What makes the difference?

On model quality assurance

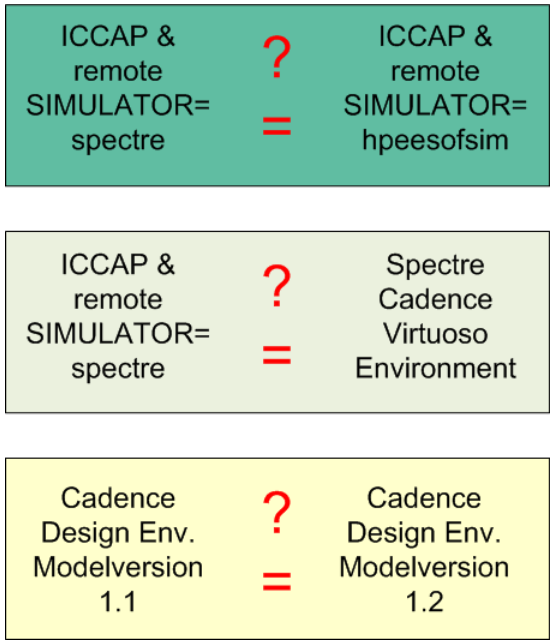
Jörg Berkner, Klaus-Willi Pieper

What makes the difference? Introduction

- We use several circuit simulators, because each one offers specific advantages
- That is why we have to deliver model parameter sets in different “flavours”
- A model quality assurance (QA) is mandatory with respect to:

1. ICCAP+Spectre vs. ICCAP+ADS
2. Spectre under ICCAP vs. Spectre under Virtuoso
3. Old vs. new model version

- These checks, however, delivers often different results. Why?



What makes the difference? Three reasons

- The reasons for deviations in simulation results are (at least) three fold:

1. Simulation condition reasons
2. Circuit related reasons
3. Model implementation reasons

- The last point brings up the following question: How to detect model implementation changes?

What makes the difference?
Agenda

1. Simulation condition reasons
2. Circuit related reasons
3. Model implementation reasons
4. How to detect model implementation changes?

What makes the difference? Simulation problem: TNOM and TEMP

- A simulation using TEMP=27 and TNOM=25 will create of course differences
- But, simulation with TEMP=TNOM may create deviations too!
- Note: ADS default is TEMP=25, TNOM=25
- Note: Cadence default is TEMP=27, TNOM=27

Extraction with TEMP=25 TNOM=25	≠	Simulation with TEMP=27 TNOM=27

- Conclusion: define the same TNOM in each model card, do not use defaults

What makes the difference? Simulation problem: Gmin

- Circuit simulator tolerance parameters affect the simulation result, e.g.Vrelto, Vabstol, Ireltol, Iabstol, Gmin
- Especially different default values for Gmin will result in different currents for low Vbe
- Conclusion: define the same Gmin in the ICCAP circuit and for the verification in the design environment

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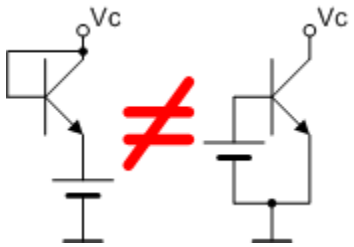
What makes the difference? Simulation circuit reasons

- It's simple: If the simulation circuits for extraction and verification are different, the results *must* be different
- Ic@Vce=const. ≠ Ic@Vbc=const.
- If you use in ICCAP a DUT circuit (e.g. for a Bias T), but in the verification not, the simulation results must be different
- If one extracted model parameter is missing in the ICCAP circuit: ICCAP reads the mps file *without error notice*, and uses then the default, instead of the extracted value
- Conclusion: Use absolute identical circuits, define ALL mp's in ICCAP!



```
*.SUBCKT emul_bias_TEE 1=P1 2=P2

.SUBCKT emul_bias_TEE 1=B 2=C 4=S
R_ser1     1     11     1m
CAC1       1     11     0.1

R_ser2     2     22     1m
CAC2       2     22     0.1

X1 22 11 0 4   lpnp_vbic_parex

.ENDS
```

```
.model pnp vbic
+ type=pnp
+ vers = 1.2
+ selft=1
+ is = 1a
+ nf = 1.00
+ nr = 1.00
```

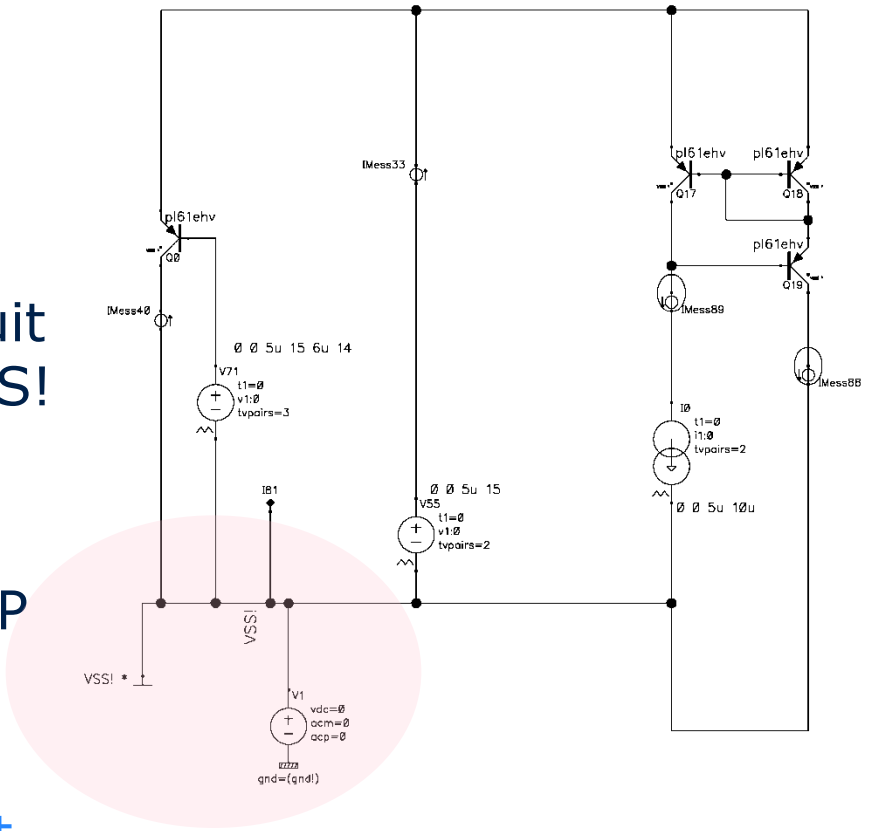
≠

```
.model pnp vbic
+ type=pnp
+ vers = 1.2
+ selft=1
+ is = 1a

+ nr = 1.00
```

What makes the difference? Simulation circuit reasons

- Special case: Lateral pnp simulation in Cadence ADS Virtuoso environment
- Problem: inherit GND connection
- You have to connect the circuit ground with general node VSS! and connect VSS! to 0V
- If you use GND only, deviations compared to ICCAP simulation will appear in the high current range
- Conclusion: Define the inherit ground connection properly!



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What makes the difference? Model implementation reasons

- Here are a number of examples for model implementation problems, founding during the last years:

1. Unknown parameters. Example: HFE, HJEI, TSF unknown in Spectre 4.4.3 implementation of HICUM 2.1
2. Different model parameter names: Cbeo in ADS and Cbe0 in Spectre. Creating an ADS-net-file using an Spectre-scs-file using the ADS-netlister resulted in zero oxid-capacitances and, consequently, in different ft-curves.
3. Wrong pin order: HICUM 2.1 (2001) in ADS 1.5, the pin order was BCEST instead of CBEST.
4. Missing equations: No collector current temperature dependence of HICUM 2.1 in ADS 1.5

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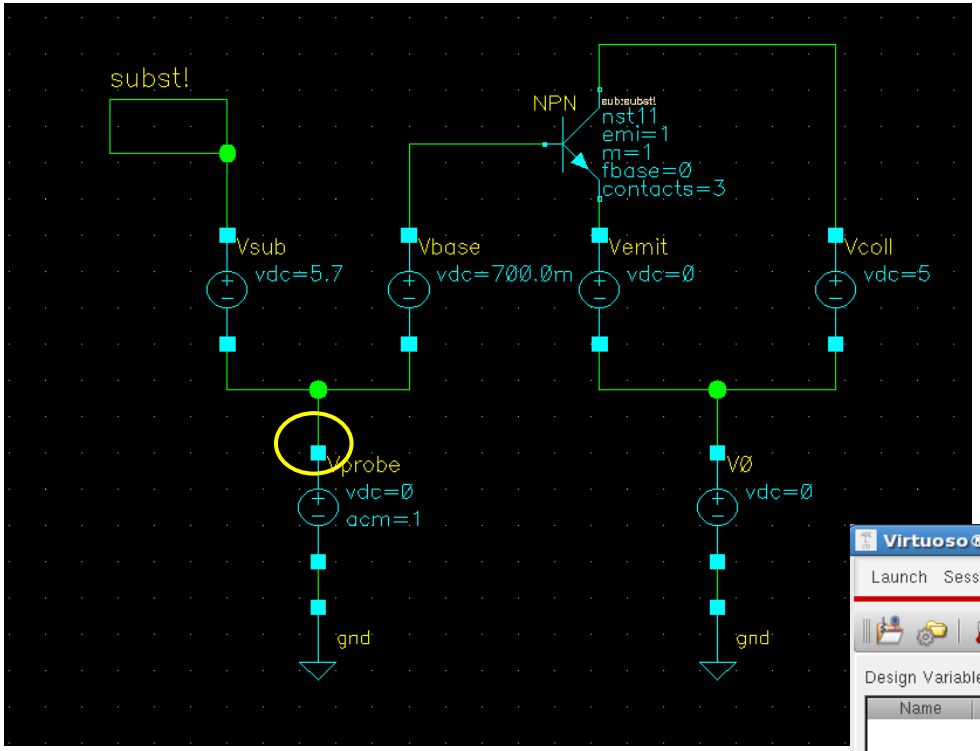
What makes the difference?
QA of model implementations

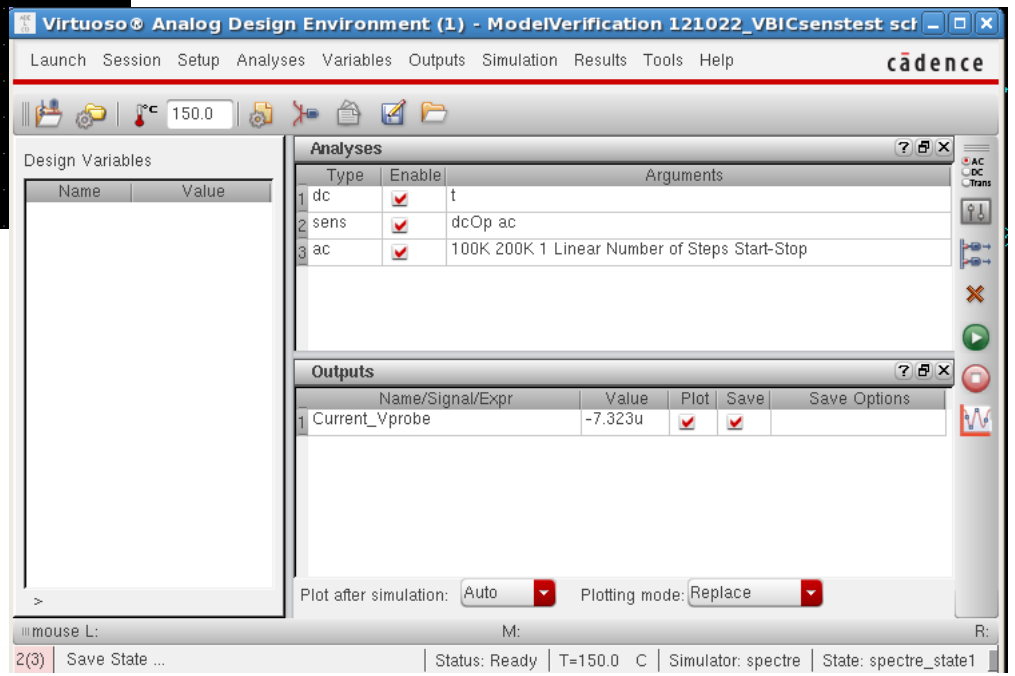
- Question: What does a modeling engineer fear most?
- Answer: A new simulator version is implemented in the Design Flow and suddenly *simulation results with the same model parameters are different* compared those of the old simulator version.
- Why:
  - It can be *killing for the product.*
  - The route cause is *hard to detect.*
  - It means in general *new parameter extraction.*

What makes the difference?
QA of model implementations

- A *fast test is needed* to check model implementations in different simulator versions against each other
- Sensitivity analysis delivers *sensitivities with respect to all model parameters*
- If sensitivities of different simulator versions are different, the *model equations have been changed*
- That's the idea of the *Sensitivity-Disaster-Check*

QA of model implementations in different Simulator versions





- DCOp and AC (100kHz) analysis
- sens analysis with respect to DCOp and AC
- high temperature (150 deg C)
- 1 current I(Vprobe:p)

What makes the difference?
QA of model implementations

DC sensitivity analysis for `dcOp':

OutputVariable Sensitivity DesignParameter Value

Vbase:p -6.4785e+09 npn:is 2.61e-16
Vcoll:p **-4.51642e+11** npn:is 2.61e-16
Vbase:p 3.7813e-05 npn:mcf 1.005
Vcoll:p **0.00263612** npn:mcf 1.005
Vbase:p 0 npn:mcr 1
Vcoll:p **0** npn:mcr 1
Vbase:p -1.87884e-08 npn:vef 36
Vcoll:p **-1.30972e-06** npn:vef 36
…

- Content of sens.output

AC sensitivity analysis for `ac':

SweepParameter SweepValue OutputVariable **SensitivityReal SensitivityImag** DesignParameter Value
freq 100000 Vbase:p **1.55922e+10 6.32781e+06** npn:is 2.61e-16
freq 100000 Vcoll:p 1.26628e+12 -3.04536e+06 npn:is 2.61e-16
freq 100000 Vbase:p **-8.05606e-05 -3.29902e-08** npn:mcf 1.005
freq 100000 Vcoll:p -0.00666218 1.67748e-08 npn:mcf 1.005
freq 100000 Vbase:p **0 0** npn:mcr 1
freq 100000 Vcoll:p 0 0 npn:mcr 1
freq 100000 Vbase:p **4.62392e-08 1.8741e-11** npn:vef 36
freq 100000 Vcoll:p 3.74358e-06 -8.64028e-12 npn:vef 36
…

QA of model implementations in different Simulator versions

- Comparison of sensitivities of HICUM Level 0 version 1.2 (DC)

Version	mmsim_7.1.0.isr3	mmsim_7.1.0.isr3	mmsim_7.2.0.isr15	mmsim_7.2.0.isr15	DeltaSens	DeltaMPvalue
Parameter	Sensitivity	MPvalue	Sensitivity	MPvalue		
af	0	1	0	1	0,0000000	0
ahc	0,000377809	0,5221	0	0,5221	1,0000000	0
ahcx			0,00039932	0,4791	1,0000000	-0,4791
aje	-3,66E-06	1,246	0	1,246	1,0000000	0
ajedc			0,00006042	2,50E+00	1,0000000	-2,5
alt0	0	2,60E-03	0	2,60E-03	0,0000000	0

- new parameters (ahcx and ajedc) were implemented in mmsim7.2.0
- parameters ahc and aje lost sensitivity in mmsim7.2.0

QA of model implementations in different Simulator versions

- Comparison of sensitivities of HICUM Level 0 version 1.2 (AC)

Version	mmsim_10.1.0.isr1	mmsim_10.1.0.isr1	mmsim_11.1.0.isr12	mmsim_11.1.0.isr12		
Parameter	SensReal	SensImag	SensReal	SensImag	DeltaReal	DeltaImag
af	0	0	0	0	0,0000000	0,0000000
ahc	-2,05E-09	-4,32E-06	-2,06E-09	-0,00000432	0,0012896	0,0000000
ahcx	-2,71E-05	9,40E-07	-2,71E-05	0,00000094	0,0000000	0,0000000
ahq			-2,71E-05	0,00000094	1,0000000	1,0000000
aje	-6,14E-11	-2,20E-07	-4,20E-10	-2,20E-07	0,7447450	0,0000000
ajedc	-0,00000376	6,68E-08	-3,76E-06	6,68E-08	0,0000000	0,0000000
alt0	-1,40E-07	-4,93E-04	-3,10E-07	-4,93E-04	0,3777778	0,0000000
cjci0	-1,09E+02	-4,07E+05	-1,09E+02	-4,07E+05	0,0000000	0,0000000

- new parameters (ahq) were implemented in mmsim11.1.0.isr12
- parameters aje and alt0 changed real part of sensitivity

QA of model implementations in different Simulator versions

- Example: HICUM, Level 0, Version 1.2

Compared mmsim versions		No. of changed parameter sensitivities	
Version 1	Version 2	DC	AC
mmsim/6.0.2.164	mmsim/6.2.0.isr5	>10	>10
mmsim/6.2.0.isr5	mmsim/7.1.0.isr3	clean	clean
mmsim/7.1.0.isr3	mmsim/7.2.0.isr15	>10	>10
mmsim/7.2.0.isr15	mmsim/10.1.0.isr1	clean	clean
mmsim/10.1.0.isr1	mmsim/11.1.0.isr12	3	7
VerilogA (5 nodes)	mmsim/11.1.0.isr12 (5 nodes)	1 (vr0c)	12

QA of model implementations in different Simulator versions

- Complete results

Microsoft Office
Excel Worksheet

- Questions?
- Let’s discuss!

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