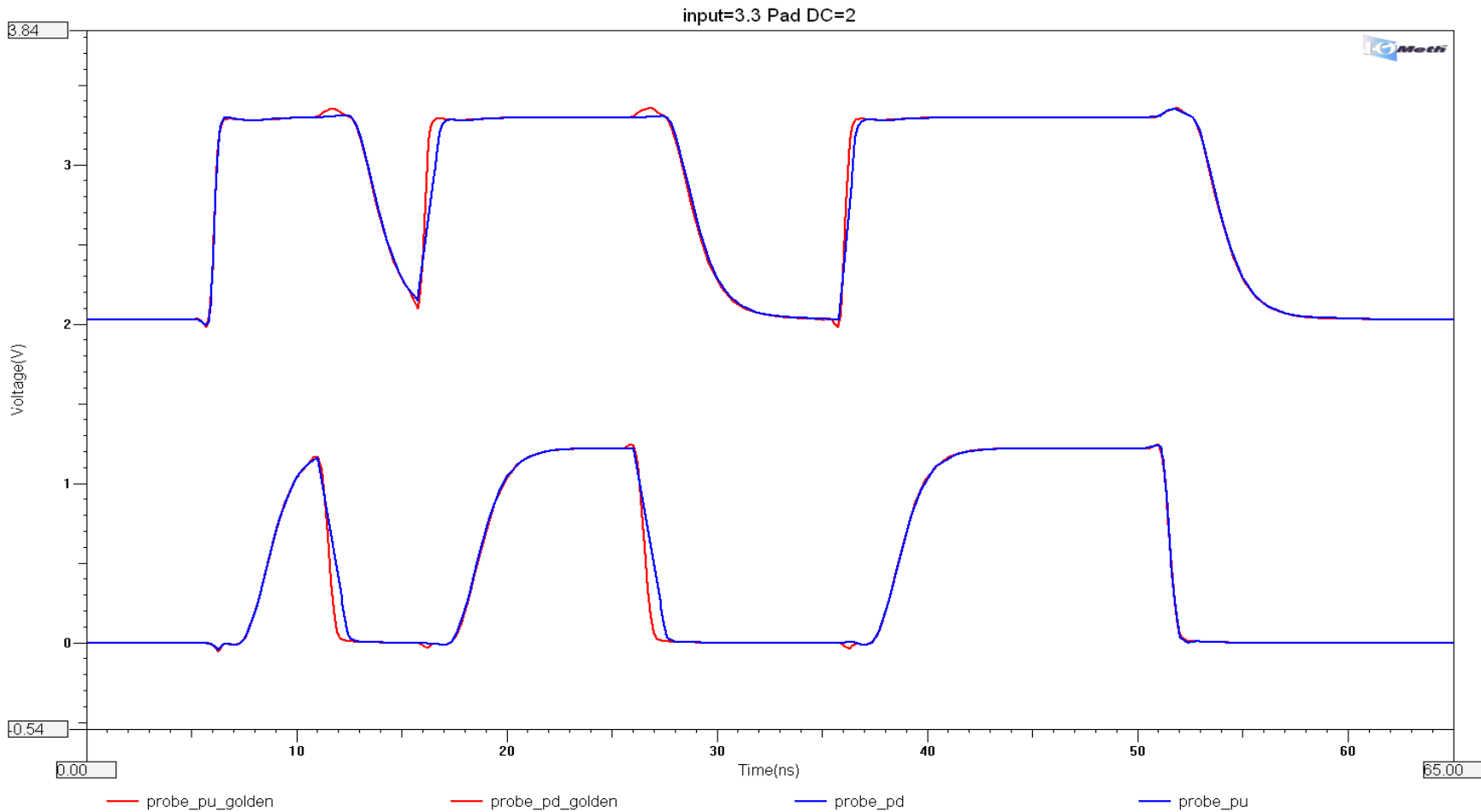


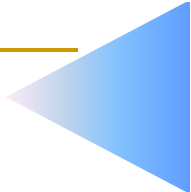
probe\_pd:           DAI = 1.06%(DA = 0.01),   DPI = 34.43%(DP = 0.45)  
probe\_pu:           DAI = 1.59%(DA = 0.02),   DPI = 54.38%(DP = 0.75)



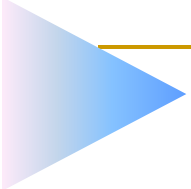
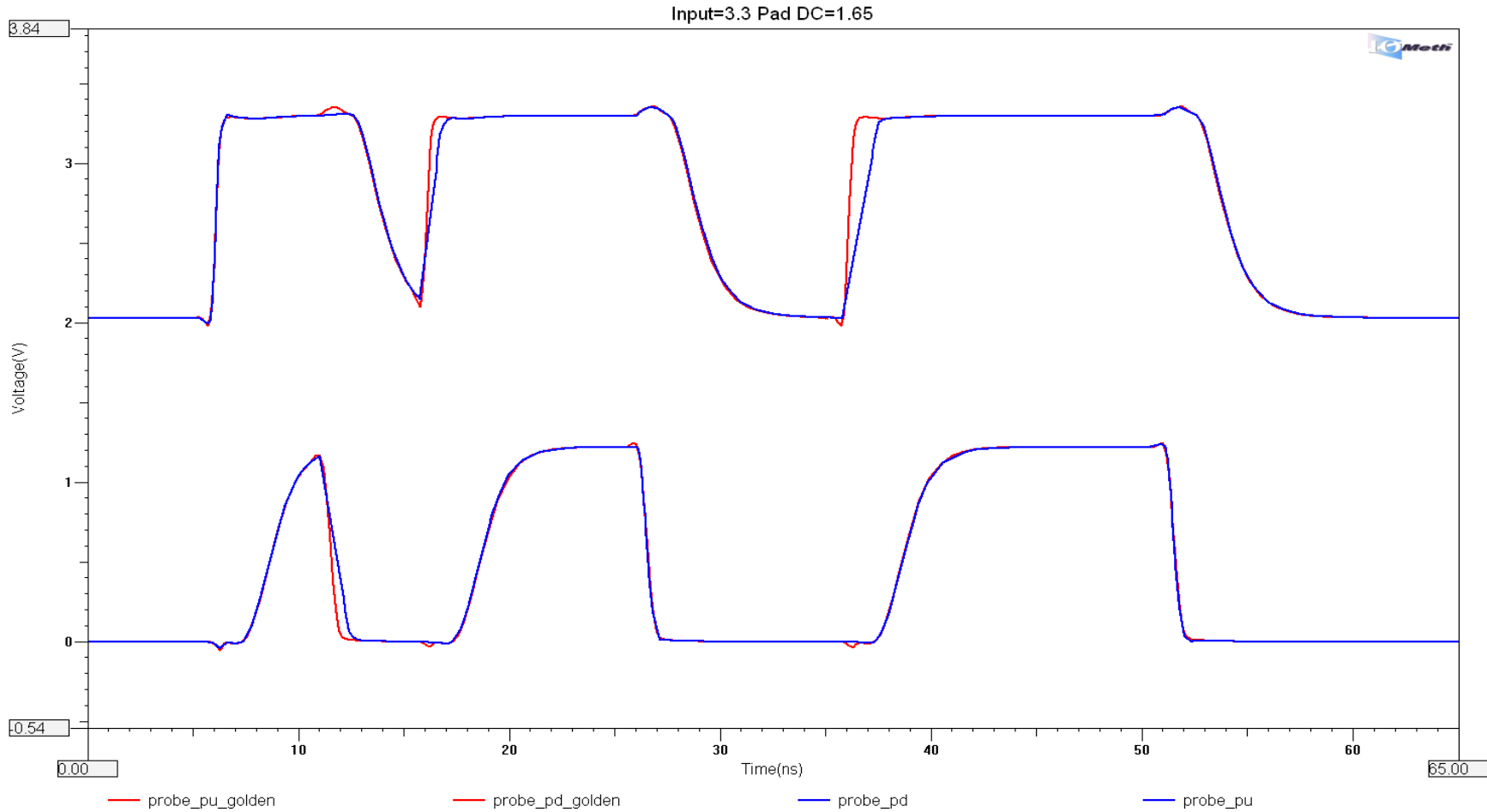


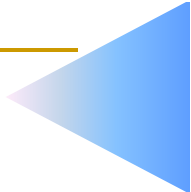
probe\_pd:           DAI = 1.09%(DA = 0.01),   DPI = 35.51%(DP = 0.46)  
probe\_pu:           DAI = 1.00%(DA = 0.01),   DPI = 35.71%(DP = 0.49)



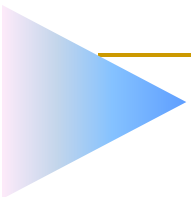
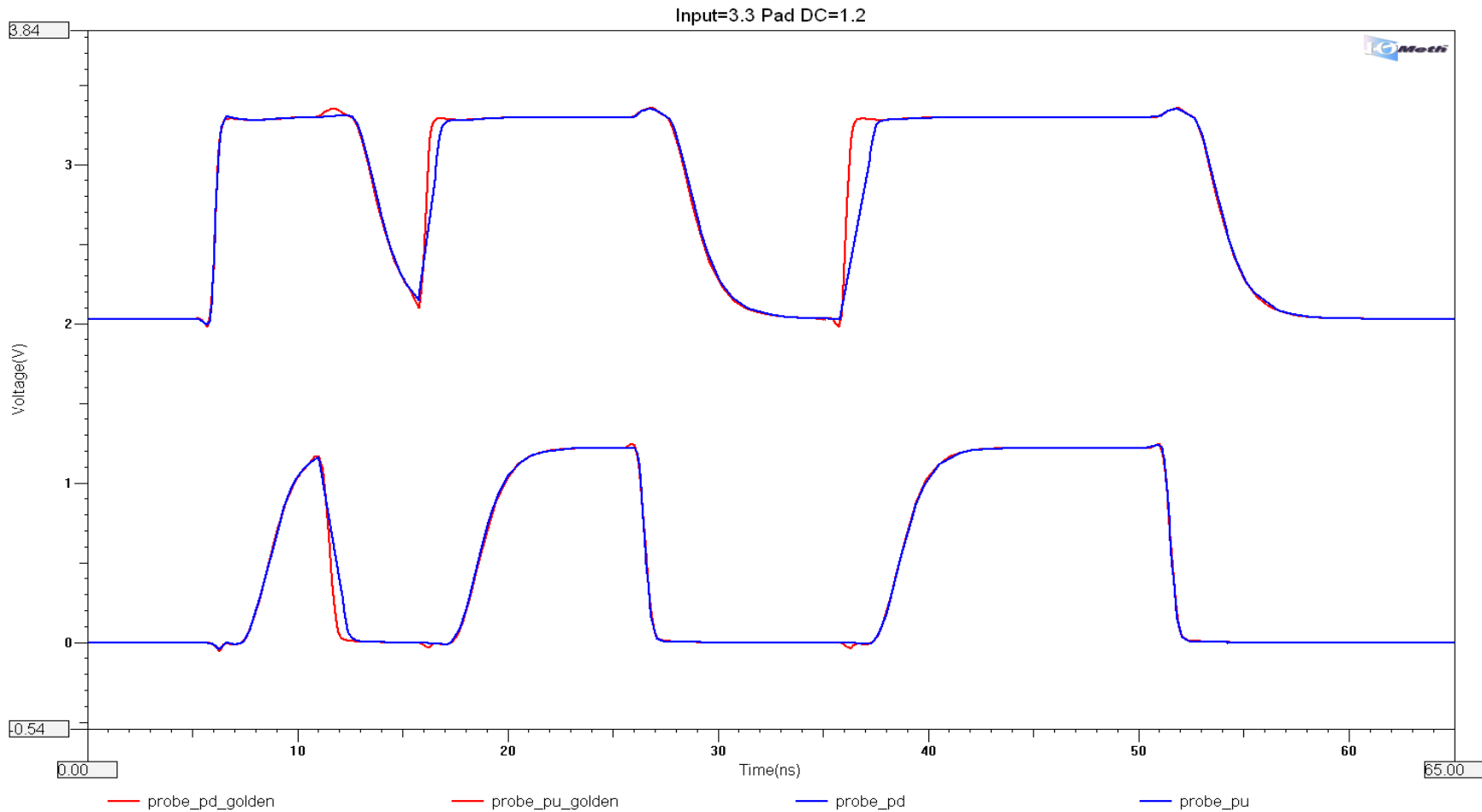


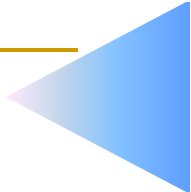
probe\_pd:           DAI = 0.62%(DA = 0.01),   DPI = 29.88%(DP = 0.39)  
probe\_pu:           DAI = 1.55%(DA = 0.02),   DPI = 55.03%(DP = 0.76)



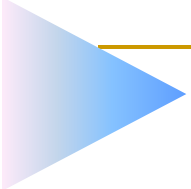
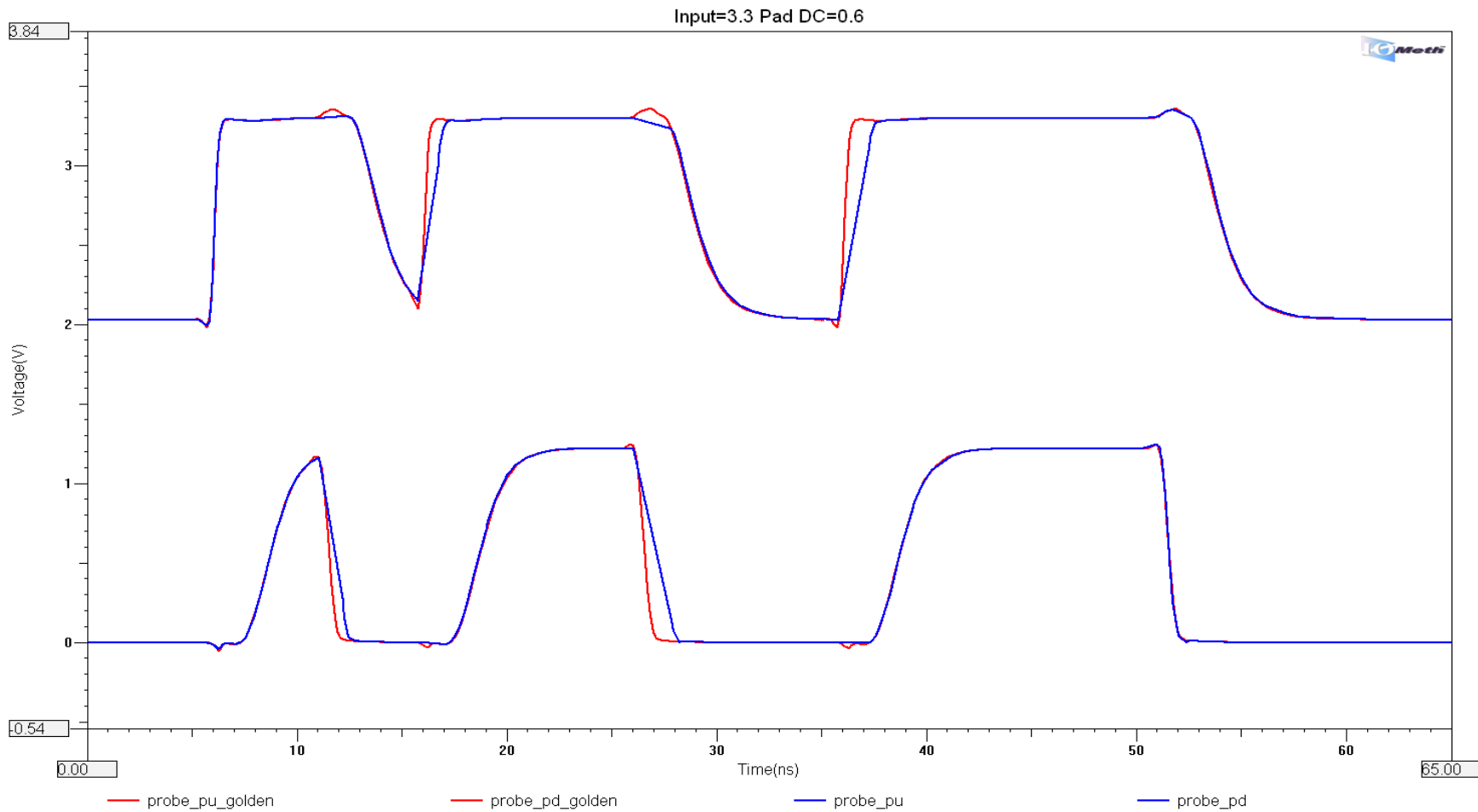


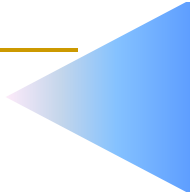
probe\_pd:           DAI = 0.60%(DA = 0.01),   DPI = 30.06%(DP = 0.39)  
probe\_pu:           DAI = 1.60%(DA = 0.02),   DPI = 55.03%(DP = 0.76)



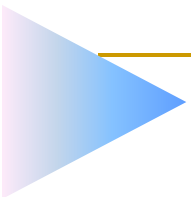
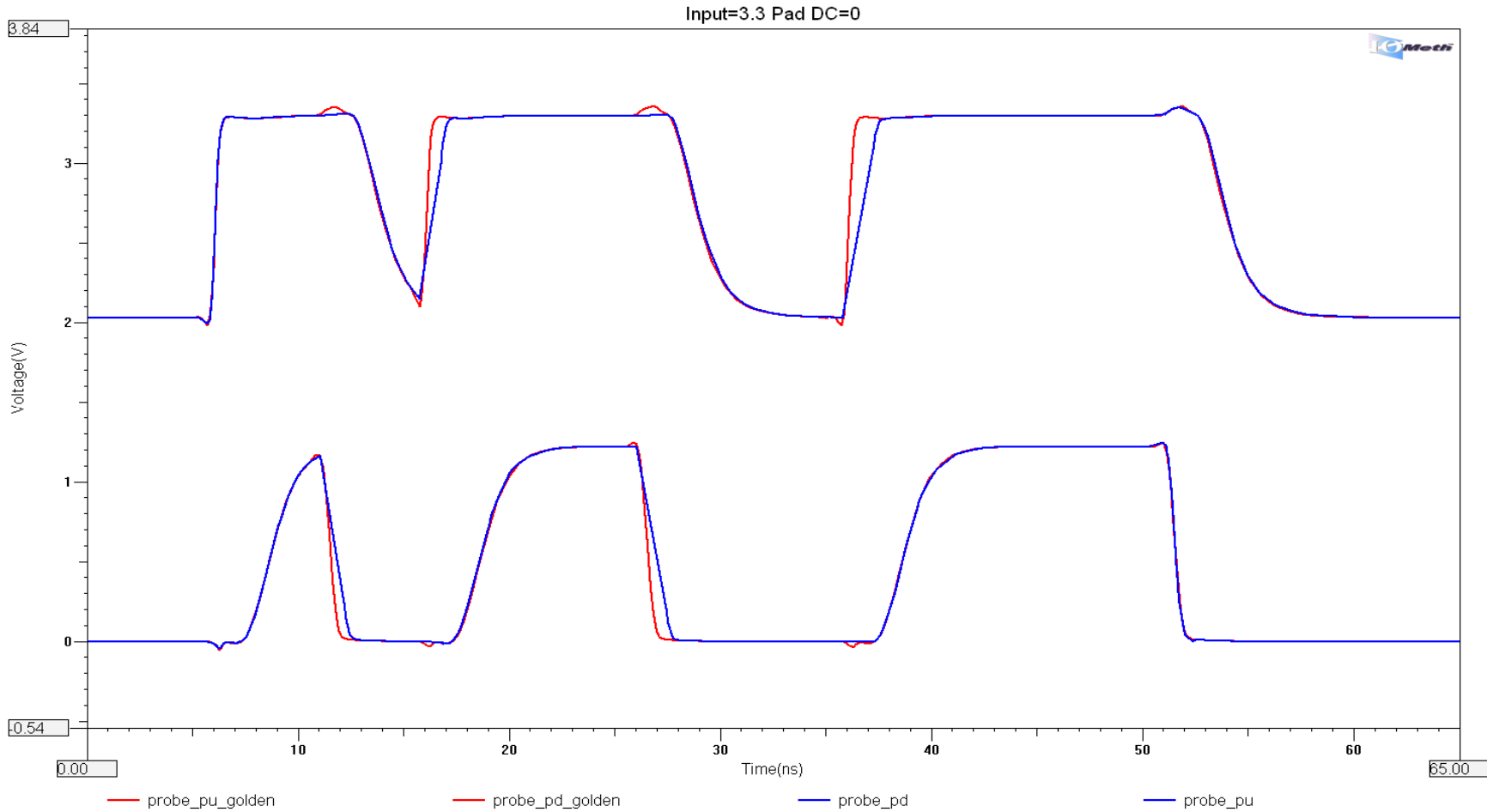


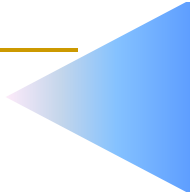
probe\_pd:           DAI = 1.43%(DA = 0.02),   DPI = 46.55%(DP = 0.60)  
probe\_pu:           DAI = 1.77%(DA = 0.02),   DPI = 54.50%(DP = 0.75)



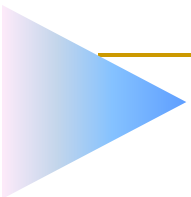
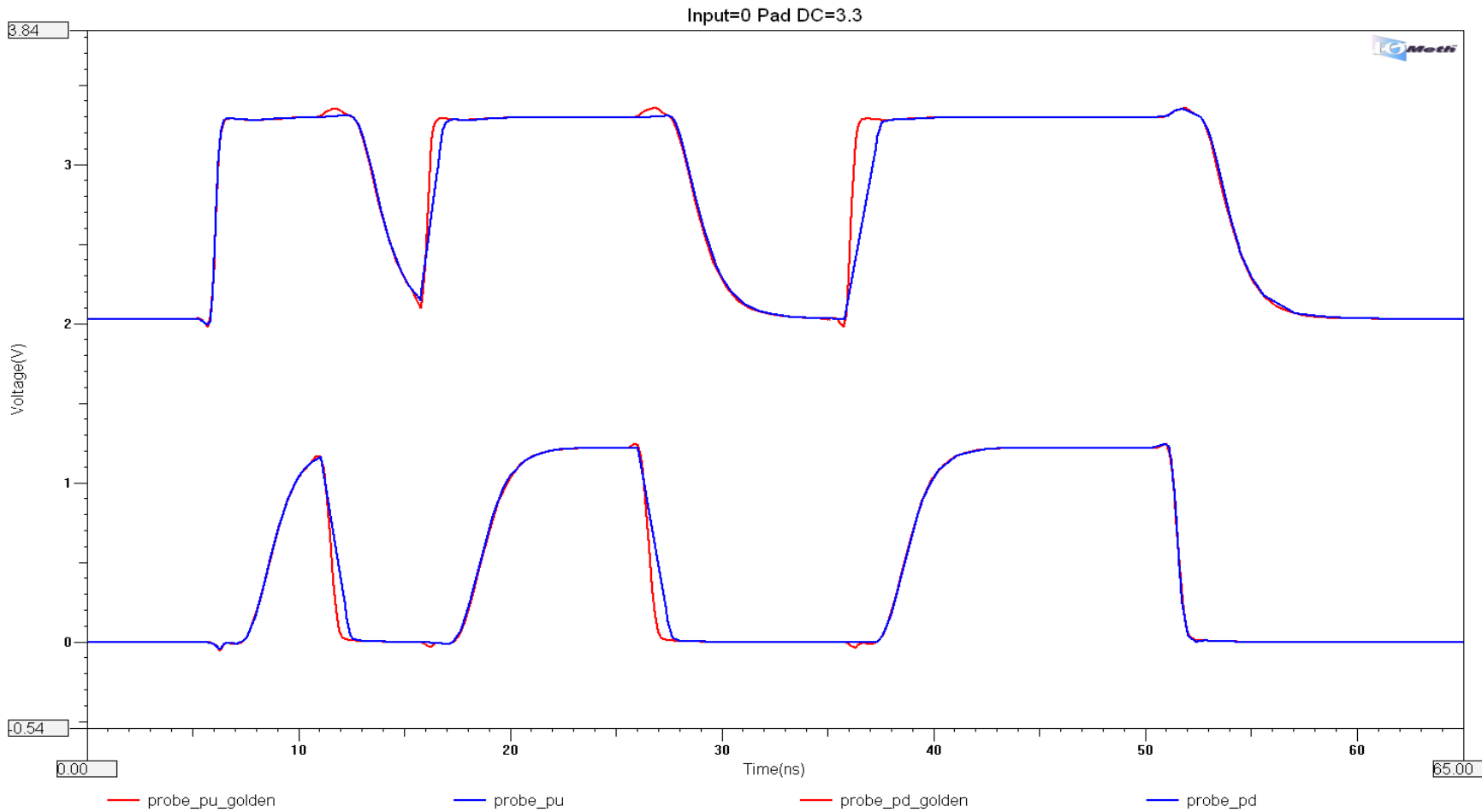


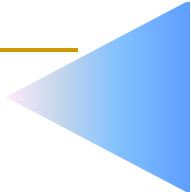
probe\_pd:           DAI = 1.14%(DA = 0.01),   DPI = 37.46%(DP = 0.48)  
probe\_pu:           DAI = 1.74%(DA = 0.02),   DPI = 54.52%(DP = 0.75)



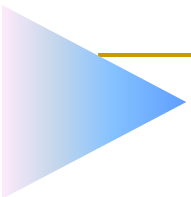
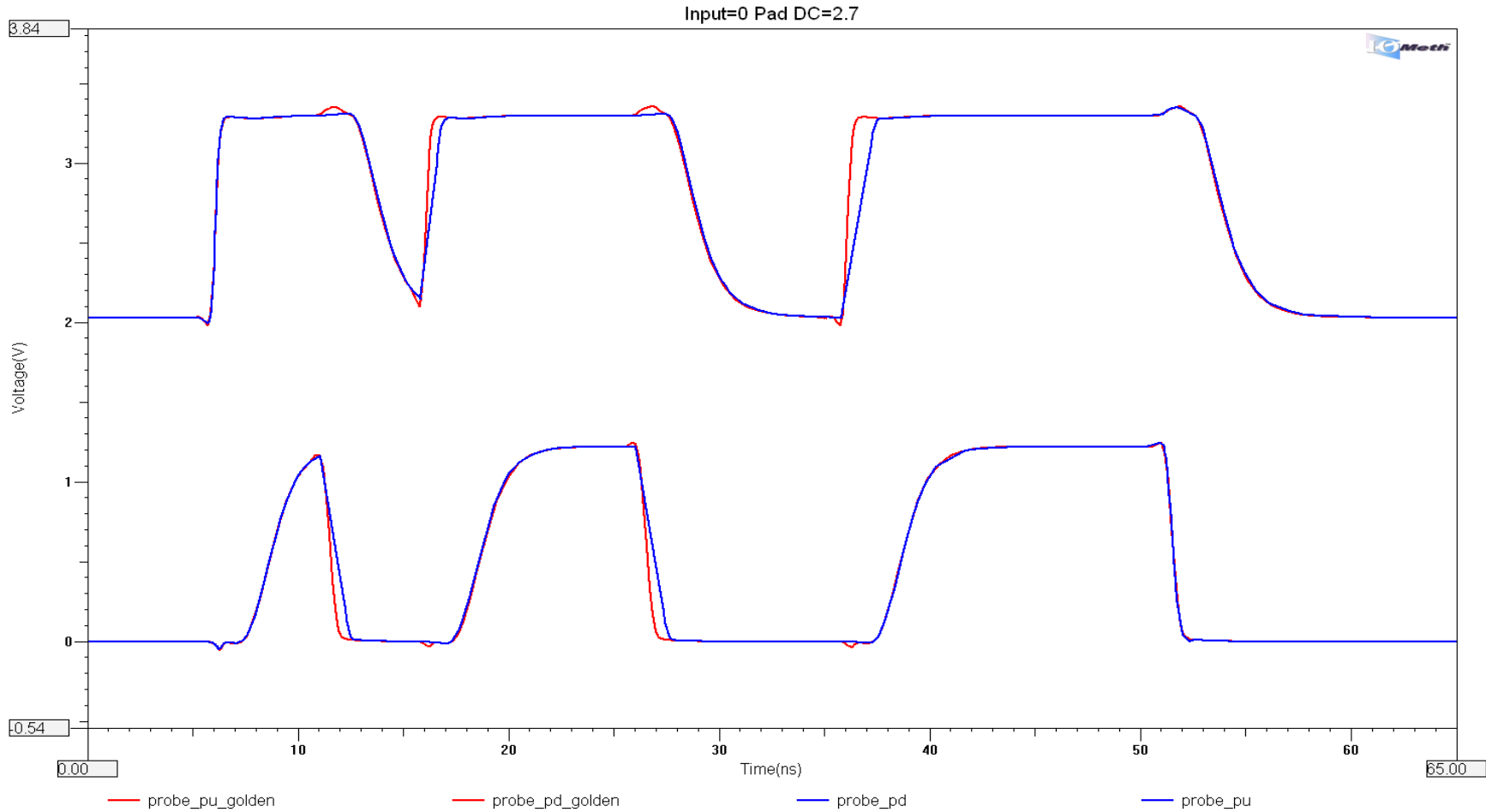


probe\_pd:           DAI = 1.08%(DA = 0.01),   DPI = 35.26%(DP = 0.46)  
probe\_pu:           DAI = 1.62%(DA = 0.02),   DPI = 54.66%(DP = 0.75)

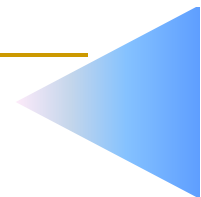




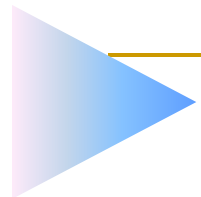
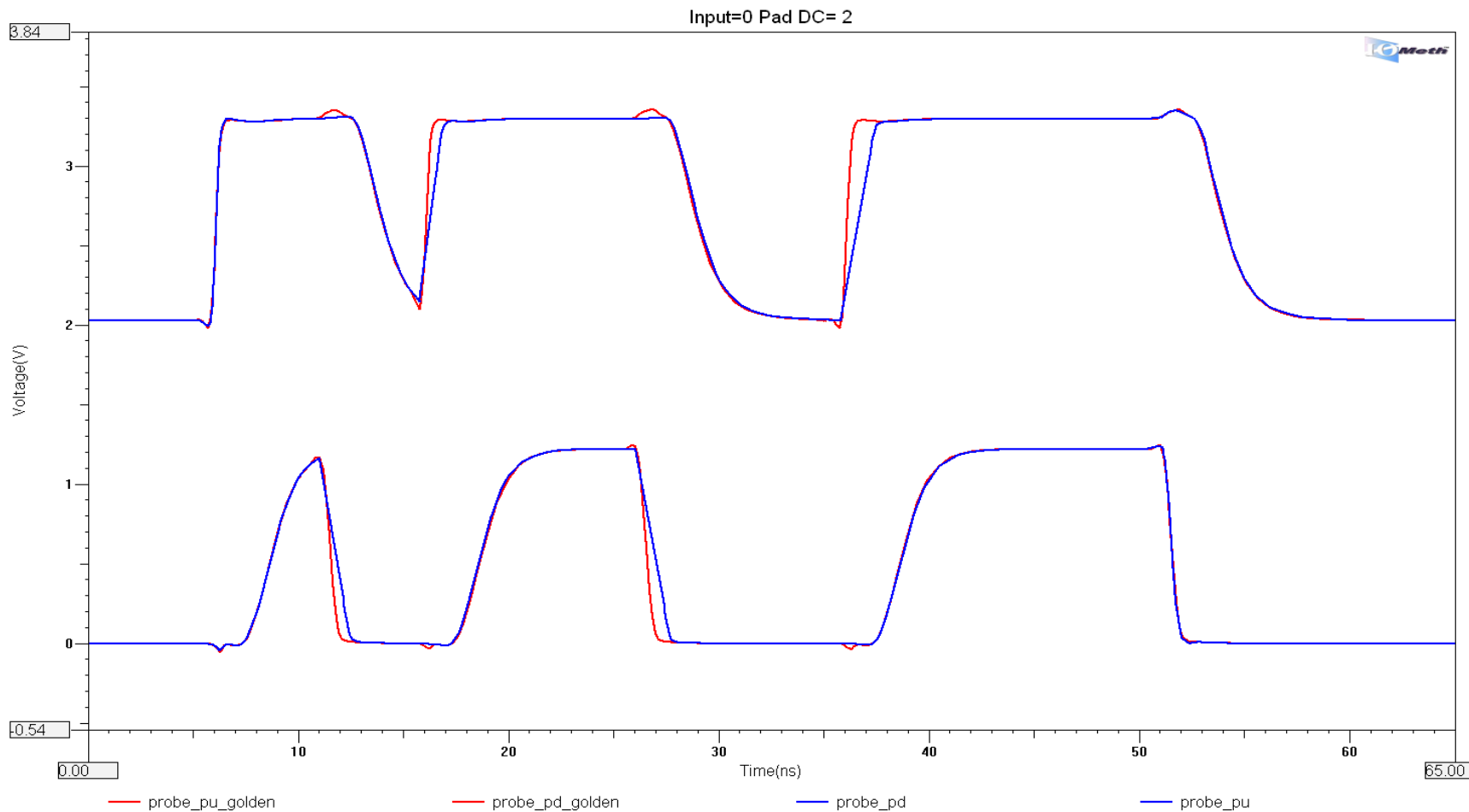
probe\_pd:           DAI = 1.08%(DA = 0.01),   DPI = 34.53%(DP = 0.45)  
probe\_pu:           DAI = 1.55%(DA = 0.02),   DPI = 53.37%(DP = 0.73)

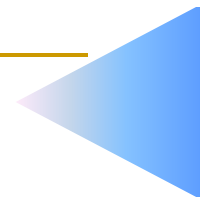




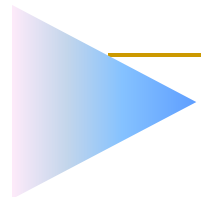
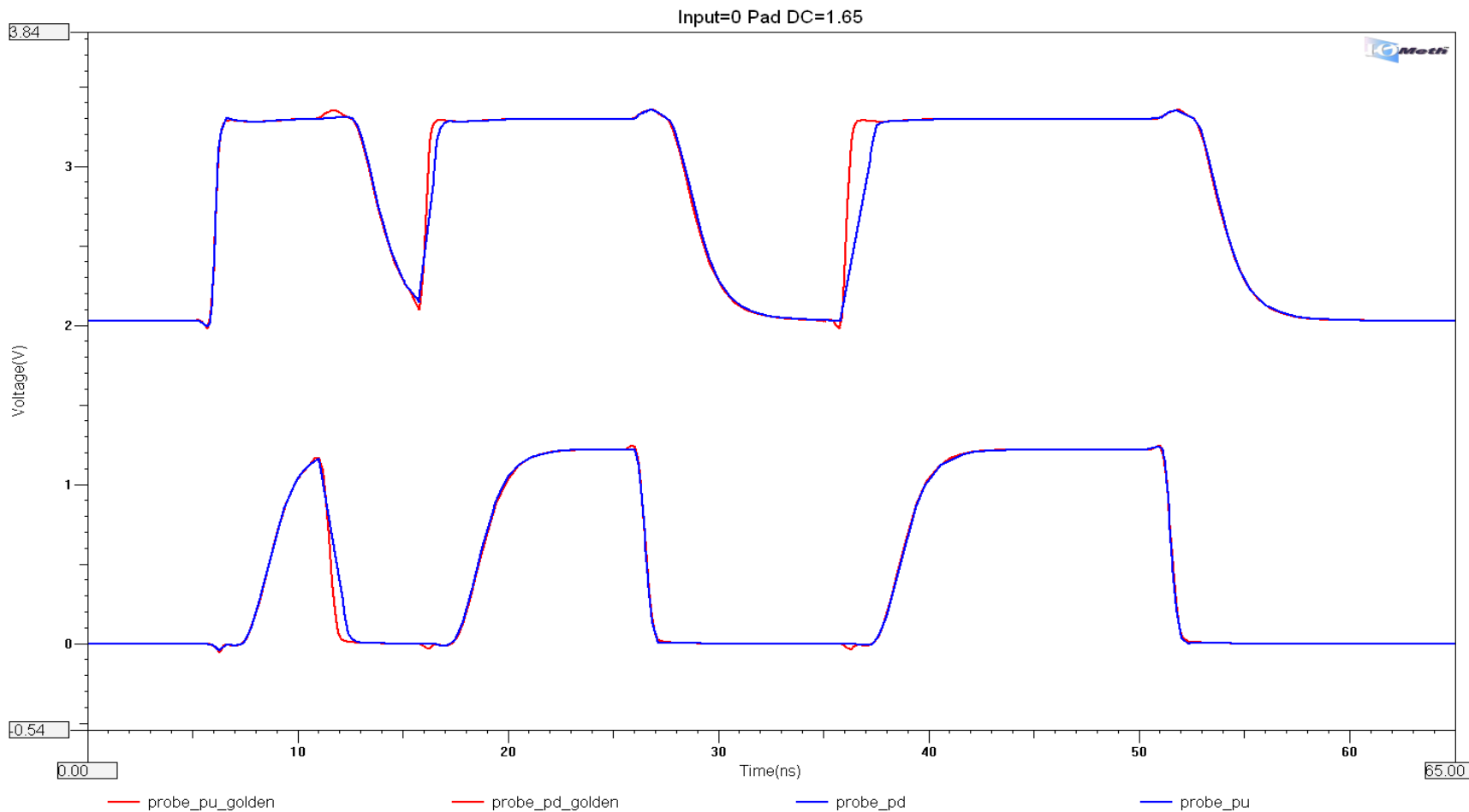


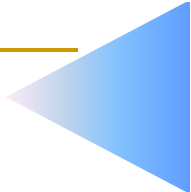
probe\_pd:           DAI = 1.15%(DA = 0.01),   DPI = 37.64%(DP = 0.49)  
probe\_pu:           DAI = 1.62%(DA = 0.02),   DPI = 54.44%(DP = 0.75)



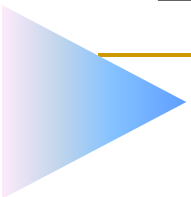
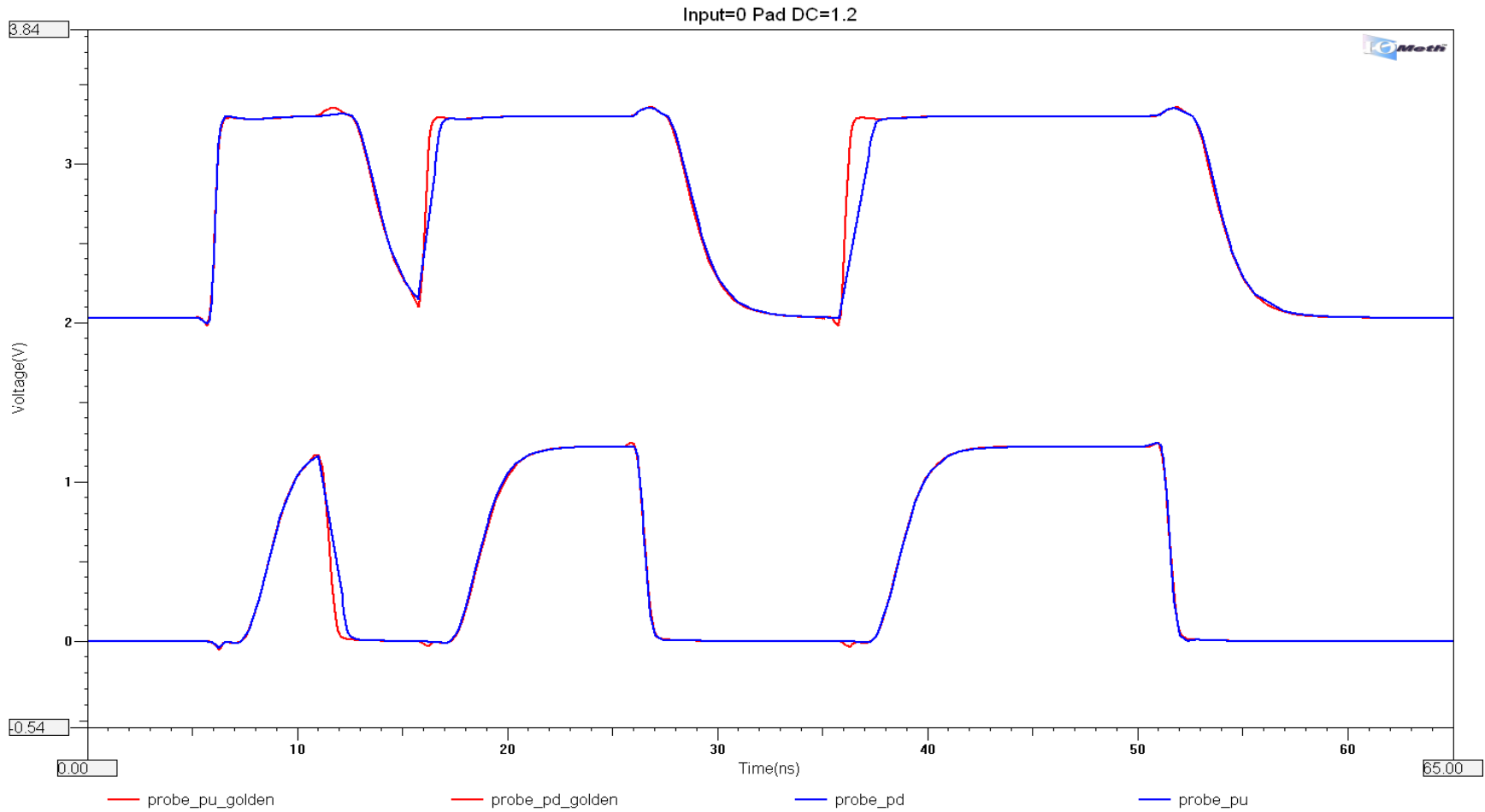


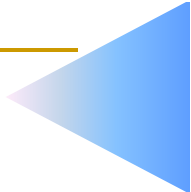
probe\_pd:           DAI = 0.62%(DA = 0.01),   DPI = 29.88%(DP = 0.39)  
probe\_pu:           DAI = 1.51%(DA = 0.02),   DPI = 54.96%(DP = 0.76)



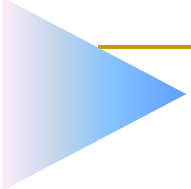
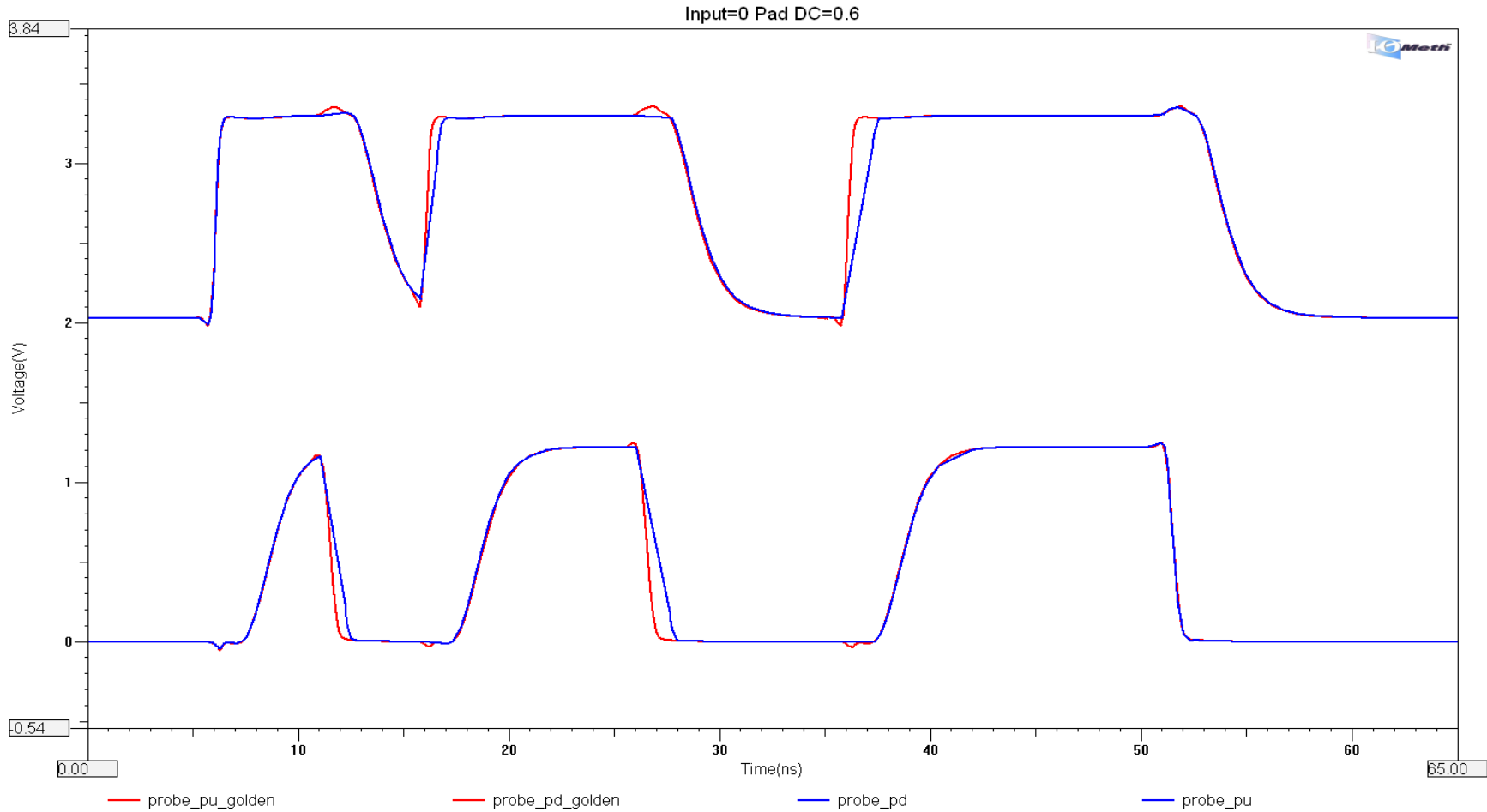


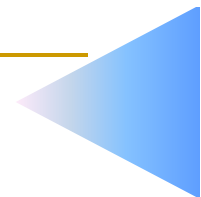
probe\_pd:           DAI = 0.59%(DA = 0.01),   DPI = 29.49%(DP = 0.38)  
probe\_pu:           DAI = 1.54%(DA = 0.02),   DPI = 54.71%(DP = 0.75)



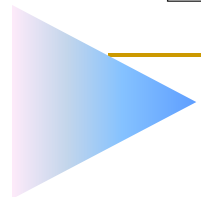
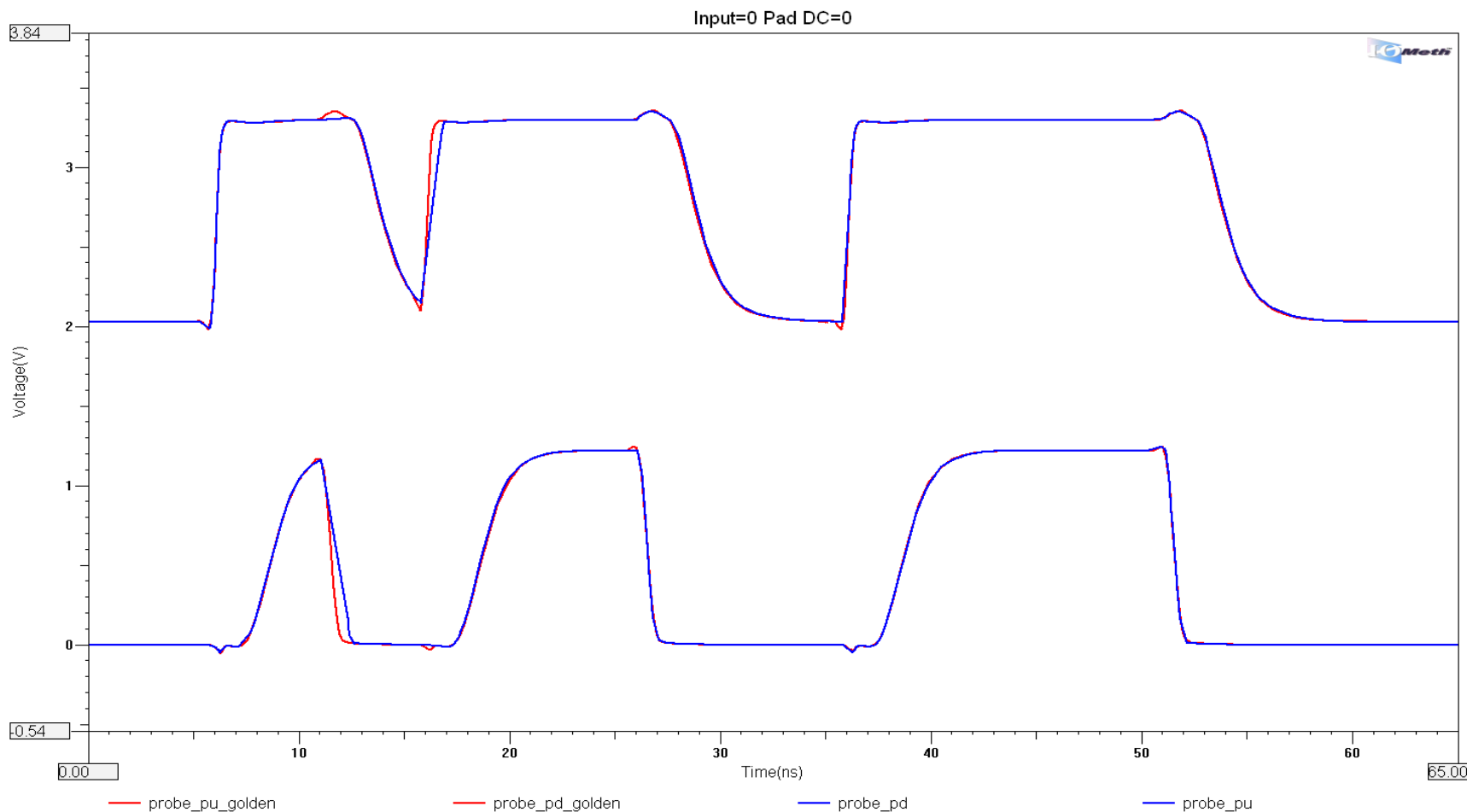


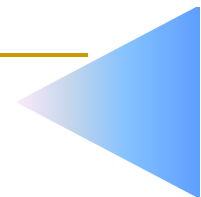
probe\_pd:           DAI = 1.30%(DA = 0.02),   DPI = 42.09%(DP = 0.54)  
probe\_pu:           DAI = 1.57%(DA = 0.02),   DPI = 54.27%(DP = 0.75)



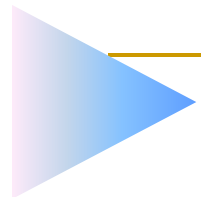
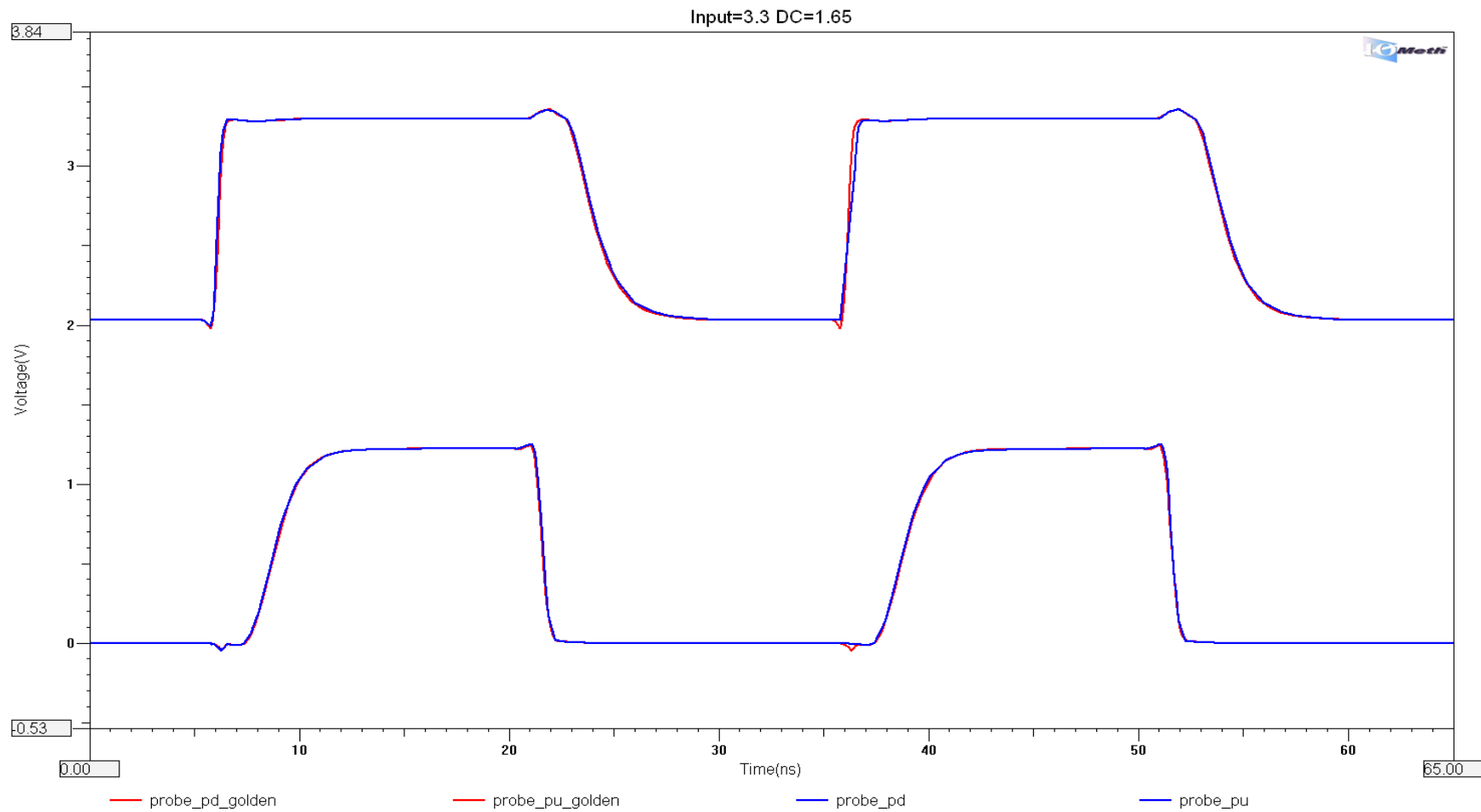


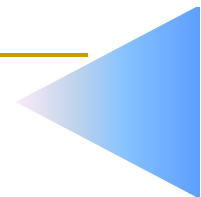
probe\_pd:           DAI = 0.61%(DA = 0.01),   DPI = 31.08%(DP = 0.40)  
probe\_pu:           DAI = 0.74%(DA = 0.01),   DPI = 34.45%(DP = 0.47)



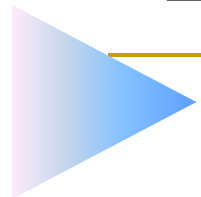
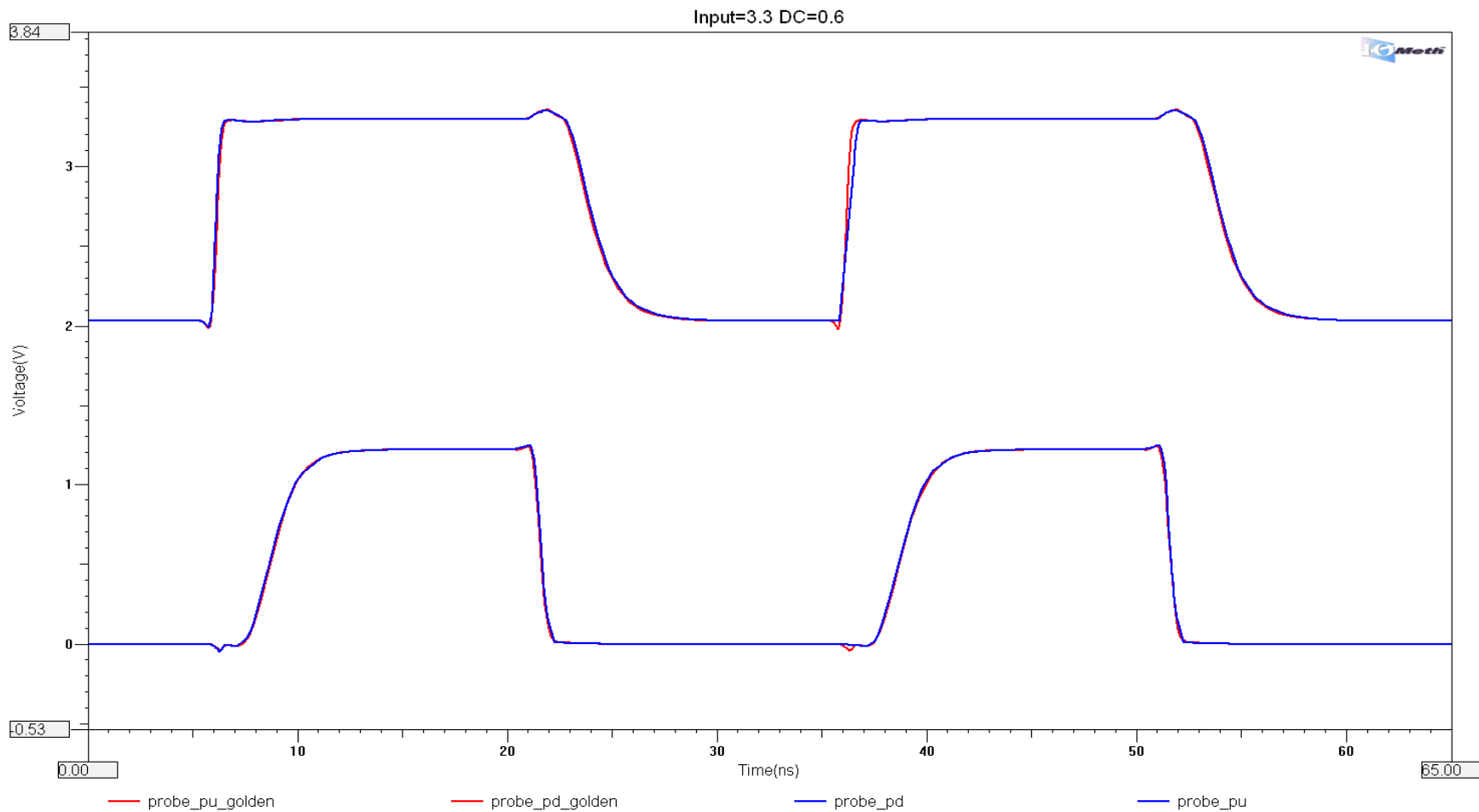


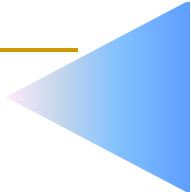
probe\_pd:           DAI = 0.29%(DA = 0.00),   DPI = 4.02%(DP = 0.05)  
probe\_pu:           DAI = 0.57%(DA = 0.01),   DPI = 24.18%(DP = 0.33)



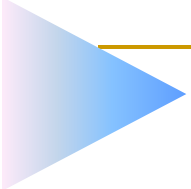
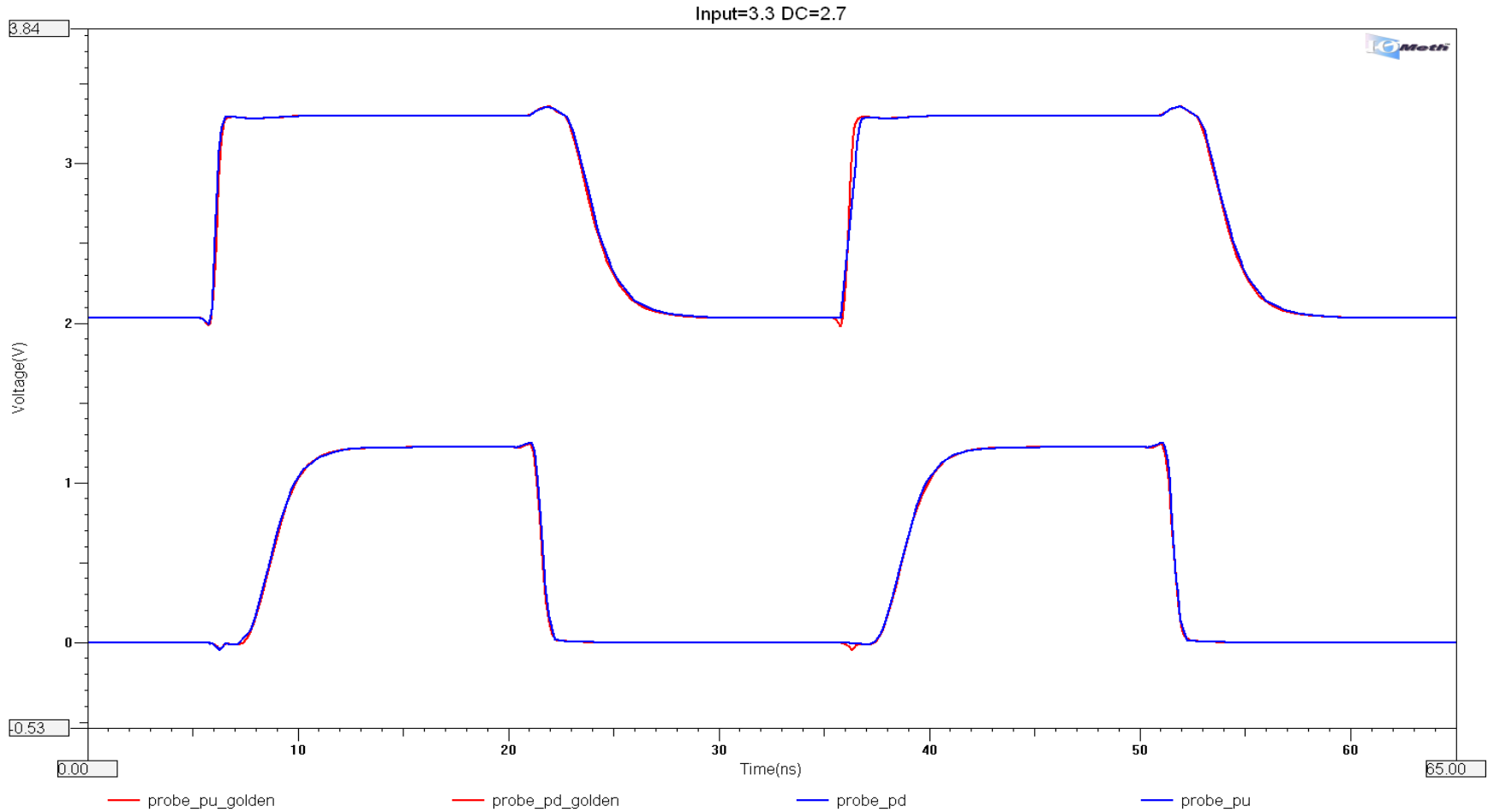


probe\_pd:           DAI = 0.30%(DA = 0.00),   DPI = 3.98%(DP = 0.05)  
probe\_pu:           DAI = 0.60%(DA = 0.01),   DPI = 26.99%(DP = 0.37)

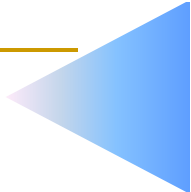




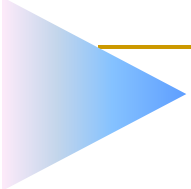
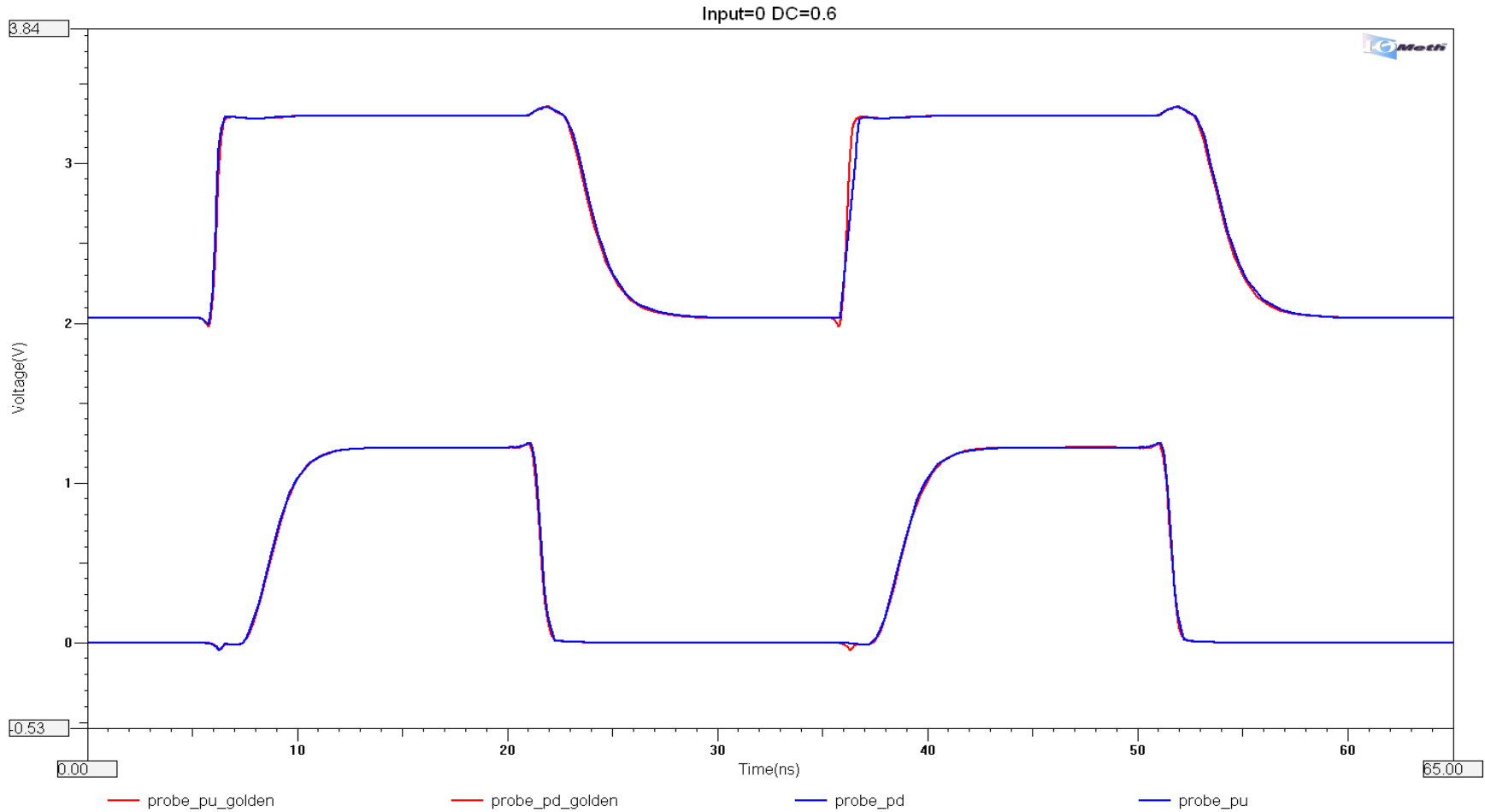
probe\_pd:           DAI = 0.30%(DA = 0.00),   DPI = 4.02%(DP = 0.05)  
probe\_pu:           DAI = 0.58%(DA = 0.01),   DPI = 25.65%(DP = 0.35)

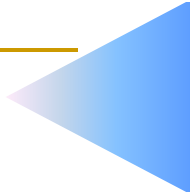




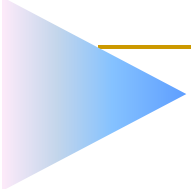
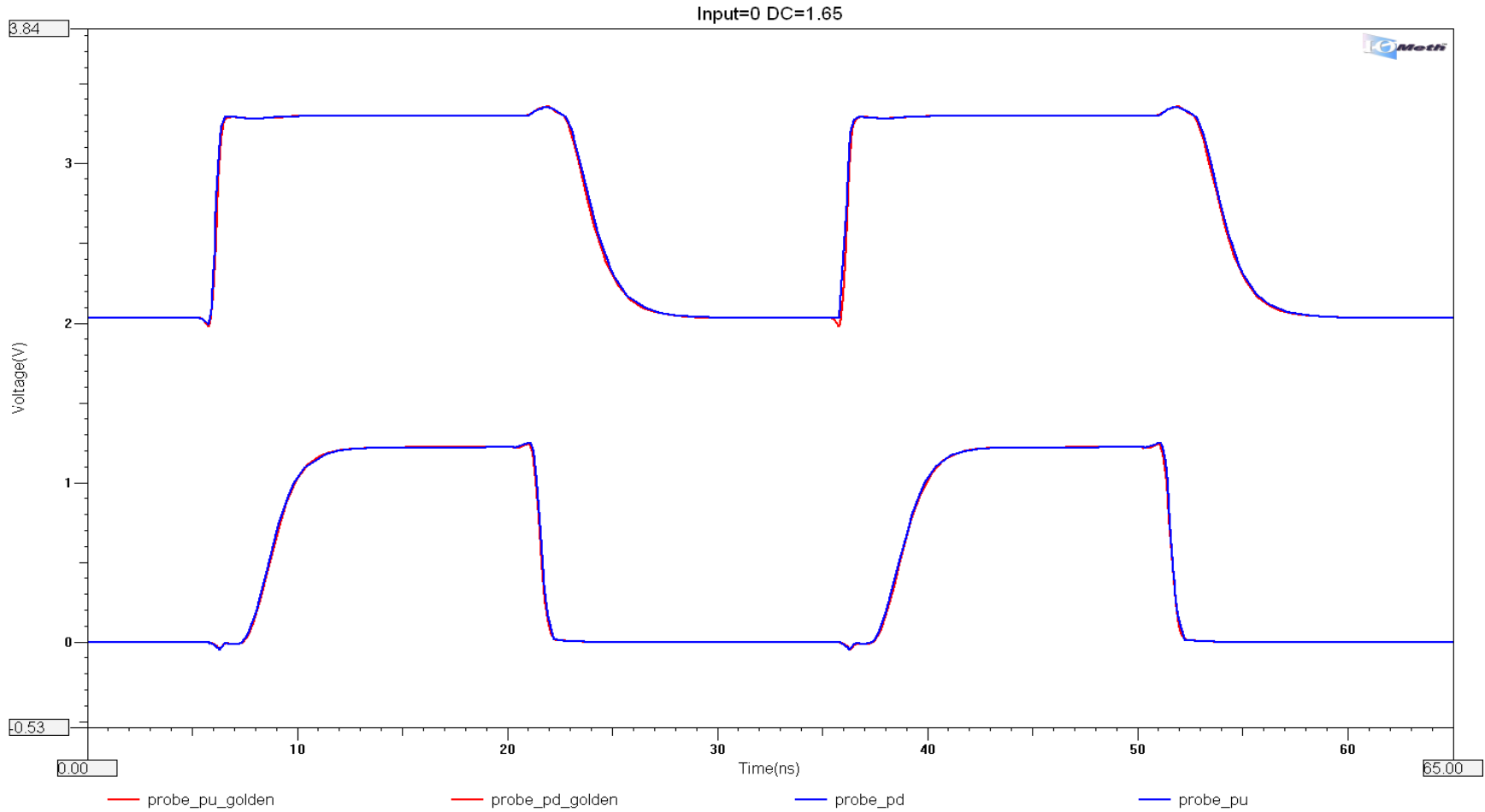


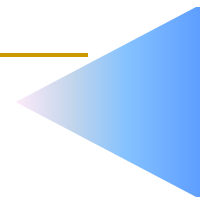
probe\_pd:           DAI = 0.29%(DA = 0.00),   DPI = 3.83%(DP = 0.05)  
probe\_pu:           DAI = 0.61%(DA = 0.01),   DPI = 28.39%(DP = 0.39)





probe\_pd:           DAI = 0.27%(DA = 0.00),   DPI = 4.00%(DP = 0.05)  
probe\_pu:           DAI = 0.48%(DA = 0.01),   DPI = 17.30%(DP = 0.24)





probe\_pd:           DAI = 0.27%(DA = 0.00),   DPI = 4.01%(DP = 0.05)  
probe\_pu:           DAI = 0.47%(DA = 0.01),   DPI = 17.38%(DP = 0.24)

