Sensitivity Analysis of IBIS-parameters with HSPICE

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Overview

- Motivation
- **Sensitivity analysis** main focus of the design process
- Scaling of the *static / dynamic curves* of a **IBIS model**
- Sensitivity analysis with a **IBIS-model**
- Summary
Motivation

- Confidence level of the IBIS-Model
- Model adjustments to the Golden Waveform
- Timing Budget of the design very small
- Application different to the IBIS-model conditions
- Design robustness has to be evaluated

Which parameter variation of the IBIS-model have the greatest impact to the time delay on the PCB?
Design Methodologies

- **Timing Spreadsheet (Worst-Case and Statistical)**
  - Uncertainty of Reference Voltage (Vth) and Loads
  - Signal integrity / ISI and EMC
  - Different Topologies
  - Thermal considerations

- **Design Solution Space** = (Electrical + Layout + Thermal) Requirements

- **→ Sensitivity Analysis ←**
  - Initial *Monte Carlo* Analysis → *significance* and *trend* of each variable
  - Determine Corner conditions
  - Eye Diagrams / fix ISI

- **Design Guidelines (only) for the actual project**
Localization of the actual analysis

Focus of investigation

Subsystem A

Subsystem B
Input-Output Buffer (HSPICE)
Scaling / tuning possibilities (HSPICE)

- pc_scal
- gc_scal
- Input Package
- GND Clamp
- Enable Package
- Power Clamp
- GND Clamp
- Threshold & Enable Logic
- Pull up Ramp
- Pull up V/I
- Power Clamp
- Output Package
- rwf_scal
- pu_scal
- pc_scal
- fwf_scal
- spd_scal
- fwf_tune
- spu_scal
- gc_scal
- pd_scal
- Enable Package
- fwf_scal
- pc_scal
- GND Clamp
- GND Clamp
- GND Clamp
HSPICE Syntax of an I/O-Buffer

```
B_IO nd _pu nd _pd nd _out nd _in nd _en V _out_of _in [nd _pc nd _gc]
+ file='file_name' model='model_name'
+ [typ={typ}|min|max|fast|slow} [power={on}|off}]
+ [buffer={3|input|output}]
+ [xv _pu=state _pu] [xv _pd=state _pd]
+ [interpol={1|2}]
+ [ramp _fwf={2|1|0}] [ramp _rfw={2|1|0}]
+ [fwf_tune=fwf_tune_value] [rfw_tune=rfw_tune_value]
+ [nowam]
  + [c _com _pu=c _com _pu_value]
  + [c _com _pd=c _com _pd_value]
  + [c _com _pc=c _com _pc_value]
  + [c _com _gc=c _com _gc_value]
  + [pu _scal=pu _scal_value]
  + [pd _scal=pd _scal_value]
  + [pc _scal=pc _scal_value]
  + [gc _scal=gc _scal_value]
  + [rfw _scal=rfw _scal_value]
  + [fwf _scal=fwf _scal_value]
  + [spu _scal=spu _scal_value]
  + [spd _scal=spd _scal_value]
```

- **If ramp=0|1**
  - **RAMP adjustment**
- **C_com distribution between nodes**
- **PU / PD + PC / GC scaling**
- **Rising WF / Falling WF scaling**
- **If power=off**
  - **adjustment of the PU/PD curves**
Definition of the Distribution Function

Gaussian Distribution

Population

Nom_value

Abs variation

3 Sigma

3.09 sigma → 99.8%

.PARAM xx=GAUSS(nominal_val, rel_variation, sigma <, + multiplier>)

Rel_variation=Abs_variation/Nom_value

Your Success is Our Goal
Timing reference -
Scaled and Reference buffer

\[ T_{co} \]

Buf_ref

Sig_ref

R_load

V_term

Buf_scal

Sig_out

R_load

V_term

\[ T_{Flight\_Time} = \text{Diff} \ T_{co} \]

\[ T_{ramp\_20\_80} \]
Scaling of the static curves

\[ I_{PU}^{\text{scal}} = pu_{\text{scal}} \times I_{\text{typ}} \]

\[ I_{PD}^{\text{scal}} = pd_{\text{scal}} \times I_{\text{typ}} \]
Waveform scaling \text{ rwf\_scal / fwf\_scal }
0.85 / 3 sigma from typical
rwf_scal → Rising Waveform

IBIS-Model: B24_2 *rfw_scal=3sigma* *typ/min/max*

-1,00E-09
-8,00E-10
-6,00E-10
-4,00E-10
-2,00E-10
0,00E+00
2,00E-10
4,00E-10
6,00E-10
8,00E-10
1,00E-09

0,2 0,4 0,6 0,8 1 1,2 1,4 1,6

Ramp_(20_80)%

Tco
fwf_scal ➔ Falling Waveform

IBIS-Model: B24_2 *fwf_scal=3sigma* *typ/min/max*

-8,00E-10
-6,00E-10
-4,00E-10
-2,00E-10
0,00E+00
2,00E-10
4,00E-10
6,00E-10
8,00E-10
1,00E-09

0,2 0,4 0,6 0,8 1 1,2 1,4 1,6

Ramp_(20_80)%

Tco

typ
Sensitivity analysis on a 4 RAM topology

\[
T_{\text{pd\_tot}} = T_{\text{co}} + T_{\text{Flight\_Time}}
\]

pu\_scal, pd\_scal, rwf\_scal, fwf\_scal

5% rel var/ Gauss Distribution

\[
T_{\text{Flight\_Time}} = 3-13\text{mm}
\]

\[
l_1 = 30-40\text{mm}
\]

\[
l_2, l_{21} = 15-20\text{mm}
\]

\[
l_r = 3-13\text{mm}
\]
Signal Integrity (SI) and ISI → FT

![Graph showing Signal Integrity and ISI](image-url)
Signal integrity (SI) and ISI (Zoom)

- Ref_Signal
- RAM1_INP.
- RAM2_INP.
Flight Time of the RAM1&2

Flight Time (rise/fall) RAM1/2 Gauss-distribution

- FT fall
- FT rise

- tdr_c_v_r1e
- tdr_c_v_r2e
- tdf_c_v_r1e
- tdf_c_v_r2e

- pu/pd_scal + r/wf_scal

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Summary

- The analysed model parameter are **simulator specific**, not IBIS model intrinsic

- The HSPICE **B-element** ➔ external controlled parameters for model scaling
  - **Pu/pd** parameter ➔ **direct** control of the static current
    (parameter+10% ➔ +10%I)
  - **WF**-parameter ➔ **no** fix correlation to the ramp, **nor** the Tco / FT
    (IBIS-model specific)

- With a **typical IBIS** model ➔ **sensitivity analysis** are possible

- **Robustness** of a design can be quantified by the parameters of the B-element
Sensitivity Analysis of IBIS-parameters with HSPICE

Thank you very much for your attention.