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Accurate IBIS model for IOs having multiple drivers causing dual-slope

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Agenda

- # Challenges
- # Circuit brief
- # Modeling using Driver Schedule
- # Results

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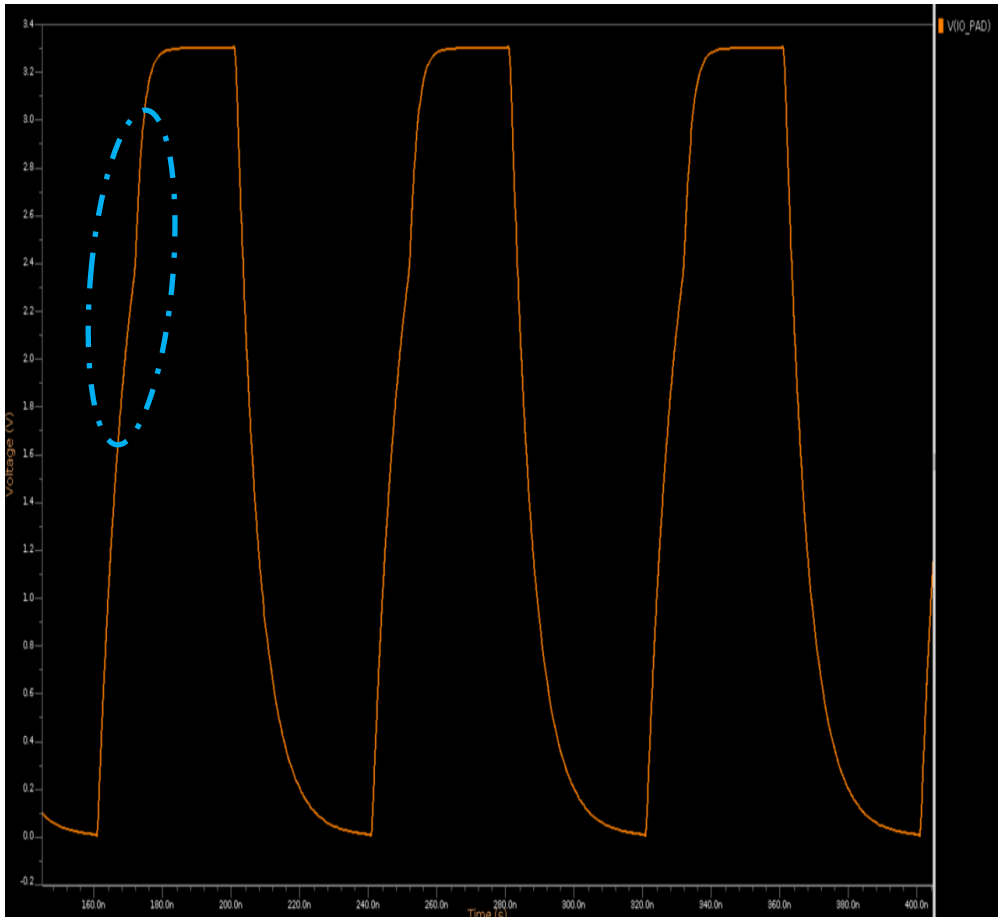
Challenges 1/3

IO Circuit Design Perspective

- Non-conventional IO design due to
  - Technology
    - Design using limited device availability.
    - Device characteristic limitation.
    - High voltage devices to be used in low voltage application and vice versa
  - Electrical specification
    - Specs over wide range of PVT corner.
    - Application induced specs like Multiple drive strengths, slews etc.
    - Stringent specs for rise/fall time and relaxed specs for delay.



IO design having dual slope rising edge.

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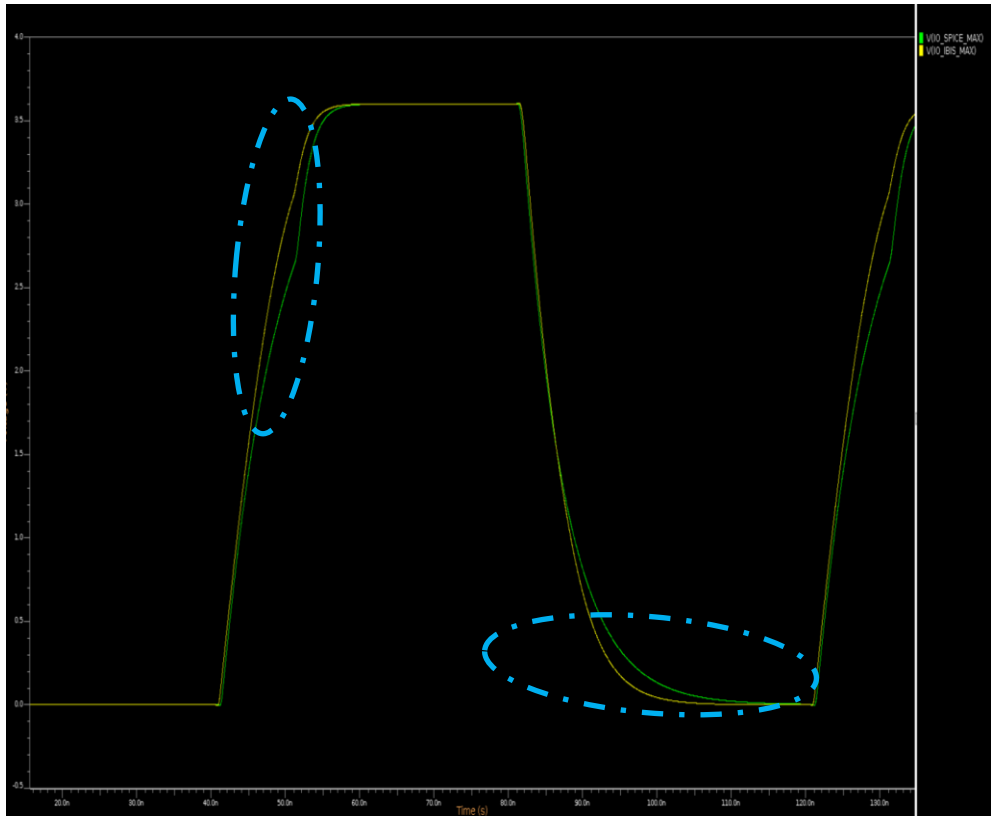
Challenges 2/3

IBIS Model Development Perspective

- Challenges due to non-conventional IO design
  - To replicate IBIS behavior as close as circuit behavior, Model developer need to select most suited IBIS keyword ([Driver Schedule], C_fixture etc..) from BIRDs.
  - To extract correct raw data for accurate IBIS model.
    - Schematic netlist alteration for intended data extraction
    - Multiple simulation setups
    - Data merging & formatting
  - To deliver efficient IBIS Model
    - It will enable smooth, efficient & effortless integration at board level.

No extra information need to pass to SI engineer for integration of multiple models, as for example scheduling : enable one model and after some specified time enable other model for same pin.



IBIS vs SPICE mismatch for dual slope Rise edge IO circuit

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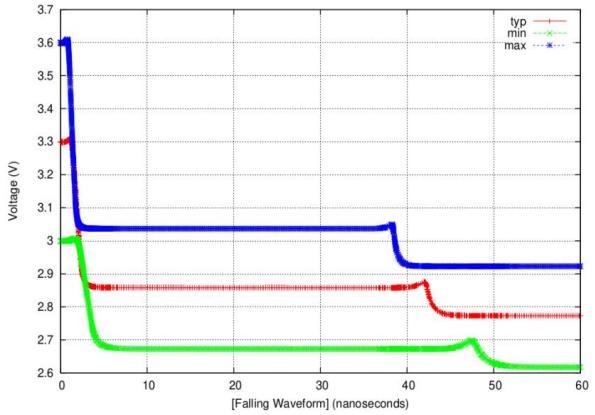
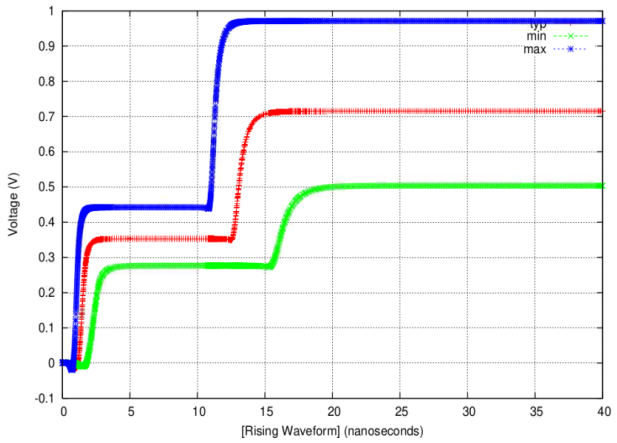
Challenges 3/3

- IBIS model for IOs having two drivers to make rise time faster (with same rise delay).
  - IBIS modeling with regular keyword does not suffice.
    - Regular IBIS keywords

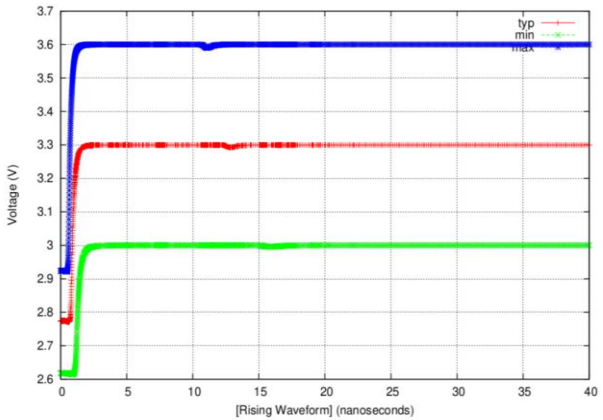
      [Pulldown] ,[Pullup], [POWER Clamp], [GND Clamp], [Rising Waveform], [Falling Waveform], C_comp etc..
  - Waveform table is having two levels in this case (shown in snapshot).
  - Special IBIS keyword to replicate this circuit behavior, like [Driver Schedule] for this scenario.



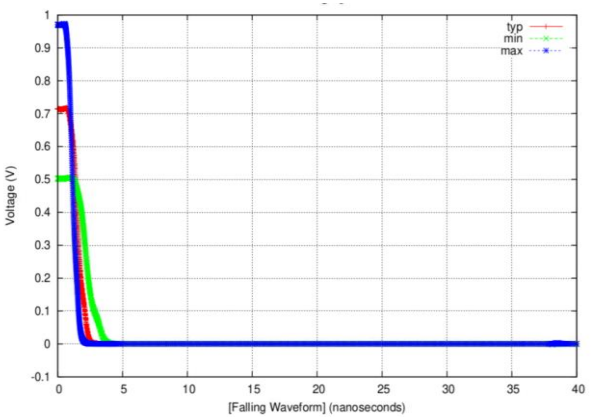
Falling High waveform



Rising Low waveform



Rising High waveform



Falling Low waveform

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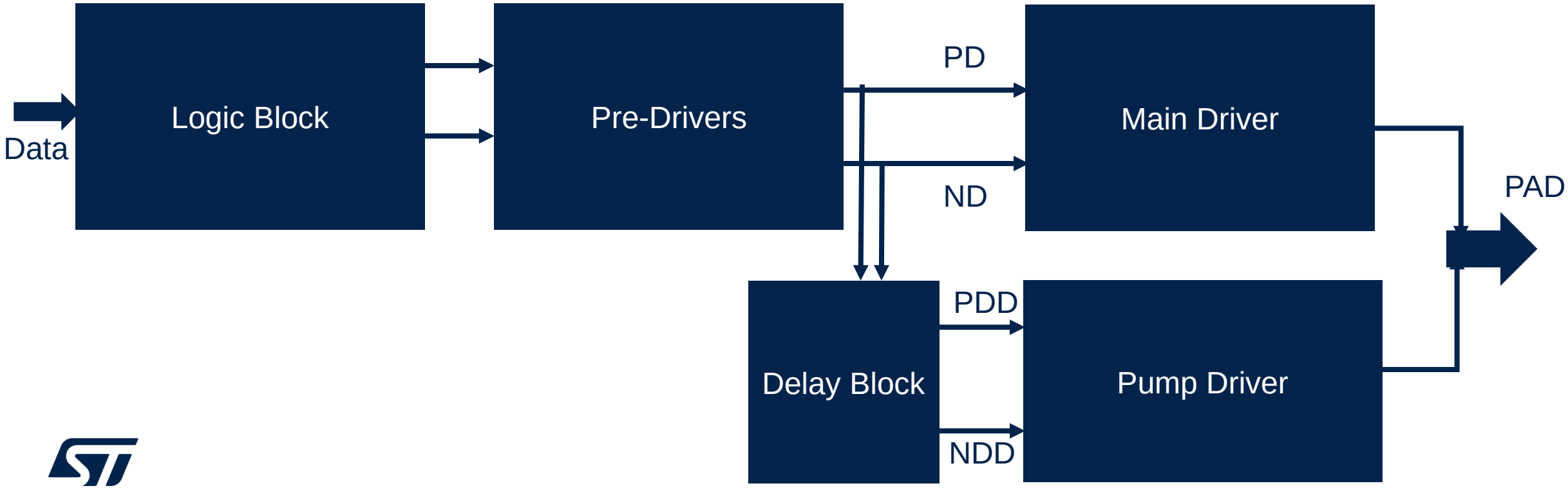
Circuit Brief 1/2

- **IO circuit is having two drivers**
  - Main driver : normal pullup-pulldown driver
  - Pump/push driver : always off pulldown; start pumping current when main driver pullups pad to some extent. Resulting in dual-slope rise edge.



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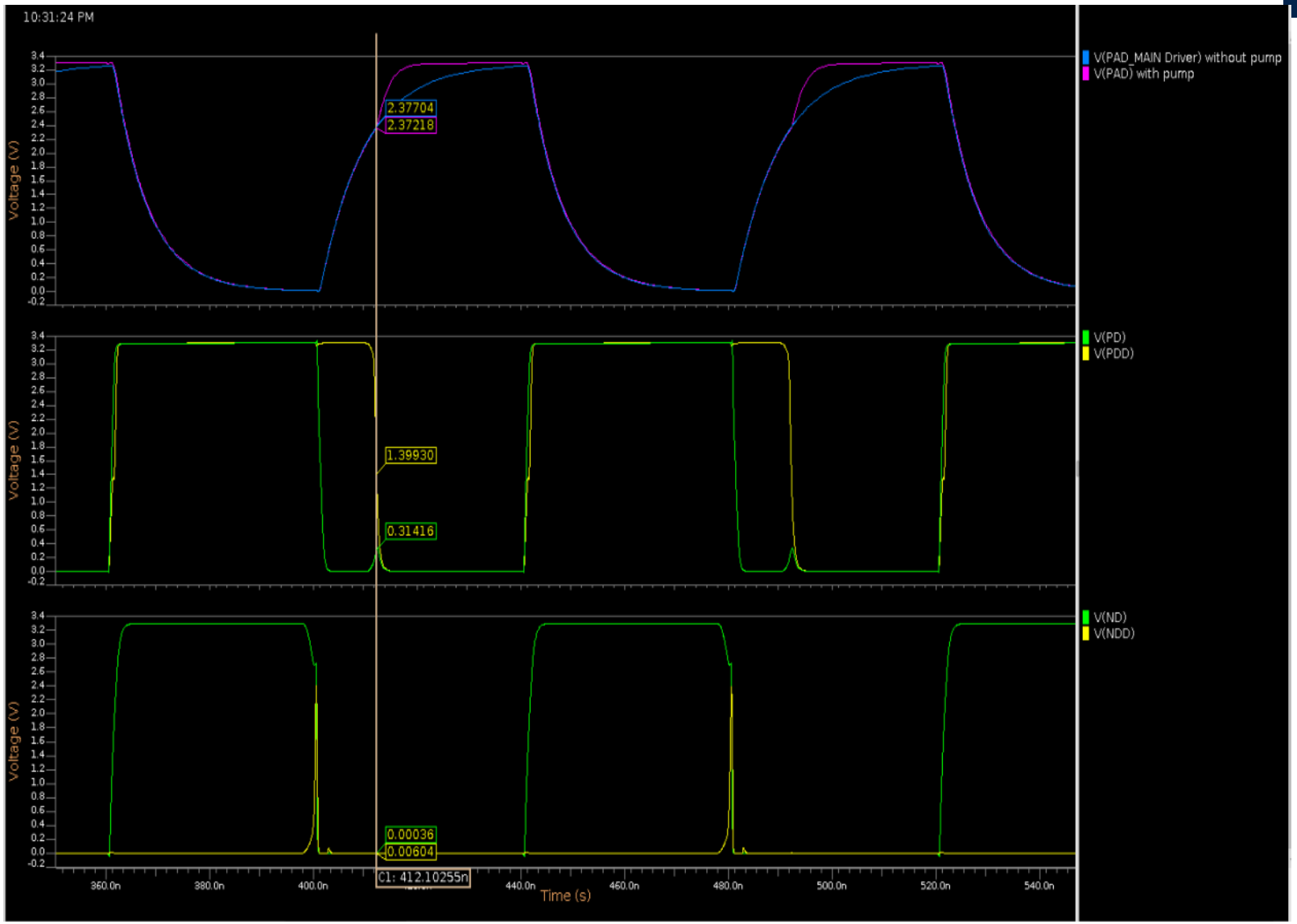
Circuit Brief 2/2

- **PD** : main driver PMOS input.
- **ND** : main driver NMOS input.
- **PDD** : PMOS input of pump driver. Its fall edge is delayed version of PD.
- **NDD** : NMOS input of pump driver, kept at logic low.



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Modeling using Driver Schedule 1/2

Model Generation flow

Steps	Action
Setup	✓ Update the schematic netlist for main driver & pump driver. ▪ Main driver : disconnect output net of pump driver from PAD ▪ Pump driver : disconnect output net of main driver from PAD ✓ Create Data extraction setup for 3 cells : TOP, main driver & Pump driver.
Generation	✓ 3 IBIS model for top, main and pump driver.
Post Processing	✓ Update “[POWER Clamp], [GND Clamp]” of main and pump driver, to keep limited data (only 2 points). ✓ TOP cell Model ▪ Update [Pullup] [Pulldown] table to keep limited information. (only 2 points) ▪ Remove waveform tables, kept only [Ramp] data ▪ Add [Driver Schedule] for timing scheduling ✓ Keep scheduled model (main_driver, pump_driver) in .ibs file, without defining it under [Pin] section.

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Modeling using Driver Schedule 2/2

Final IBIS Model template

```
[Model]     TOP_CELL
|-----------------------------------------------
|
[Driver Schedule]
| Model_name Rise_on_dly Rise_off_dly Fall_on_dly Fall_off_dly
main_driver 0.0nS NA 0.0nS NA
pump_driver 0.0nS NA 0.0nS NA
|
|-----------------------------------------------
[POWER Clamp]
|-----------------------------------------------
|-----------------------------------------------
[GND Clamp]
|-----------------------------------------------
|-----------------------------------------------
[Pullup]
[Pulldown]
[Ramp]
|
[Model]     main_driver
|-----------------------------------------------
|-----------------------------------------------
[POWER Clamp]
[GND Clamp]
[Pullup]
|-----------------------------------------------
|-----------------------------------------------
[Pulldown]
|-----------------------------------------------
|-----------------------------------------------
[Ramp]
[Rising Waveform]
| rising high data
[Falling Waveform]
| Falling high data
[Rising Waveform]
| rising low data
[Falling Waveform]
| falling low data

|
[Model]     pump_driver
|-----------------------------------------------
[POWER Clamp]
[GND Clamp]
[Pullup]
|-----------------------------------------------
|-----------------------------------------------
[Pulldown]
|-----------------------------------------------
|-----------------------------------------------
[Ramp]
|
[Rising Waveform]
| rising high data
[Falling Waveform]
| Falling high data
[Rising Waveform]
| rising low data
```

Schedule timing

Top Model

Scheduled Models

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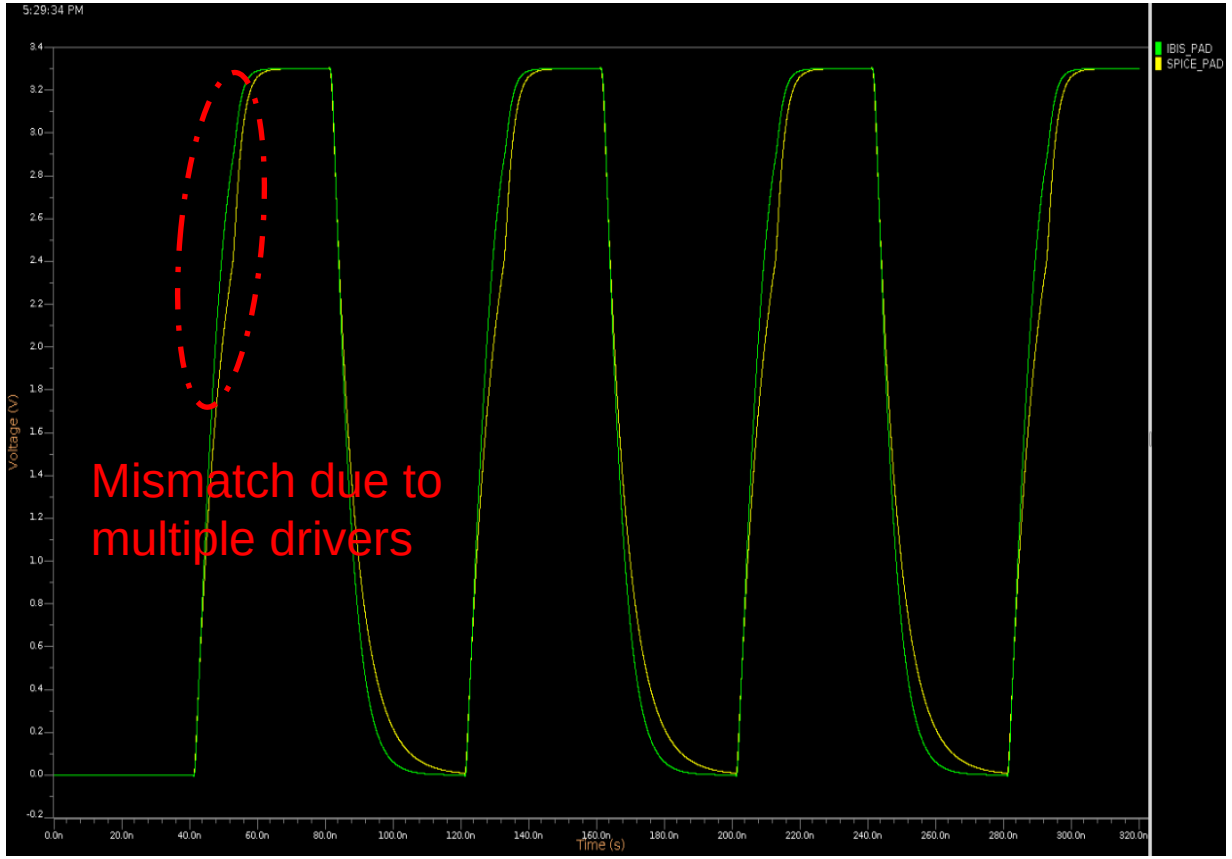
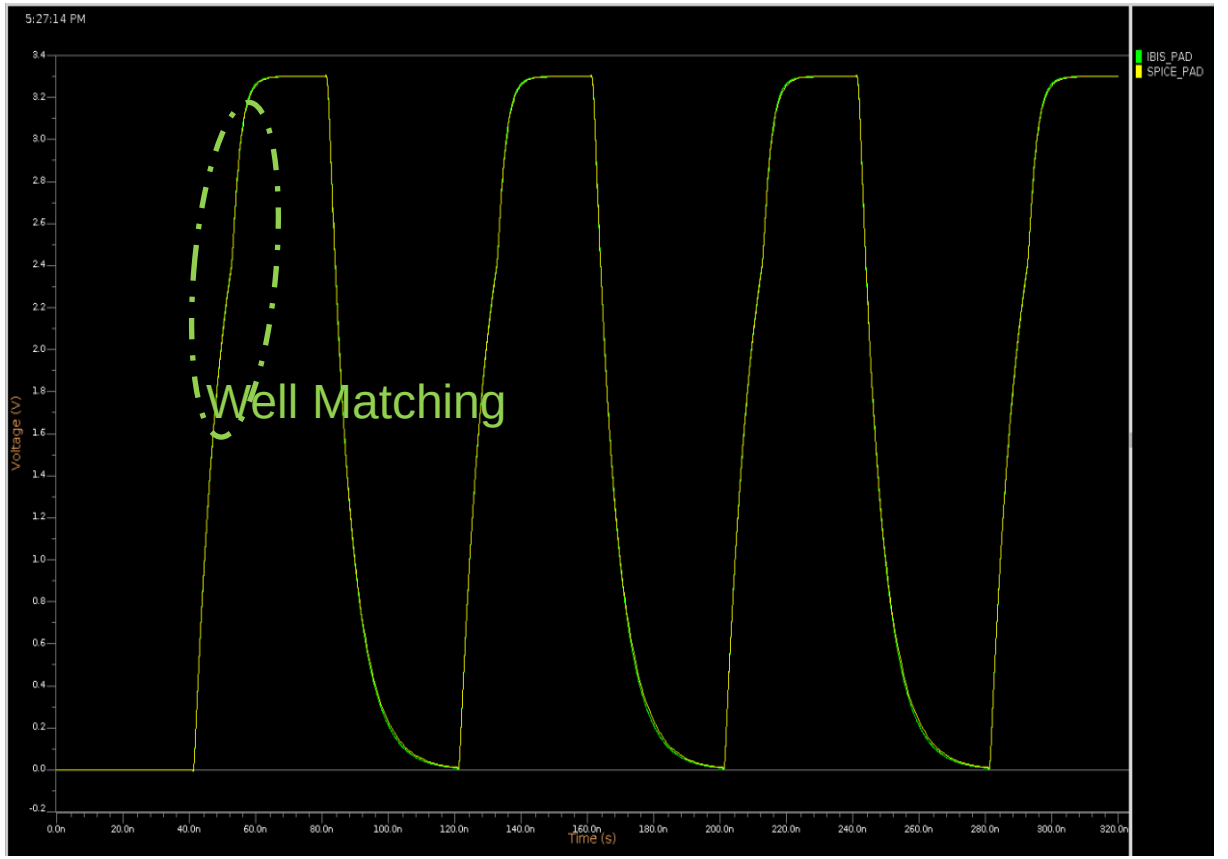
Results

- IBIS vs SPICE correlation
  - >99% matching correlation when schedule model tables has been used by driver scheduling timing.



IBIS Model developed with normal Keywords



IBIS Model developed with [Driver Schedule]

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