CMOS065: TECHNOLOGY VARIATION MODELING

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INTRODUCTION

- The modeling methodology used, in CMOS065 technology, in order to account for the technology variations is described in this presentation.

- The goals of this presentation is to describe:
  - the principles of the methodology and the stand-alone usage,
  - the model library structure,
  - the user interface developped in ArtistKit.

- The methodology used in CMOS065 is based on previous developments in HCMOS9 and has been developped in collaboration with the FTM design teams (SRAM, IO, and Analog teams). It also answers some customer requests.

- This methodology has been implemented in the Design-Kit 4.1.

PRINCIPLES AND STAND-ALONE USAGE

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DEFINITION OF A TECHNOLOGY VARIATION

- **In order to define a technology variation, we have to answer the 3 following questions:**

  - What are the physical <u>origins</u> of this technology variation?

  - How this technology variation is <u>distributed</u>?

  - What are the devices and the electrical behavior impacted by this technology variation?
    i.e. what are the <u>correlations</u> linked to this technology variation?

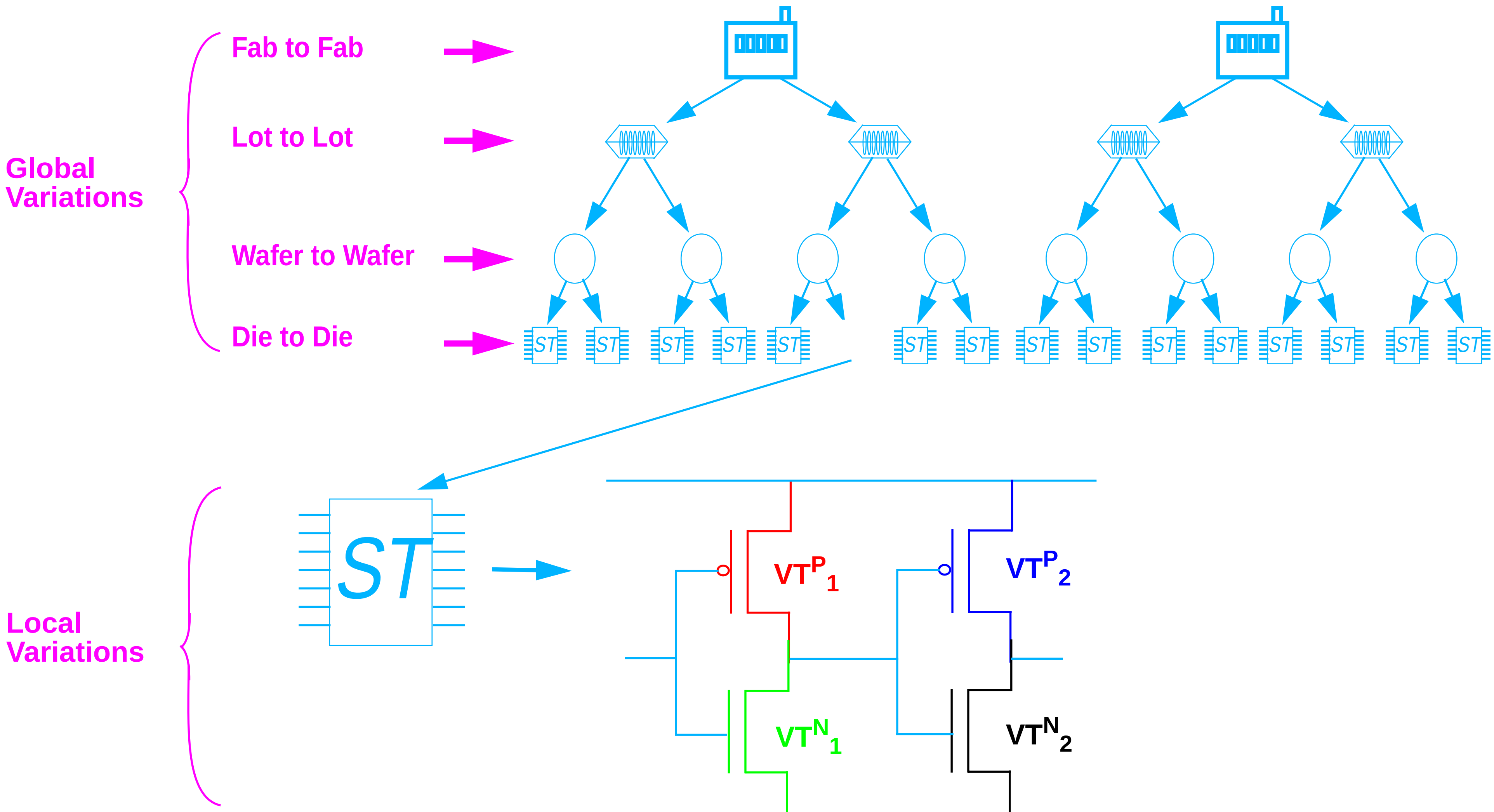
THE TECHNOLOGY VARIATIONS: ORIGINS

- **Device performances are affected by two types of technology variations:**

  - **global variations**, which affect all devices of the chip in the same way, due to process variability, leading to parameter variations (including fab to fab, lot to lot, wafer to wafer and die to die variations)
    - ➢ For example, the following process parameters are impacted by global variations:
      - Etching and Lithography: Poly and Active CD for MOS transistors and resistors,
      - Oxidations: TOX for MOS transistors and capacitors,
      - Implants: VT for MOS transistors, sheet resistances for resistors.

  - **local variations**, which vary from one device to another, causing mismatch between identically designed devices (intra-die variations)
    - ➢ For example the following device parameters are impacted by local variations:
      - VT and mobility for MOS transistors,
      - Sheet resistances for resistors.

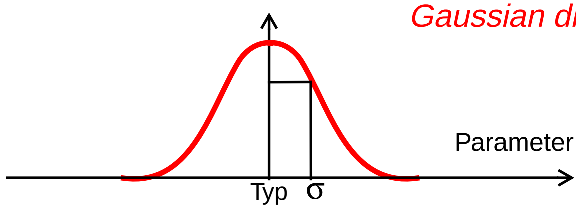
The Technology Variations: Origins (Cont.)



THE TECHNOLOGY VARIATIONS: DISTRIBUTION

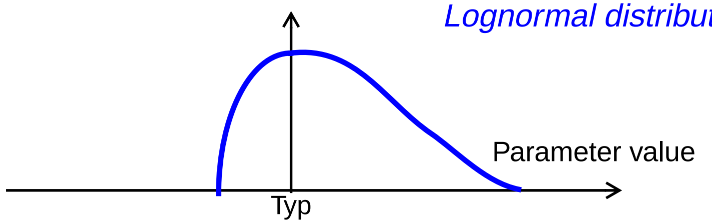
- **Technology variations are usually specified into different ways:**
  - For a GAUSSIAN distribution, the technology variation is defined by the mean value and the standard deviation value (σ).

Gaussian distribution



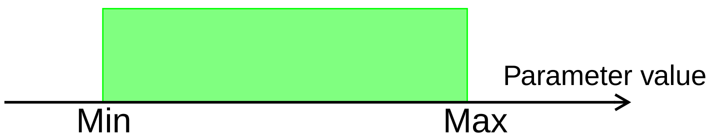
  - For a LOGNORMAL distribution, the logarithmic value of the technology variation is defined by a gaussian distribution.

Lognormal distribution



  - For a UNIFORM distribution, the technology variation is defined by the minimum and the maximum values. All the values between MIN and MAX have the same probability.

Uniform distribution



THE TECHNOLOGY VARIATIONS: CORRELATIONS

- **Several kinds of correlations may exist between some sources of <u>global</u> variations**

  - Intrinsic correlations:
    - correlations between some device parameters of one same device
      (e.g. body factor KB versus threshold voltage VT for a MOS transistor)

  - Intra-Family correlations:
    - correlations between some devices of one same family
      (e.g. Poly CD between NMOS and PMOS or between GO1 and GO2)

  - Extra-Family correlations:
    - correlations between different families of devices
      (e.g. Poly Sheet Resistance between MOS transistors and resistors)

- **No correlation exists between the various sources of <u>local</u> variations.**

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- **Technology Variation Modeling Methodology**
  - **Overview**
  - Statistical Models
  - User Defined Corner Models
  - Pre-defined Corner Models
- **Examples**
- **Conclusion**
- **Perspectives**
- **Appendix**

Modeling of the technology variations

- **For each device, the modeling of the technology variations is based on a typical model (the nominal behaviours for sizing, biasing and temperature effects are already defined).**

- **Then, the technology variations impacting the device are identified and defined (Origin, Distribution, Correlations).**

- **Each technology variation is linked to, at least, one model parameter. Then, each impacted model parameter is modified from its typical value using:**

  - direct laws, e.g. for MOS transistors, $\Delta T_{OX}^{model} = \Delta T_{OX}^{process}$

  - undirect laws, e.g. for MOS transistors, as overlap capacitances are inversely proportional to T_{OX},

$$\Delta CGDO^{model} = \frac{\Delta T_{ox}^{process}}{(T_{ox}^{typ} \pm \Delta T_{ox})} CGDO^{typ}$$

MODELING OF THE TECHNOLOGY VARIATIONS (CONT.)

- **According to the existing correlations between devices, the global variations can be separated in 2 categories:**
  - **specific** variations which are **not correlated** to other devices,
  - **common** variations which are **correlated** to several devices.

- **The specific variations are defined in the model library file of each device.**

- **In order to better identify the global variations correlated to several devices (Intra or Extra family correlations), some “common” files have been defined in the design environment:**
  - **common_poly.lib** including the variations of Poly CD, Poly Sheet and Contact resistances,
  - **common_active.lib** including the variations of OD CD, OD Sheet and Contact resistances,
  - **common_go1.lib** including the variations of oxide thickness for GO1 devices,
  - **common_go2.lib** including the variations of oxide thickness for GO2 devices.

- **These model libraries have to be declared in the netlist in order to simulate a device impacted by one (or more) of the common global variations.**

MODELING OF THE TECHNOLOGY VARIATIONS (CONT.)

- **3 modeling methodologies are available in order to describe the technology variations taking into account the pratical and use aspects:**

  - the **statistical** models,
  - the **User Defined Corner** models,
  - the **Pre-Defined Corner** models.

- **These 3 methodologies are applicable to both <u>global</u> and <u>local</u> variations.**

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STATISTICAL MODELS

- **Each technology variation is defined following a statistical distibution law (Gauss, Uniform or Lognormal), and all kinds of correlations are taken into account during the simulation.**

- **Then, a <u>Monte-Carlo</u> algorithm is used in order to randomly select, for each run, a value for each technology variation with the probability defined by the related distribution law (Gaussian, Uniform, ...).**

- **Following the origins of the technology variations (global or local) and following the design needs (Yield or Functional analysis), several statistical models are available.**

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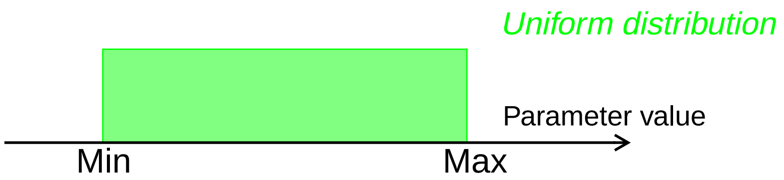
STATISTICAL MODELS: THE "MULTIFAB" OPTION

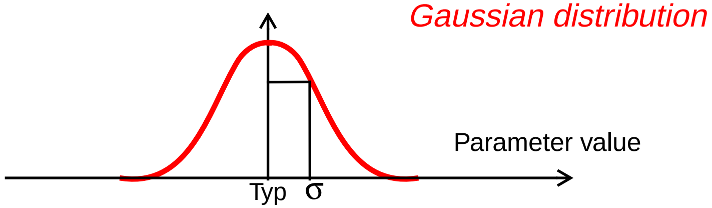
- **For Functional Analysis:**
  - The model must allow to evaluate the design sensitivity to a process shift within the Process Control Monitoring limits (LSL, USL).
  - Therefore, all the global variations have been defined using **UNIFORM** distibution laws in order to give the same probability to all the values between lower (MIN) and upper (MAX) limits.



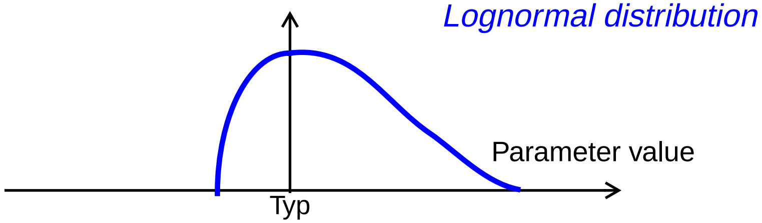
  - This statistical model configuration is called "**Multi Fab**". And, in this case:
    - each value between Min and Max is reachable with the same probability,
    - all correlations are taken into account.

STATISTICAL MODELS: THE "CROLLES" OPTION

- **For Yield Analysis:**
  - The model must be as close as possible to **a mature process in the reference fab** (i.e. Crolles2).
  - Therefore, realistic distribution laws are used to define each global variation. Three kinds of laws are used:
    - GAUSSIAN distributions when mean value and standard deviation (σ) value are known.



    - LOGNORMAL distributions when the logarithmic value of the global variation is defined by a gaussian distribution whose mean value and standard deviation value are known.



    - UNIFORM distributions are used in all other cases.
  - This statistical model configuration is called "**Crolles**". And, in this case also, all the correlations are taken into account.

STATISTICAL MODELS: GLOBAL VARIATIONS (EXAMPLES)

- **The global statistical models are activated using a specific library in each model library file.**
  The example below is given for a unsalicided SVTLP PMOS and a unsalicided P+ Poly resistor.
  - For Functional Analyis, the "**Multi Fab**" statistical models must be used and the following libraries have to be declared:

.lib common_poly.lib	PRO_**statmultifab**
.lib common_active.lib	PRO_**statmultifab**
.lib common_go1.lib	PRO_**statmultifab**
.lib LPmos_bsim4_svt.lib	SVTLP_**statmultifab**
.lib resistor.lib	RPOLYP_**statmultifab**

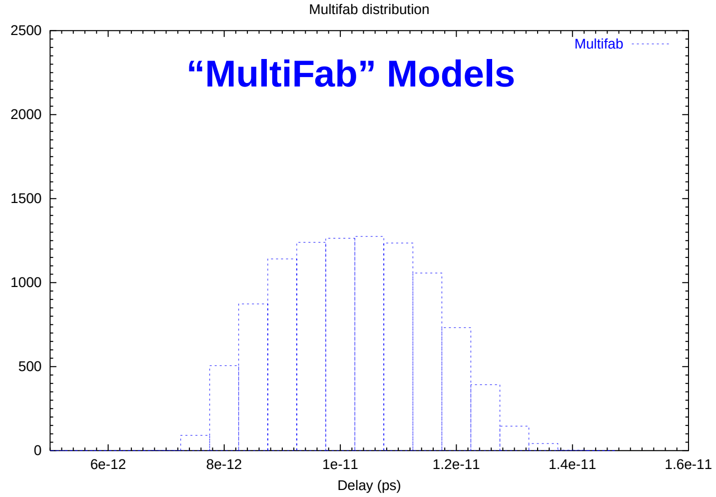
  - For Yield Analyis, the "**Crolles**" statistical models must be used and the following libraries have to be declared:

.lib common_poly.lib	PRO_**statcrolles**
.lib common_active.lib	PRO_**statcrolles**
.lib common_go1.lib	PRO_**statcrolles**
.lib LPmos_bsim4_svt.lib	SVTLP_**statcrolles**
.lib resistor.lib	RPOLYP_**statcrolles**

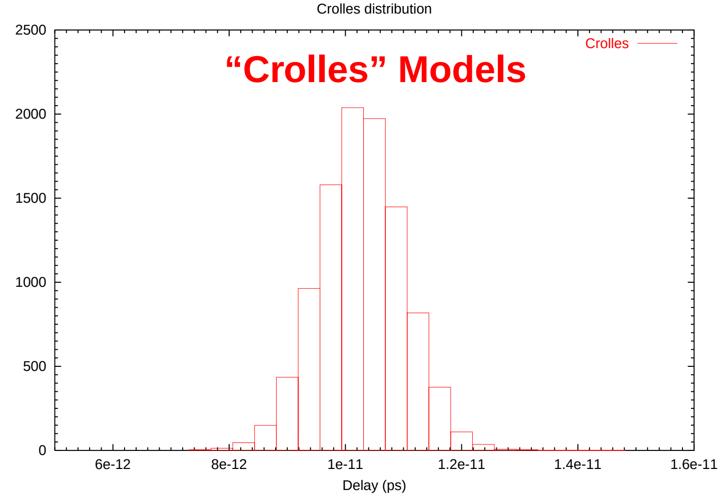
- **Then, the Monte-Carlo simulations can be performed using, for example, the .mc command in ELDO.**

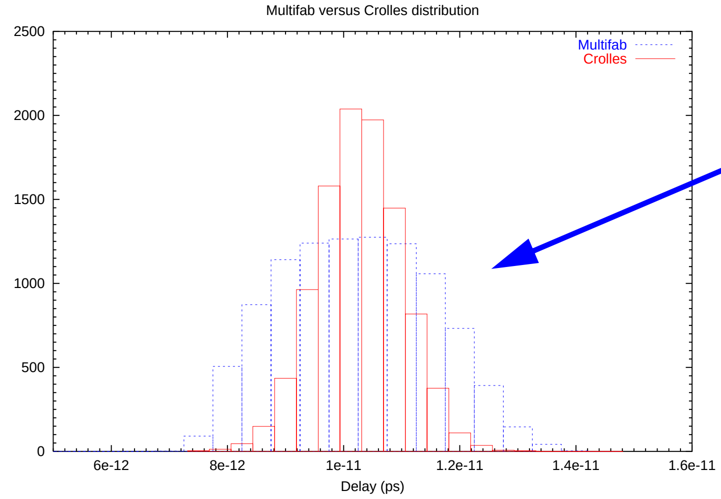
STATISTICAL MODELS: GLOBAL VARIATIONS (EXAMPLES)

- **Comparison of the spread of the delay of a simple Ring Oscillator (FO1, SVTLP, Wn/Wp=0.36/0.5) in the case of the "MultiFab" and "Crolles" options:**



10000 runs, sigtail=6





The "Multi-Fab" simulations show a larger spread (x1.7) than the "Crolles" ones.

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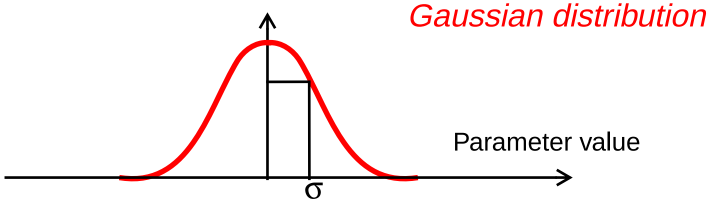
STATISTICAL MODELS: LOCAL VARIATIONS

- **Using measurements and extractions performed on pairs of close devices, the local variations of the impacted parameters P (VT and mobility for MOS transistors, body and head resistance for resistors) are modeled using the following equation:**

$$\sigma_P = \frac{A}{\sqrt{2 \cdot mult \cdot W \cdot L}} + B$$ **, where mult is the number of devices in parallel.**

- **Using the above extracted standard deviation, the related local variation is defined using a Gaussian distribution law:**



- **By definition, no correlations exist between different devices even if they belong to the same family.**

Statistical Models: Local Variations (Example)

- **For each device family (LP SVT MOS transistors, SVT25 MOS transistors, resistors, ...), flags have been defined in order to globally activate (or not) the local variation simulation. These flags are named “**<family>_dev” **(**svtlp_dev **for example) and must be defined in the netlist.**
  - <family>_dev = 0: no local variations taken into account for the related family,
  - <family>_dev = 1: local variations are taken into account for the related family.

- **By definition, the local variations must be locally activated for each device of the circuit. Therefore, the instance parameter “**<u>mismatch</u>**” has also been defined.**
  - mismatch = 0: no local variations taken into account for the related device,
  - mismatch = 1: local variations are taken into account for the related device.

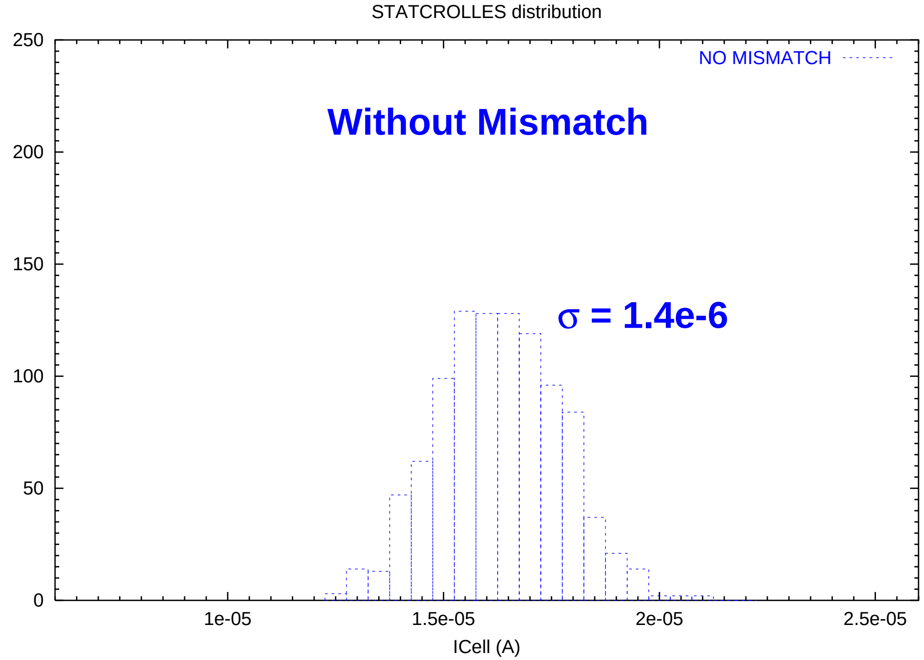
- **The example below is given for a unsalicided SVTLP PMOS and a unsalicided P+ Poly resistor:**

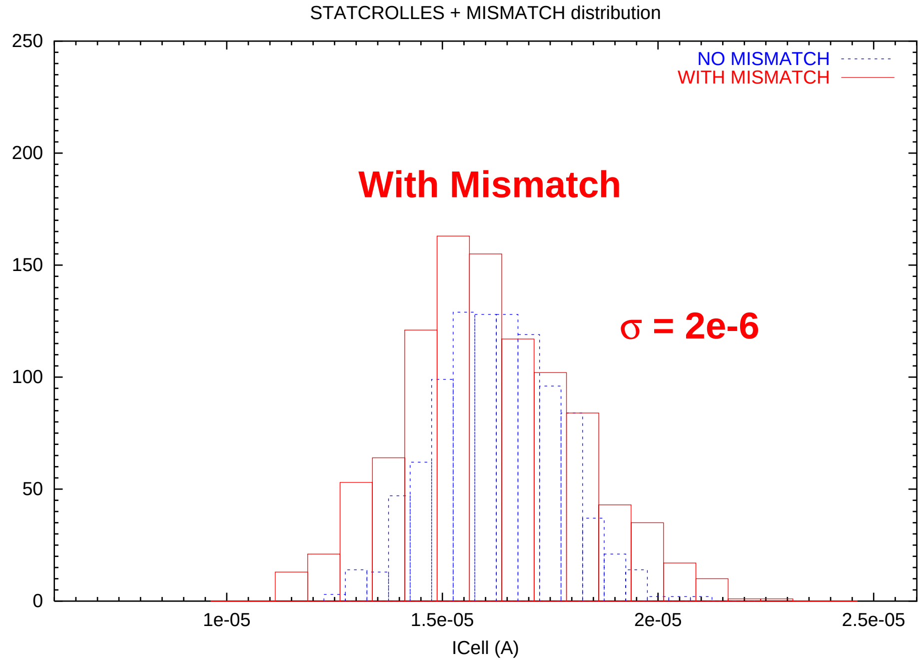
```
.param svtlp_dev = 1
.param rpolyp_dev = 1
...
XM1   D G S B        PSVTLPRPO   W=w L=l ... mismatch=1 ...
XR1   Plus Minus B   RPPORPO     W=w L=l ... mismatch=1 ...
```

- **Then, the Monte-Carlo simulations can be performed using, for example, the .mc command in ELDO.**

STATISTICAL MODELS: LOCAL VARIATIONS (EXAMPLES)

- **Impact of the local variations on the spread of the Read Current (ICell) of a Single Port SRAM Cell (LP SVT 0.525um2):**





SUMMARY TABLE

Model	Model Libary	Instance Parameter	Global Parameter
Statistic Crolles	*_STATCROLLES	--	--
Statistic MultiFab	*_STATMULTIFAB	--	--
Statistic Mismatch	Any	mismatch=1	<family>_dev=1

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USER DEFINED CORNER (UDC) MODELS

- **The Monte-Carlo simulations using the Statistical Models are often time consuming. Besides, it is often necessary to perform a great number of runs in order to get statiscally relevant results (1 ppm bit fail for SRAM, ...).**

- **Moreover, some design analysis require to easily simulate one given process or mismatch configuration (design qualification versus silicon, design optimization, ...).**

- **Therefore, some specific models have been defined in order to reach,** <u>using only one run</u>**, any value included between the MIN and MAX limits of each technology variation.**
  This model option has been named "<u>User Defined Corner</u>" models (or UDC models), because the combination of the technology variations can be fully defined by the user.

- **The UDC models are available for both <u>global</u> and <u>local</u> variations. And, they take all the correlations into account.**

- **In fact, in most of the design situations, the UDC models allow to simulate a particular run of a Monte-Carlo simulation. However, no information about the probability of occurence of this run is available.**

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UDC Models: Global Variations

- **In this model option, each global variation is defined using a parametric number of sigma:**
  - "ΔP = nsigma_P x sigma_P"
  - sigma_P is defined according to the process specifications,
  - nsigma_P must be defined by the user.

- **The sign convention for the number of sigma is:**
  - nsigma_P < 0 to go towards the MIN corner (or SLOW corner for MOS transistors),
  - nsigma_P > 0 to go towards the MAX corner (or FAST corner for MOS transistors).

- **The UDC Models are activated using a specific model library in each model library file.
  The name of the UDC library use the extension "_USER" (PSVTLP_USER for example).**

- **In order to limit the number of parameters to be declared for each device, some global variations have been grouped according to the main device performances.
  For example, only one parameter is defined for the specific variations of PMOS SVT LP: "**psvtlp_user**".
  This specific number of sigma impacts the variations of VT, mobility, acces resistance, Junction capacitance and leakage for all the PMOS SVT LP devices used in the circuit.**

UDC Models: Global Variations (Example)

- **The example below is given for a unsalicided SVTLP PMOS in FAST corner and a unsalicided P+ Poly resistor in RMIN corner.**

To be defined by the user

.param **poly_cd_user** = -2
.param **nsigma_ppoly_drsh_user** = -3
.param **nsigma_ppoly_drsc_user** = -3
.param **nsigma_ppoly_drshu_user** = -3
.param **nsigma_ppoly_drhi_user** = -3
.lib common_poly.lib **PRO_USER**

.param **active_cd_user** = 2
.param **nsigma_psd_drshu_user** = -3
.param **nsigma_psd_drsc_user** = -3
.lib common_active.lib **PRO_USER**

.param **nsigma_lp_dtox_user** = -2
.param **nsigma_lp_dcfring_user** = -2
.lib common_go1.lib **PRO_USER**

Common UDC Parameters

.param **psvtlp_user** = -2
.lib LPmos_bsim4_svt.lib **SVTLP_USER**

.param **rpolyp_user** = -3
.lib resistor.lib **RPOLYP_USER**

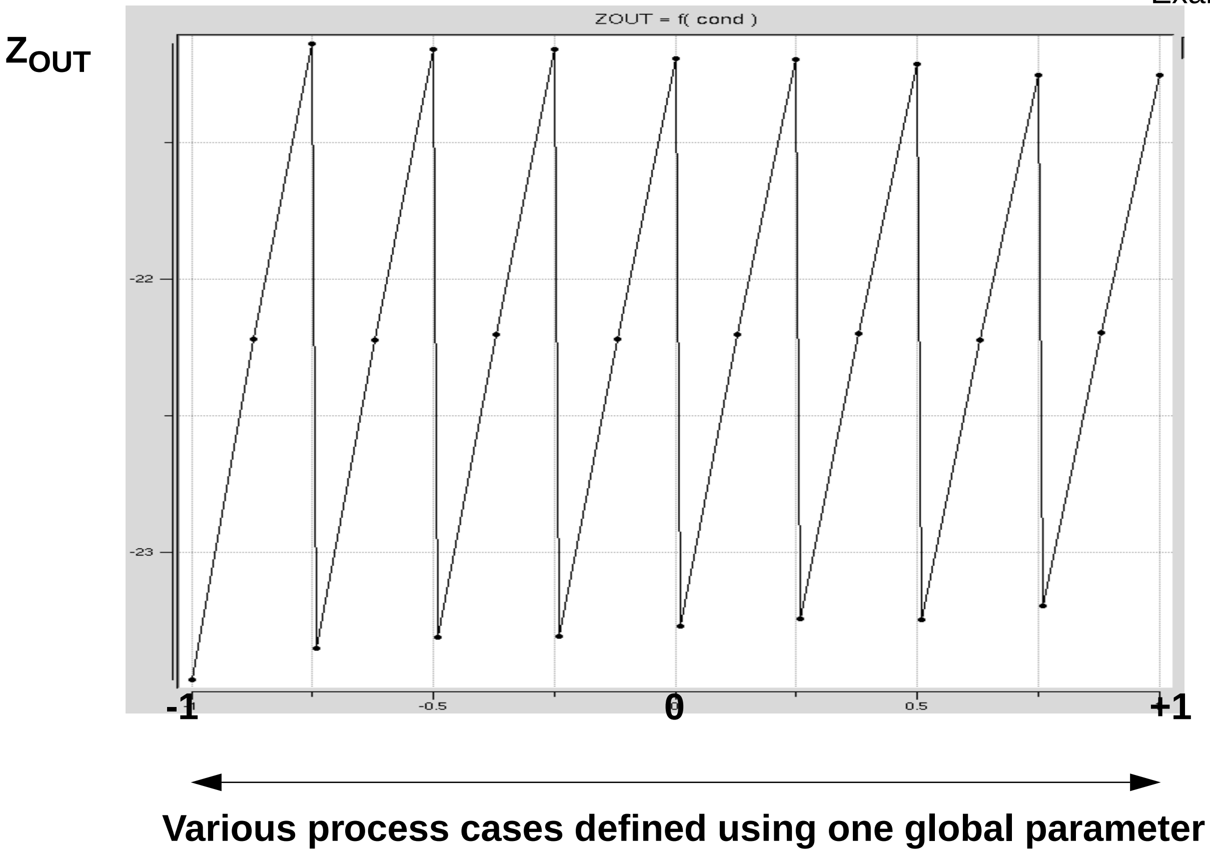
Specific UDC Parameters

UDC Models: Global Variations (Example)

- Some IO applications are designed in order to adapt their ouput characteristics to the technology variations. In these circuits, the UDC models are used in order to scan the process variation range in a discrete number of cases.

- The following graph shows the output impedance of a NMOS buffer versus the various process cases. The buffer size is adapted in order to limit the variation of the output impedance.

Example provided by M. Rien.



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UDC MODELS: LOCAL VARIATIONS

- **This methodology is only available for the MOS transistors!**

- **As for the global variations, a parametric number of sigma is defined for each local variations (VT and mobility):**

  - **"ΔVT = dvt_mdev *** σ_{VT}" and **"Δmu = dmu_mdev *** σ_{mu}"

  - $$\sigma_p = \frac{A}{\sqrt{2 \cdot mult \cdot W \cdot L}} + B,$$

  - **dvt_mdev** and **dmu_mdev** must be **locally** defined by the user. The sign convention is defined as follows:

    "If dvt_mdev (or dmu_mdev) is **negative**, |VT| (or mobility) is **decreased**".

- **Therefore, 3 instance parameters have to be defined in order to use this methodology:**

  - **mismatch** = 1 or 0, with the same convention as for the statistical models,

  - **dvt_mdev** defining the number of sigma for the local variation of VT,

  - **dmu_mdev** defining the number of sigma for the local variation of mobility.

UDC Models: Local Variations (Example)

- **The same flags used for the statistical models are used in order to globally activate (or not), for each device family, the User Defined Corner Models for the local variations.**

- **These flags are named** <family>_dev **(**svtlp_dev **for example) and must be defined in the netlist.**
  - <family>_dev = 3: the local UDC variations are taken into account in the corners for the related family.

- **The example below is given for a unsalicided SVTLP PMOS, in the case of a "3 sigma" VT decrease and a "2 sigma" mobility increase due to the local variations :**

.param **svtlp_dev = 3**

...
...

XM1   D G S B   PSVTLPRPO W=w L=l ... **mismatch=1 dvt_mdev=-3 dmu_mdev=2** ...
...
...

SUMMARY TABLE

Model	Model Libary	Instance Parameter	Global Parameter
Statistic Crolles	*_STATCROLLES	--	--
Statistic MultiFab	*_STATMULTIFAB	--	--
Statistic Mismatch	Any	mismatch=1	<family>_dev=1
Global User Defined Corners	***_USER**	**--**	***_user**
Local User Defined Corners	***_USER, *_TT, *_SS, ...**	**mismatch=1, dmu_mdev, dvt_mdev**	**<family>_dev=3**

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PRE-DEFINED CORNER (PDC) MODELS

- **In the case of the MOS transistors, the Pre-Defined Corners have been created in order to reach the Worst case and the Best case of some specific circuit performances for some design applications.**

- **The circuit performances covered by the pre-defined corners are mainly digital performances:**

  - circuit speed performances (FF, SS corners),

  - ION(NMOS)/ION(PMOS) ratio (SF, FS corners).

- **Depending on the considered performance, the number of sigma of the model parameter is defined and fixed.**

- **For the passive devices, the Pre-Defined Corners are generated in order to reach the Best Case or the Worst Case of the device value: for example, minimum capacitance (CMIN) or maximum resistance (RMAX).**

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PDC MODELS: GLOBAL VARIATIONS (MOSFET)

	Speed Worst Case		N/P ratio Worst Case			N/P ratio Best Case		Speed Best Case	
Parameters	**SSA**	**SS**	**SFA**	**SF**	**TT**	**FS**	**FSA**	**FF**	**FFA**
XL (m)	**+3σ**	**+2σ**	**0**	**0**	**0**	**0**	**0**	**-2σ**	**-3σ**
XW (m)	**-3σ**	**-2σ**	**0**	**0**	**0**	**0**	**0**	**+2σ**	**+3σ**
TOX (m)	**+3σ**	**+2σ**	**0**	**0**	**0**	**0**	**0**	**-2σ**	**-3σ**
VTH0 N (V)	**+3σ**	**+2σ**	**+4σ**	**+3σ**	**0**	**-3σ**	**-4σ**	**-2σ**	**-3σ**
VTH0 P (V)	**-3σ**	**-2σ**	**+4σ**	**+3σ**	**0**	**-3σ**	**-4σ**	**+2σ**	**+3σ**
RDSW N (Ohm.m)	**+3σ**	**+2σ**	**0**	**0**	**0**	**0**	**0**	**-2σ**	**-3σ**
RDSW P (Ohm.m)	**+3σ**	**+2σ**	**0**	**0**	**0**	**0**	**0**	**-2σ**	**-3σ**
Mobility N (m2/Vs)	**-3σ**	**-2σ**	**0**	**0**	**0**	**0**	**0**	**+2σ**	**+3σ**
Mobility P (m2/Vs)	**-3σ**	**-2σ**	**0**	**0**	**0**	**0**	**0**	**+2σ**	**+3σ**
Area CJ N (F/m2)	**+Δ**	**+Δ**	**+Δ**	**+Δ**	**0**	**-Δ**	**-Δ**	**-Δ**	**-Δ**
Area CJ P (F/m2)	**+Δ**	**+Δ**	**-Δ**	**-Δ**	**0**	**+Δ**	**+Δ**	**-Δ**	**-Δ**
Perimetric CJ N (F/m)	**+Δ**	**+Δ**	**+Δ**	**+Δ**	**0**	**-Δ**	**-Δ**	**-Δ**	**-Δ**
Perimetric CJ P (F/m)	**+Δ**	**+Δ**	**-Δ**	**-Δ**	**0**	**+Δ**	**+Δ**	**-Δ**	**-Δ**
Diode Current N	**1/10**	**1/10**	**0**	**0**	**0**	**0**	**0**	**x10**	**x10**
Diode Current P	**1/10**	**1/10**	**0**	**0**	**0**	**0**	**0**	**x10**	**x10**

- **Depending on the considered performance, the number of sigma of each model parameter is fixed.**

PDC Models: Global Variations (Examples)

- **The global Pre-Defined Corner models are activated using a specific library in each model library file. The example below is given for SVTLP MOSFETs in the SF corner and resistors in the RMAX corner.**

.lib common_poly.lib	PRO_**SF**
.lib common_active.lib	PRO_**SF**
.lib common_go1.lib	PRO_**SF**
.lib LPmos_bsim4_svt.lib	SVTLP_**SF**
.lib resistor.lib	RPOLYP_**RMAX**

  - **Note: In the case of the SF and FS corners, the “common” variations are set to their typical values. Therefore, the above setting is equivalent to the following one:**

.lib common_poly.lib	PRO_**TT**
.lib common_active.lib	PRO_**TT**
.lib common_go1.lib	PRO_**TT**
.lib LPmos_bsim4_svt.lib	SVTLP_**SF**
.lib resistor.lib	RPOLYP_**RMAX**

PDC MODELS: CORRELATIONS

- **For the Pre-Defined Corners, only the correlations between the MOS transistors are taken into account (GO1/GO2, HVT/SVT, ...).**

- **<u>The correlations between the passive devices and the MOS transitors have been removed</u> in order to simplify the use of the Pre-Defined Corners.**

- **Therefore, a trade-off between an easy use of the PDC Models and a possible over-design has been found. This trade-off is aligned with the Library Charaterization needs (Digital, IO, ...).**

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PDC MODELS: LOCAL VARIATIONS

- **This methodology is only available for the MOS transistors!**

- **As for the global variations, the number of sigma for the VT and mobility variations are fixed following the critical performance (speed or N/P ratio).**

- **However, in this case, <u>a new value of sigma for VT and the mobility is calculated</u>. Indeed, considering both <u>global</u> and <u>local</u> variations, the variances have to be added.**

  The new sigma value becomes:

$$\sigma_{total} = \sqrt{\sigma_{global}^{2} + \sigma_{local}^{2}}$$

  - where $\sigma_{local} = \frac{A}{\sqrt{2 \cdot mult \cdot W \cdot L}} + B$.

- **In this case also, the mismatch contribution can be "globally" activated using the flag <family>_dev:**
  - <family>_dev = 2: the PDC local variations are taken into account in the corners for the related family.

- **However, as the mismatch variations are <u>globally</u> added to the process variations, the instance parameter "mismatch" has no effect on the PDC simulations.**
  In other words, the mismatch contribution in the PDC models can not be "<u>locally</u>" removed.

SUMMARY TABLE

Model	Model Libary	Instance Parameter	Global Parameter
Statistic Crolles	*_STATCROLLES	--	--
Statistic MultiFab	*_STATMULTIFAB	--	--
Statistic Mismatch	Any	mismatch=1	<family>_dev=1
Global User Defined Corners	*_USER	--	*_user
Local User Defined Corners	*_USER, *_TT, *_SS, ...	mismatch=1, dmu_mdev, dvt_mdev	<family>_dev=3
Global Pre-defined Corners	***_TT, *_SS, ...**	**--**	**--**
Local Pre-defined Corners	***_TT, *_SS, ...**	**--**	**<family>_dev=2**

CONTENTS

EXAMPLES OF APPLICATION

- The main objective of this part is to give some guidelines for the simulation of the technology variations using simple design applications. It is not to be exhaustive nor to cover all the possible applications.

- The examples have been selected in order to focuse on some specific aspects and, then, to make the user aware of some application range and some limitations of each model option.

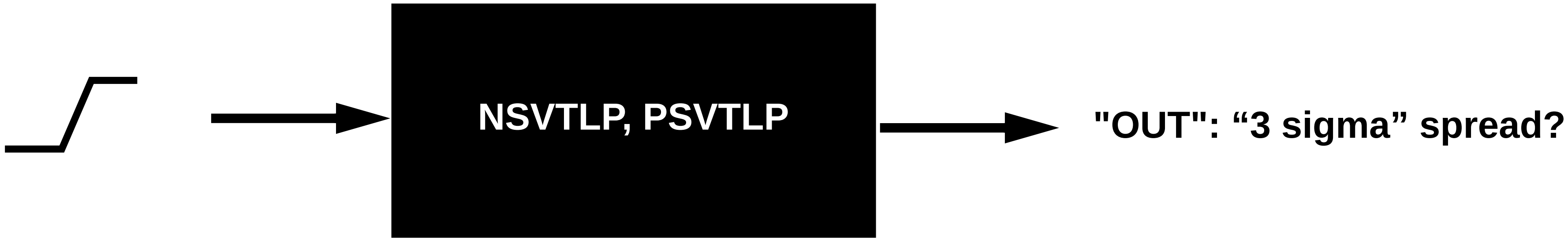
- The user may turn to account the indications available in this part for his own design application.

CONTENTS

EXAMPLE OF GLOBAL VARIATION ANALYSIS

- Let's consider a "Black Box" circuit for which only the devices used are known: NSVTLP and PSVTLP.

- We want to evaluate the "3 sigma spread" of the output characteristic ("OUT"). Comparing this spread with the specifications, we will know if a 99.7% yield is reachable.

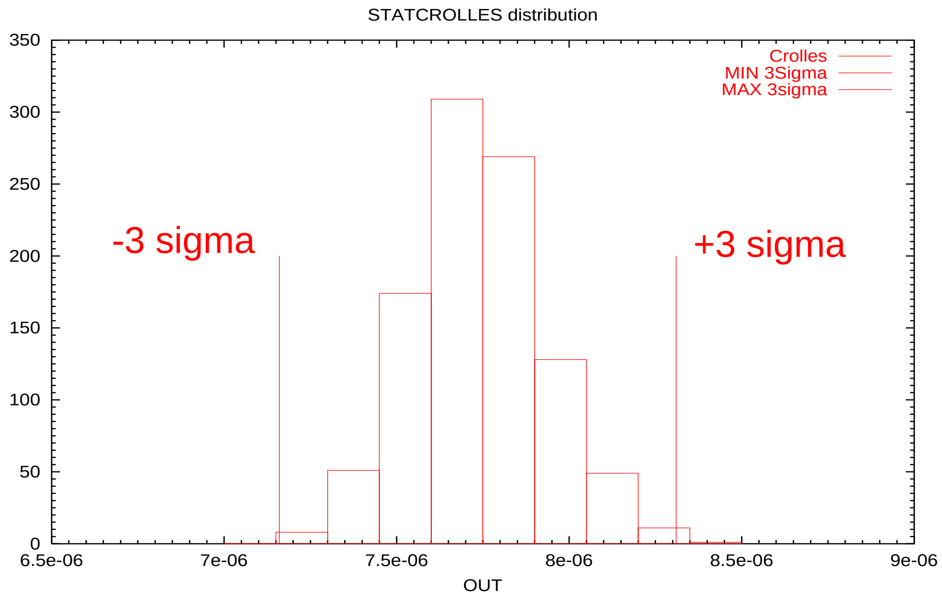


- The various technology variation modeling can be used, but the results and the available information will be different.

CONTENTS

STATISTICAL SIMULATIONS

- **A Monte-Carlo simulation using the STATCROLLES models has been performed (1000 runs, sigtail=6). The results are:**
  - Nominal value = 7.737U
  - Average value = 7.736U (= M)
  - Standard Deviation = 0.191U (= S)
  - Range = [7.219U , 8.373U]
  - The “3 sigma” spread is equal to:
    [Average - 3*sigma, Average + 3*sigma] = [7.16U, 8.31U]



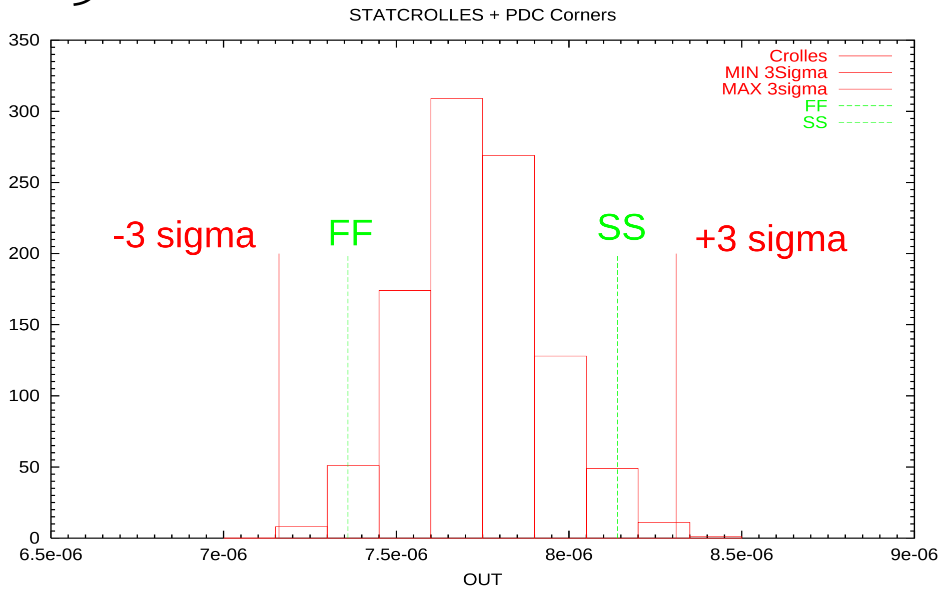
CONTENTS

PRE-DEFINED CORNER SIMULATIONS

- **Even if no information are available about "OUT" (linked to speed performances?), we propose to perform some simulations using the SS, FF corners.**

- **The simulation results are:**
  - ➢ FF corner: OUT = 7.356U
  - ➢ SS corner: OUT = 8.141U

  To be compared with the “3 sigma” spread using Monte-Carlo simulations: [7.16U, 8.31U]



- **The Pre-Defined corners SS, FF are obviously not suitable for the evaluation of the spread of "OUT"!**

CONTENTS

USER-DEFINED CORNER SIMULATIONS

- **We know that the devices used in the circuit are NSVTLP and PSVTLP.**
  As specified in the Appendix, the UDC parameters to be defined in the netlist for these devices are:
  - active_cd_user: for Active CD variations,
  - poly_cd_user: for Poly CD variations,
  - nsigma_lp_dtox_user: for Oxide Thickness variations,
  - nsvtlp_user: for NSVTLP specific variations (implants, ...),
  - psvtlp_user: for PSVTLP specific variations (implants, ...).

- **The first approach is to simulate all the possible cases, i.e. 2^5 = 32 simulations, using the maximum/minimum limits for each UDC parameter. The MIN/MAX results are given in the table below:**

	active_cd_user	poly_cd_user	nsigma_lp_dtox_user	nsvtlp_user	psvtlp_user	"OUT" value
Minimum Case	-4	-3	-4	+4	+4	6.303U
Maximum Case	+4	+3	+4	-4	-4	9.547U

- First comment: The spread is very larger than the “3 sigma” spread obtained using Monte-Carlo: [7.16U, 8.31U],
- Second comment: The MIN/MAX UDC parameter combination differs from the PDC one.

	active_cd_user	poly_cd_user	nsigma_lp_dtox_user	nsvtlp_user	psvtlp_user	"OUT" value
FF Corner	+2	-2	-2	+2	+2	7.356U
SS Corner	-2	+2	+2	-2	-2	8.141U

USER-DEFINED CORNER SIMULATIONS (CONT.)

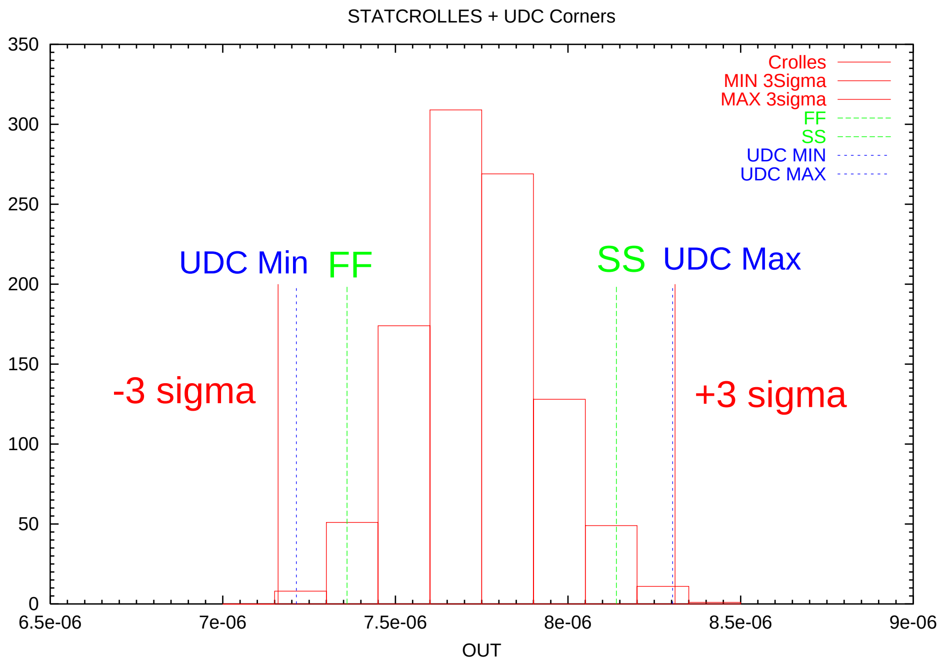
- **After the analysis of the <u>32 simulations</u>, we found the UDC combination related to the MIN/MAX values of "OUT".**
- **However, we still don't know how to evaluate the "3 sigma" spread of "OUT"!**
- **A quick approach is to assume that <u>the effects of all the 5 UDC parameters are equivalent, linear and without inter-actions</u>.**
  Then, one demonstrates that the "3 sigma" spread may be reach using a "<u>3/sqrt(N)</u>" sigma corner, where N is the number of UDC parameters. In our case, we will set all our parameters to +/- 1.34 in the MIN/MAX cases found in the previous analysis.
- **The results are given in the table below:**

	active_cd_user	poly_cd_user	nsigma_lp_dtox_user	nsvtlp_user	psvtlp_user	"OUT" value
Minimum Case	-1.34	-1.34	-1.34	+1.34	+1.34	7.213U
Maximum Case	+1.34	+1.34	+1.34	-1.34	-1.34	8.303U

  - The UDC MIN/MAX spread is now closer to the "3 sigma" spread obtained using the Monte-Carlo simulations: [7.16U, 8.31U].

USER-DEFINED CORNER SIMULATIONS (CONT.)

- Using all the available combinations (32) of the UDC parameters and assuming that all the UDC parameters have a linear and equivalent impact on "OUT", an estimation of the "3 sigma" spread is found.



- However, the Monte-Carlo "3 sigma" spread is still not included in the UDC MIN/MAX range.

CONTENTS

UDC Models: Principal Component Analysis

- **How to proceed if the effects of UDC parameters are not equivalent, not linear and with interactions?**

- **Using the Hadamard's Matrix theory, it is possible to define a <u>Design of Experiments</u> (DOE) in order to evaluate the weigth of each UDC parameters by simulating a minimum number of runs: 4 runs up to 3 parameters, 8 runs up to 7 parameters, 12 runs up to 11 parameters, ...**

- **In our case, 5 UDC parameters are available, we have to simulate the following 8 runs:**

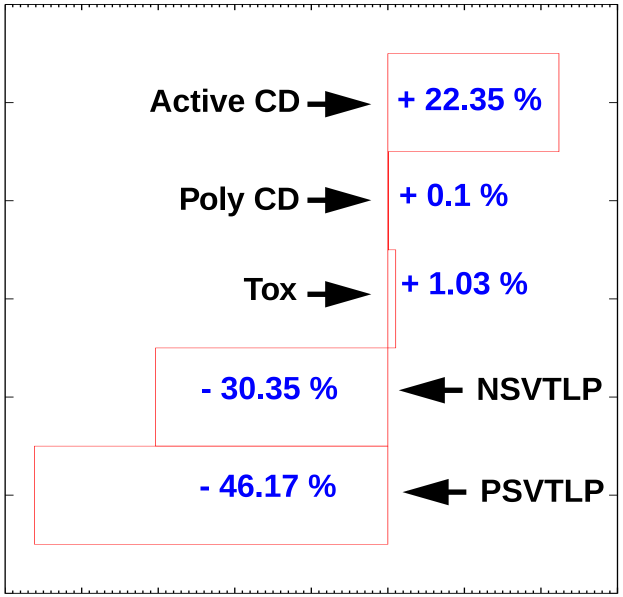
Run	active_cd_user	poly_cd_user	nsigma_lp_dtox_user	nsvtlp_user	psvtlp_user
1	+n	+n	+n	-n	+n
2	-n	+n	+n	+n	-n
3	-n	-n	+n	+n	+n
4	+n	-n	-n	+n	+n
5	-n	+n	-n	-n	+n
6	+n	-n	+n	-n	-n
7	+n	+n	-n	+n	-n
8	-n	-n	-n	-n	-n

➢ n must be fixed in order to include the desired "OUT" spread (3 sigma in our case). Therefore, we can choose n=3 or n=max. Let's take n = 3.

UDC Models: Principal Component Analysis (Cont.)

- **Using the Pareto analysis of the simulation results, we found 3 principal components among the 5 UDC parameters:**

<u>Pareto Analysis</u>:



- **Then, <u>using only 8 runs</u>, we found that 98.9% of the "OUT" variations are due to 3 parameters: Active CD, and the specific parameters of NSVTLP and PSVTLP mainly due to implant variations.**

- **Moreover, using the sign of the contributions, we know on which direction the MIN/MAX limits of "OUT" stand (the same directions as those obtained by the previous 32 UDC runs).**

- **<u>Note</u>: Some indications about the Hadamard matrix and the Pareto Analysis are given in the Appendix.**

UDC MODELS: SIMPLE MODEL CONSTRUCTION

- **At this step of our UDC analysis, we performed 8 runs and we know:**
  - that the effects of the 5 parameters are not equivalent,
  - what are the 3 principal components,
  - the direction to choose to reach the MIN/MAX limits of our output characteristics.

- **But, we can also express "OUT" using a linear function of the 5 UDC parameters:**
  - "OUT" = a_0 + a_1.active_cd_user + a_2.poly_cd_user + a_3.nsigma_lp_dtox_user + a_4.nsvtlp_user + a_5.psvtlp_user

- **The following values have been found using the weigths already calculated during the Pareto analysis:**

Coefficient	Value
a0	7.775e-6
a1	1.015e-7
a2	6.717e-9
a3	2.182e-8
a4	-1.183e-7
a5	-1.459e-7

- **The square value of the regression coefficient is equal to R^2 = 0.9992 (very good value close to 1).**
  - For a regression coefficient R2 < 0.98, the user has to deeply analyse the DOE matrix used and to change it if necessary (increase the order of the model, include interactions,...).

UDC MODELS: SIMPLE MODEL CONSTRUCTION (CONT.)

- **But,**

    How to estimate the value of the mean and σ values of "OUT"?

    Are additional runs necessary?

- **Considering that each UDC parameter follows a Normal Distribution law (mean = 0, σ = 1), it is now possible to apply the Monte-Carlo simulations to the quadratic expression of "OUT" in order to evaluate its mean and σ values.**

- **No additional run is, then, necessary. But, the simulator (ELDO for example) may be still useful!**

UDC MODELS: SIMPLE MONTE-CARLO SIMULATIONS

- **A simple ELDO netlist can be proposed in order to apply the Monte-Carlo simulations to the quadratic expression of “OUT”:**
  - First, the gaussian distribution laws (N(0,1)) for the UDC parameters are defined:

```
.param x1 = 0.0 LOT/gauss={1}
.param x2 = 0.0 LOT/gauss={1}
.param x3 = 0.0 LOT/gauss={1}
.param x4 = 0.0 LOT/gauss={1}
.param x5 = 0.0 LOT/gauss={1}
```

  - In order to remain consistent with our D.O.E. construction, we trunc the gaussian distribution to the max limit used.

```
.option sigtail = 3
```

  - Then, the linear, quadratic, and iteration coefficients are defined:

```
.param a0 = 7.775e-6 a1 = 1.015e-7 a2 = 6.717e-9 a3 = 2.182e-8 a4 = -1.183e-7 a5 = -1.459e-7
.param out = a0 + a1.x1 + a2.x2 + a3.x3 + a4.x4 + a5.x5
```

  - A “virtual” netlist using 2 voltage sources is defined, and a “pseudo” DC analysis is performed:

```
vout 1 0 dc out
vin 2 0 dc 1
.dc vin 0 1 1
```

  - The value of the voltage on the node “1” is, then, equal to “OUT”

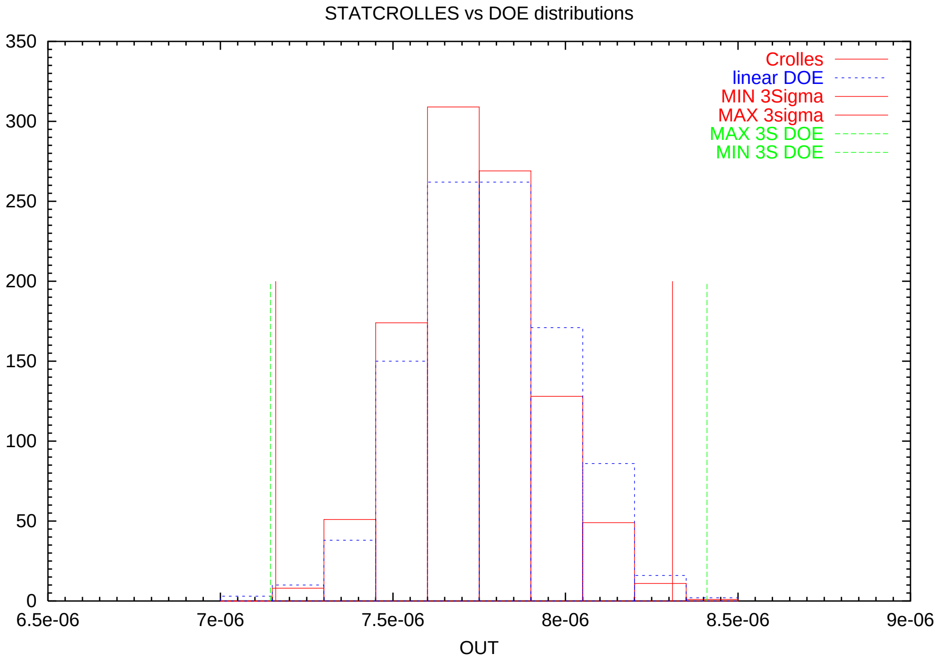
```
.extract label=out yval(v(1), 1)
```

  - Then, 1000 (or more) runs are performed:

```
.mc 1000 v(1)
```

UDC Models: Simple Monte-Carlo Simulations (Cont.)

- **Using only <u>8 UDC simulations</u>, we are now able to evaluate the sigma and mean values of “OUT”:**
  - Mean = 7.775U (i.e. 0.5% higher than the Monte-Carlo value: 7.736U),
  - Sigma = 0.21U (i.e. 10% higher than the Monte-Carlo value: 0.191U),
  - “3 sigma” Minimum value = 7.145U (i.e. 0.2% smaller than the Monte-Carlo value: 7.16U),
  - “3 sigma” Maximum value = 8.41U (i.e. 1.2% higher than the Monte-Carlo value: 8.31U).



UDC Models: Simple Monte-Carlo Simulations (Cont.)

- **The various simulation durations are summarized in the table below for the circuit used in the example:**

Simulation Methodology	Number of runs	Total Duration	Available Information
Monte-Carlo (STATCROLLES)	1000	1 hour	Mean + Sigma
Full UDC	32	30 s	Worst/Best Case Direction
DOE + Simple Monte-Carlo	8	9 s (6 s + 3 s)	Worst/Best Case Direction, Principal Components, Mean + Sigma.

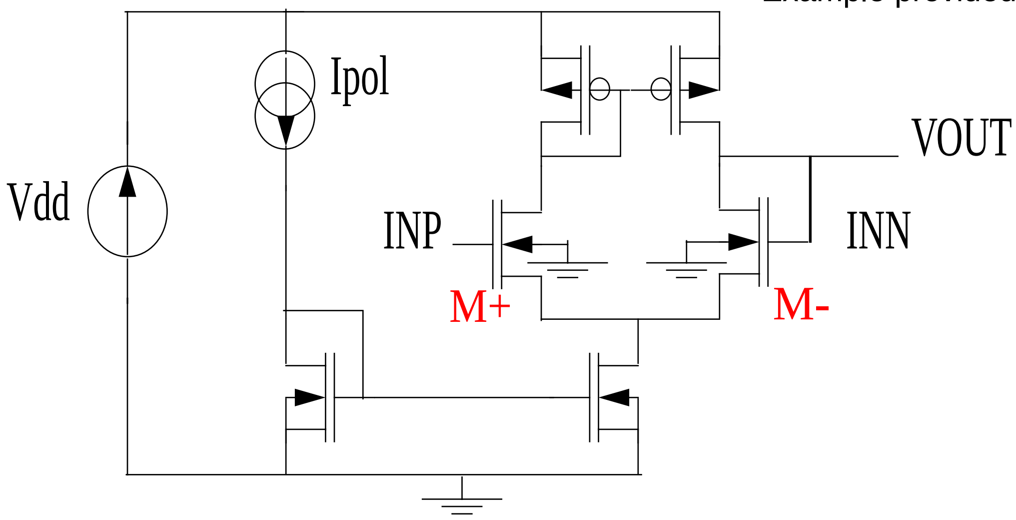
- **It is important to note that <u>the Monte-Carlo simulation remains the most realistic methodology</u> in order to estimate the technology variations.**
  However, when the Monte-Carlo simulations are not applicable (duration, ...), the definition of some Design Of Experiments using the User Defined Corner models may be a good way to evaluate the variations of the performances of a circuit.

CONTENTS

EXAMPLE OF LOCAL VARIATION ANALYSIS

❑ **The Differential Amplifier is a typical example of a circuit impacted by the local variations.**

Example provided by F. Hasbani



❑ **The difference between the identically designed MOS transistors M+ and M- will strongly impact the value of VOUT.**

❑ **The impact of the local variations on the Differential Amplifier can be evaluate using the statistical or the User Defined Corner simulations.**

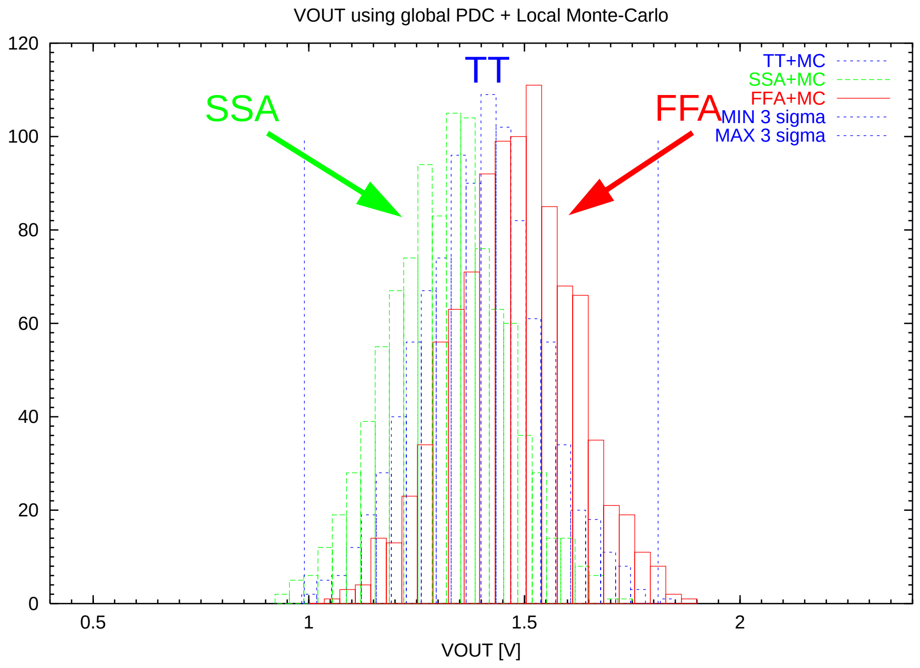
❑ **In this example, we will try to evaluate the “3 sigma” spread of VOUT due to the local variations.**

CONTENTS

MONTE-CARLO SIMULATIONS

- **In the typical case, VOUT=1.4V when VINN=VINP=VDD/2. What is the spread of VOUT due to the technology variations?**

- **In order to evaluate the spread of VOUT, we performed 3 Monte-Carlo simulations (1000 runs each):**
  - Global pre-defined corner TT + Monte-Carlo for Local variations,
  - Global pre-defined corner SSA + Monte-Carlo for Local variations,
  - Global pre-defined corner FFA + Monte-Carlo for Local variations.



- The Monte-Carlo simulations on each pre-defined corner show that the impact of the global variations is neglectible versus the local variations.

- The "3 sigma" spread due to the local variations is [0.99,1.81 V] in the typical case.

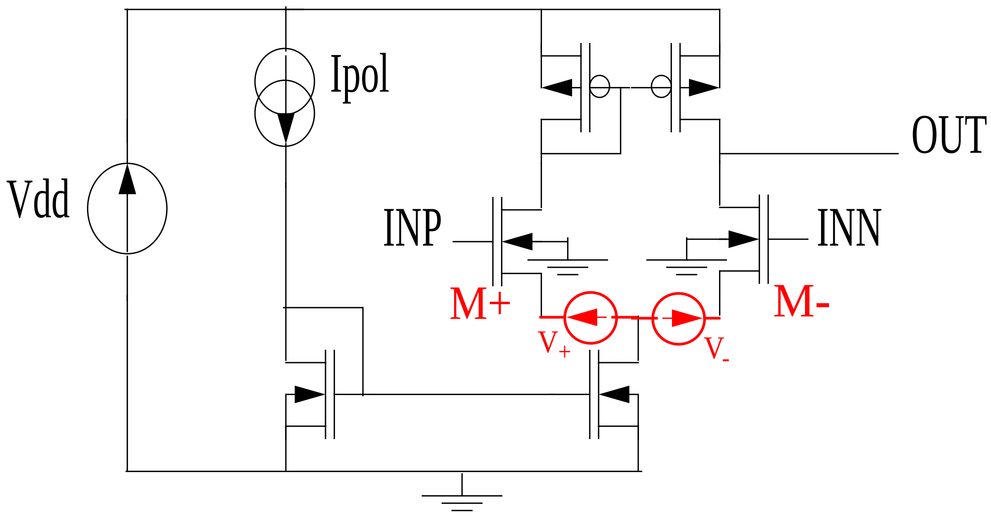
CONTENTS

- **Definition of a technology variation**
- **Technology Variation Modeling Methodology**
- **Examples**
  - Example of Global Variation Analysis
  - Example of Local Variation Analysis
    - Statistical Simulations
    - **User Defined Corner Simulations**
  - When Local Pre-Defined Corners should be used?
- **Conclusion**
- **Perspectives**
- **Appendix**

MISMATCH CORNERS: THE OBSOLETE METHODOLOGY

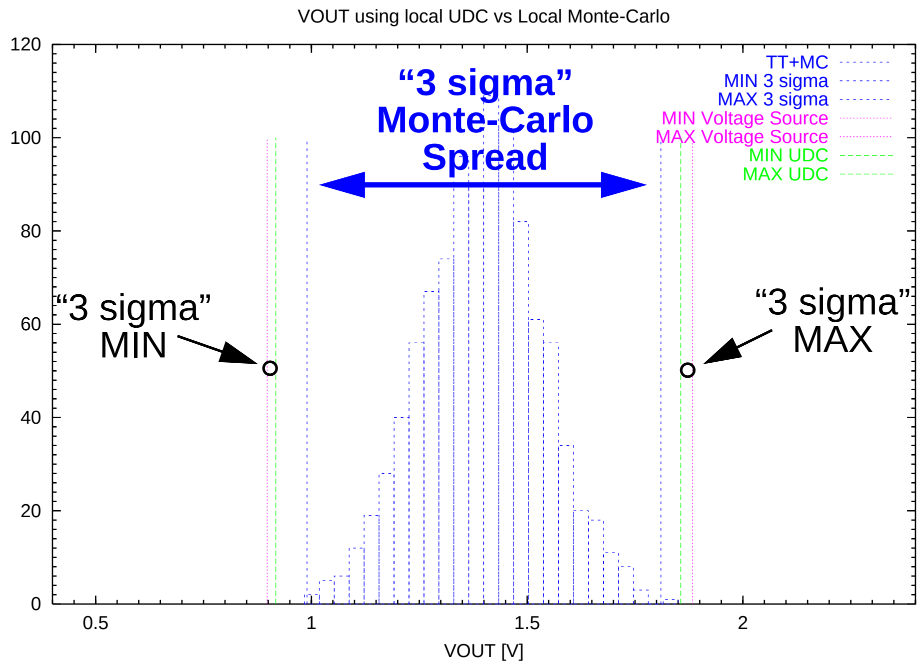
- **The analysis of the Differential Amplifier shows that only the VT mismatch between M+ and M- transistors is responsible for the variation of VOUT (note: here also, the Principal Component Analysis (Pareto) can be used in order to evaluate the weights of each mismatch component and confirm this statement).**

- **Without the User Defined Corners for local variations, the often used methodology was to:**
  - Read the A_{vt} data in the DRM,
  - Calculate the VT sigma value (σ_{VT}) using the W/L size of M+ and M-,
  - Define 2 DC Voltage Sources ($V_+ = n*\sigma_{VT}$ for M+ and $V_- = -n*\sigma_{VT}$) on the common Source node of M+ and M-, Note: the value of n can be set equal to $3/\sqrt{2}$ if we try to evaluate the "3 sigma" spread using only 2 equivalent parameters.



Mismatch Corners: UDC models for Local Variations

- **It also possible to use the local UDC models in order to evaluate the "3 sigma" spread of VOUT.**
- **In this case, it is not necessary to modify the netlist nor to read the DRM. We only have to specify, in the instance line of the transistors M+ and M-, the number of VT sigma using dvt_mdev (+/-** $3/\sqrt{2}$).
- **Equivalent results are found using the UDC models for local variations and the complicated Voltage Source methodology:**



CONTENTS

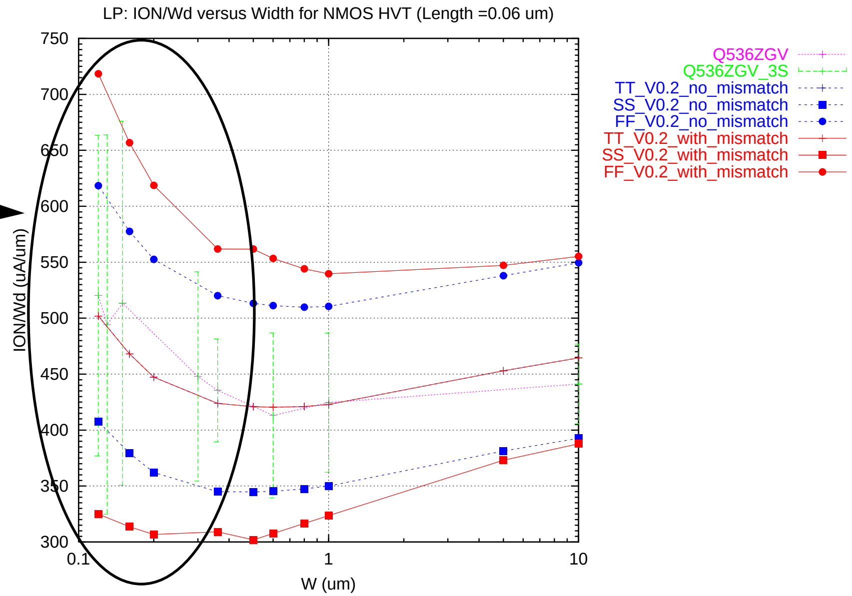
WHEN LOCAL PRE-DEFINED CORNERS SHOULD BE USED?

- **<u>Remind</u>: The pre-defined corners for local variations use the same σ_{VT} and σ_{β} values as those used for the Monte-Carlo simulations. These σ values are combined and added to the global variations in order to reach the worst cases for speed and ION_N/ION_P ratio.**

- **<u>Note</u>: the PDC local variations impact all the MOS transistors of a die in the same way.**

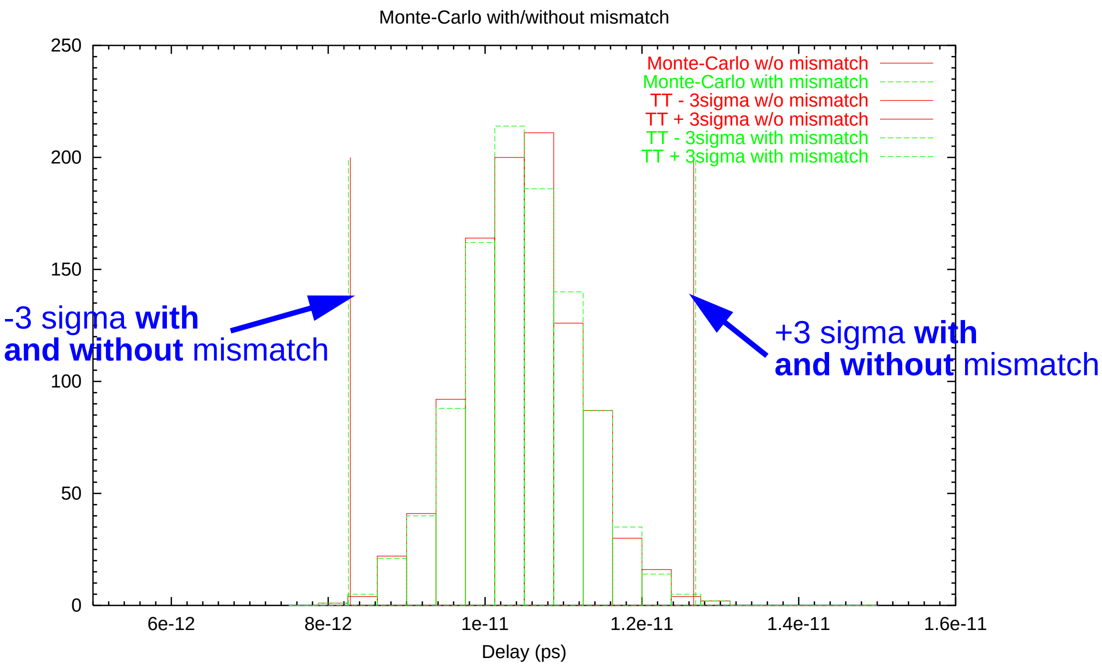
- **Therefore, they are suitable for the comparison of simulated data versus the Process Control Monitoring (PCM) results, especially for the narrow and short devices.**
  Indeed, in the PCM data, both local and global variations are taken into account (measurement of the electrical characteristics of one single transistor on several dies of several wafers of several lots).

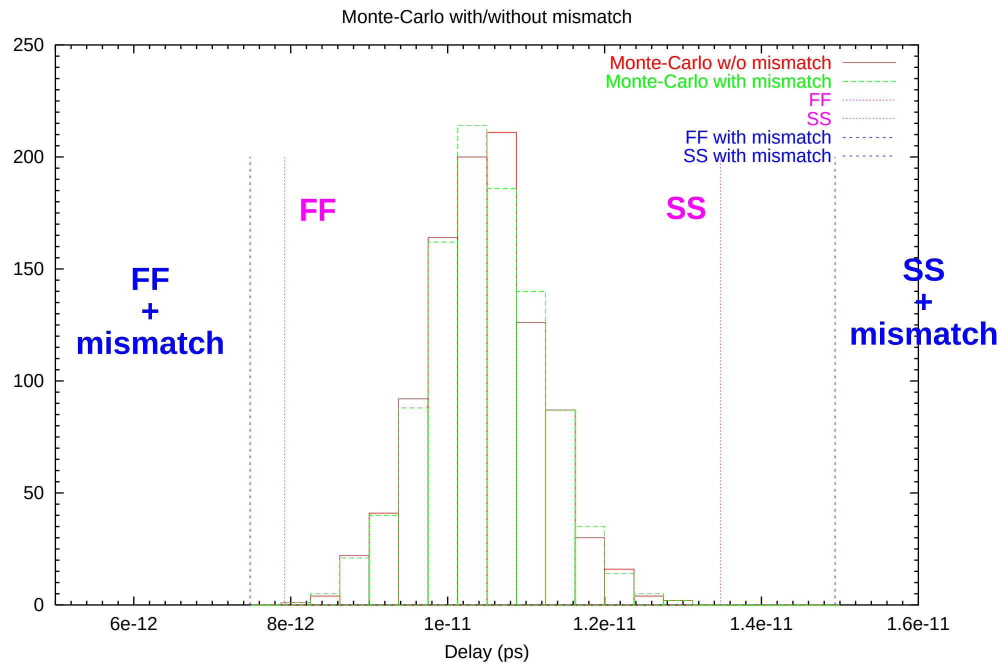
The "3 sigma" spread of ION variations for individual transistors are better taken into account using the local PDC models.



MONTE-CARLO VERSUS PRE-DEFINED CORNERS

- However, when more than 2 or 3 transistors are used, the Pre-Defined corners may lead to a too large spread.
- Indeed, the probability that all the transistors of one same circuit are impacted by the local variations in the same way is very low!
- Let's take again the example of a Ring Oscillator (Fan-Out1, 5 stages, Wn/Wp=0.36/0.5u). Only 10 transistors are used in this circuit. The picture below shows that the FF, SS corners including mismatch over-estimate the spread of 1000 Monte-Carlo runs (using both Local and Global variations).





CONTENTS

- Definition of a technology variation
- Technology Variation Modeling Methodology
- Examples
- Conclusion
- Perspectives
- Appendix

CONCLUSION

- The Technology Variation Modeling methodology used in CMOS065 has been described including the various model options (Statistical, User Defined, and Pre-Defined Models) for both global and local variations.

- Some simple examples of design applications have also been given in order to focuse on some important advantages and limitations of the different model options.

- In particular, it has been shown that:

  - The “Crolles” Statistical simulations can be considered as a reference for the analysis of the technology variations,

  - The Pre-Defined Corners for MOS transistors are dedicated to the applications for which the speed performances, the ION values, or the ION_N/ION_P ratio are the crucial parameters,

  - The User Defined Corners can be used in all others cases, and particularly, in order to evaluate the principal factors of variations for functionnality analysis or for design optimization.

PERSPECTIVES

- **The silicon validation of the sigma values and the correlations will be done for the maturity milestone 4. In fact, a statistically significant sampling is needed in order to analyze these aspects of a compact model. However, some preliminary validations will be lead for the V1.0 models during the beginning of 2006 (for both global and local variations).**

- **The methodology may still improve depending on the feedbacks and the new requests of the design teams (all your feedbacks will be welcome).**

BACK-UP SLIDES

CONTENTS

- **Definition of a technology variation**
- **Technology Variation Modeling Methodology**
- **Examples**
- **Conclusion**
- **Perspectives**
- **Appendix**
  - Summary Table
  - Description of the Hadamard Matrix
  - Pareto Analysis
  - Definition of the UDC parameters

APPENDIX

SUMMARY TABLE

Model	Figure of Merit	Correlation	Amplitude	Possible Application	Model Libary	Instance Parameter	Global Parameter
Statistic Crolles	Any	All	distributed	Yield (Memory, Analog, ...)	*_STATCROLLES	--	--
Statistic MultiFab	Any	All	distributed	Functionality	*_STATMULTIFAB	--	--
Statistic Mismatch	Any	No	distributed	Functionality (Memory, Analog, ...)	Any	mismatch=1	<family>_dev=1
Global User Corners	Any	All	variable	Functionality, Design Optimization (IO, ...)	*_USER	--	*_user
Local User Corners	Any	No	variable	Functionality (Memory, ...)	*_USER, *_TT, *_SS, ...	mismatch=1, dmu_mdev, dvt_mdev	<family>_dev=3
Global Pre-defined Corners	Speed, N/P ratio, C, R	Mosfet Only	fixed	Digital Library Charaterization	*_TT, *_SS, ...	--	--
Local Pre-defined Corners	Speed, N/P ratio	Mosfet Only	fixed	Analog/IO Library Characterization	*_TT, *_SS, ...	--	<family>_dev=2

DESCRIPTION OF THE HADAMARD MATRIX

- **It has been demonstrated that the effects (or the weights) of <u>k factors</u> on a given characteristic "OUT" can be estimated using <u>N experiments</u> where N is a multiple of 4 (if k > 2).**

- **To do so, the effects of all the k factors are assumed to be linear and independent (no iterations). "OUT" can then be expressed by: OUT = $b_0 + b_1 * X_1 + b_2 * X_2 + \ldots + b_i * X_i + \ldots + b_k * X_k$. Where, the X_i are related to one given factor and is equal to +1 or -1.**

- **The matrix of the N experiments is then defined starting the first line given below, followed by the circular permutation of the first line and ended by a line of -1.**

- N = 4: + + - ← k = 3
- N = 8: + + + - + - - ← $4 \le k < 7$ (Matrix example for N = 5 given in the Global UDC example chapter)
- N = 12: + + - + + + - - - + - ← $8 \le k < 11$
- N = 16: + + + + - + - + + - - + - - - ← $12 \le k < 15$
- N = 20: + + - - + + + + - + - + - - - - + + - ← $16 \le k < 19$
- N = 24: + + + + + - + - + + - - + + - - + - + - - - - ← $20 \le k < 23$

PARETO ANALYSIS

- **Using the N results (OUT_i) obtained using the Hadamard matrix, it is now possible to calculate the weigths of each factor (b_j) by:**
  - multiplying, for the column j and each line i, OUT_i by X_i,
  - adding all the N values of OUT_i*X_i for column j,
  - and, then, dividing by N ($b_j = \sum_i \frac{OUT_i \cdot X_i}{N}$),
  - b0 is the mean value of OUT_i ($\sum_i \frac{OUT_i}{N}$).

- **The Pareto graph is obtained by calculating the following percentage:** $100 \cdot \left(b_j^2 \big/ \left(\sum_j b_j^2 \right) \right)$.

STATISTICAL SIMULATION RESULTS

- **The estimation of the standard deviation (sigma) and of the average value is strongly depedent on the number of runs (N). Indeed, assuming that "OUT" follows a normal law N(M, S), we are sure at (1-α)*100 % that:**

  - $$M - \frac{T_{(N-1,\,\alpha/2)} \cdot S}{N^{1/2}} < Mean < M + \frac{T_{(N-1,\,\alpha/2)} \cdot S}{N^{1/2}}$$

    - where T is given by the Student's t-distribution with N degrees of freedom.

  - $$\frac{(N-1) \cdot S^2}{\chi^2_{(N-1,\,\alpha/2)}} < Sigma^2 < \frac{(N-1) \cdot S^2}{\chi^2_{(N-1,\,1-\alpha/2)}}$$

    - where χ is given by the Chi2 distribution with N degrees of freedom.

- **The values of Student's and Chi2 distributions are available in tables in many statistic books.**

- **In the case of our example, we can affirm that we are sure at 95% that** 7.726 < Mean < 7.746 **and** 0.183U < Sigma < 0.208U.

- **In order to have a better estimation of the Mean and Sigma values of "OUT", the number of runs has to be increased.**

- **However, due to the simulation duration, it is often not possible to use the Monte-Carlo simulations.**
  The other model options are then necessary (PDC or UDC).

DEFINITION OF THE UDC PARAMETERS

❑ LP SVT Devices:

NSVTLP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_lp_dtox_user	common_go1	Oxide Thickness for LP devices	SS	FF	+/- 4
	nsigma_lp_dcfring_user	common_go1	Fringe Capacitance for LP devices	no Impact	no Impact	+/- 4
	nsvtlp_user	**LPmos_bsim4_svt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

PSVTLP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_lp_dtox_user	common_go1	Oxide Thickness for LP devices	SS	FF	+/- 4
	nsigma_lp_dcfring_user	common_go1	Fringe Capacitance for LP devices	no Impact	no Impact	+/- 4
	psvtlp_user	**LPmos_bsim4_svt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

❑ LP SVT RPO Devices:

NSVTLPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NSVTLP devices + the parameters defined below for the RPO resistances					
	nsigma_nsd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_npoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

PSVTLPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as PSVTLP devices + the parameters defined below for the RPO resistances					
	nsigma_psd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_ppoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

❑ LP HVT Devices:

NHVTLP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_lp_dtox_user	common_go1	Oxide Thickness for LP devices	SS	FF	+/- 4
	nsigma_lp_dcfring_user	common_go1	Fringe Capacitance for LP devices	no Impact	no Impact	+/- 4
	nhvtlp_user	**LPmos_bsim4_hvt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

PHVTLP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_lp_dtox_user	common_go1	Oxide Thickness for LP devices	SS	FF	+/- 4
	nsigma_lp_dcfring_user	common_go1	Fringe Capacitance for LP devices	no Impact	no Impact	+/- 4
	phvtlp_user	**LPmos_bsim4_hvt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

❑ LP HVT RPO Devices:

NHVTLPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NHVTLP devices + the parameters defined below for the RPO resistances					
	nsigma_nsd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_npoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

PHVTLPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as PHVTLP devices + the parameters defined below for the RPO resistances					
	nsigma_psd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_ppoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

❑ LP LVT Devices:

NLVTLP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_lp_dtox_user	common_go1	Oxide Thickness for LP devices	SS	FF	+/- 4
	nsigma_lp_dcfring_user	common_go1	Fringe Capacitance for LP devices	no Impact	no Impact	+/- 4
	nlvtlp_user	**LPmos_bsim4_lvt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

PLVTLP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_lp_dtox_user	common_go1	Oxide Thickness for LP devices	SS	FF	+/- 4
	nsigma_lp_dcfring_user	common_go1	Fringe Capacitance for LP devices	no Impact	no Impact	+/- 4
	plvtlp_user	**LPmos_bsim4_lvt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

❑ LP LVT RPO Devices:

NLVTLPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NLVTLP devices + the parameters defined below for the RPO resistances					
	nsigma_nsd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_npoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

PLVTLPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as PLVTLP devices + the parameters defined below for the RPO resistances					
	nsigma_psd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_ppoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

❑ GP SVT Devices:

NSVTGP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_gp_dtox_user	common_go1	Oxide Thickness for GP devices	SS	FF	+/- 4
	nsigma_gp_dcfring_user	common_go1	Fringe Capacitance for GP devices	no Impact	no Impact	+/- 4
	nsvtgp_user	**GPmos_bsim4_svt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

PSVTGP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_gp_dtox_user	common_go1	Oxide Thickness for GP devices	SS	FF	+/- 4
	nsigma_gp_dcfring_user	common_go1	Fringe Capacitance for GP devices	no Impact	no Impact	+/- 4
	psvtgp_user	**GPmos_bsim4_svt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

❑ GP SVT RPO Devices:

NSVTGPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NSVTGP devices + the parameters defined below for the RPO resistances					
	nsigma_nsd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_npoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

PSVTGPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as PSVTGP devices + the parameters defined below for the RPO resistances					
	nsigma_psd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_ppoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

❑ GP HVT Devices:

NHVTGP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_gp_dtox_user	common_go1	Oxide Thickness for GP devices	SS	FF	+/- 4
	nsigma_gp_dcfring_user	common_go1	Fringe Capacitance for GP devices	no Impact	no Impact	+/- 4
	nhvtgp_user	**GPmos_bsim4_hvt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

PHVTGP	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_gp_dtox_user	common_go1	Oxide Thickness for GP devices	SS	FF	+/- 4
	nsigma_gp_dcfring_user	common_go1	Fringe Capacitance for GP devices	no Impact	no Impact	+/- 4
	phvtgp_user	**GPmos_bsim4_hvt**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

❑ GP HVT RPO Devices:

NHVTGPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NHVTGP devices + the parameters defined below for the RPO resistances					
	nsigma_nsd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_npoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

PHVTGPRPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as PHVTGP devices + the parameters defined below for the RPO resistances					
	nsigma_psd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_ppoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

❑ GO2 SVT25 Devices:

NSVT25	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FFA	SSA	+/- 4
	poly_cd_user	common_poly	Poly CD	SSA	FFA	+/- 3
	nsigma_go2h_dtox_user	common_go2	Oxide Thickness for 50Angst. devices	SSA	FFA	+/- 4
	nsigma_go2h_dcfring_user	common_go2	Fringe Capacitance for 50Angst. devices	no Impact	no Impact	+/- 4
	nsvt25_user	**mos_bsim4_svt25**	**Specific variations (VT, mobility)**	**FFA**	**SSA**	**+/- 4**

PSVT25	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_go2h_dtox_user	common_go2	Oxide Thickness for 50Angst. devices	SS	FF	+/- 4
	nsigma_go2h_dcfring_user	common_go2	Fringe Capacitance for 50Angst. devices	no Impact	no Impact	+/- 4
	psvt25_user	**mos_bsim4_svt25**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

❑ GO2 SVT25 RPO Devices:

NSVT25RPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NSVT25 devices + the parameters defined below for the RPO resistances					
	nsigma_nsd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_npoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

NSVT25RPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NSVT25 devices + the parameters defined below for the RPO resistances					
	nsigma_psd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_ppoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

❑ GO2 SVT18 Devices:

NSVT18	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FFA	SSA	+/- 4
	poly_cd_user	common_poly	Poly CD	SSA	FFA	+/- 3
	nsigma_go2n_dtox_user	common_go2	Oxide Thickness for 28Angst. devices	SSA	FFA	+/- 4
	nsigma_go2n_dcfring_user	common_go2	Fringe Capacitance for 28Angst. devices	no Impact	no Impact	+/- 4
	nsvt18_user	**mos_bsim4_svt18**	**Specific variations (VT, mobility)**	**FFA**	**SSA**	**+/- 4**

PSVT18	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	FF	SS	+/- 4
	poly_cd_user	common_poly	Poly CD	SS	FF	+/- 3
	nsigma_go2n_dtox_user	common_go2	Oxide Thickness for 28Angst. devices	SS	FF	+/- 4
	nsigma_go2n_dcfring_user	common_go2	Fringe Capacitance for 28Angst. devices	no Impact	no Impact	+/- 4
	psvt18_user	**mos_bsim4_svt18**	**Specific variations (VT, mobility)**	**FF**	**SS**	**+/- 4**

❑ GO2 SVT18 RPO Devices:

NSVT18RPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NSVT18 devices + the parameters defined below for the RPO resistances					
	nsigma_nsd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_nsd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_npoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_npoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

NSVT18RPO	Parameter to be defined	Number of Sigma Definition	Library file	Corner direction if >0	Corner direction if <0	Maximum variation
	Same parameters as NSVT18 devices + the parameters defined below for the RPO resistances					
	nsigma_psd_drshu_user	Unsalicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsc_user	OD Contact resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drsh_user	Salicided OD Sheet resistance	common_active	SS	FF	+/- 4
	nsigma_psd_drhi_user	OD Interface resistance	common_active	SS	FF	+/- 4
	nsigma_ppoly_drsh_user	Salicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drsc_user	Poly Contact resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drshu_user	Unsalicided Poly Sheet resistance	common_poly	SS	FF	+/- 4
	nsigma_ppoly_drhi_user	Poly Interface resistance	common_poly	SS	FF	+/- 4

❑ LP SVT SRAM Single-Port 0.525um2 Devices:

NSVTLPPDSP NSVTLPPGSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	nsramspsvtlp_user	**FF**	**SS**

PSVTLPPUSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	psramspsvtlp_user	**FF**	**SS**

❑ LP SVT SRAM Single-Port 0.620um2 Devices:

NSVTLPPDSP620 NSVTLPPGSP620	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	nsramsp620svtlp_user	**FF**	**SS**

PSVTLPPUSP620	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	psramsp620svtlp_user	**FF**	**SS**

❑ LP SVT SRAM Dual-Port 0.97um2 Devices:

NSVTLPPDDP NSVTLPPGDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	nsramdpsvtlp_user	**FF**	**SS**

PSVTLPPUDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	psramdpsvtlp_user	**FF**	**SS**

❑ LP HVT SRAM Single-Port 0.525um2 Devices:

NHVTLPPDSP NHVTLPPGSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	nsramsphvtlp_user	**FF**	**SS**

PHVTLPPUSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	psramsphvtlp_user	**FF**	**SS**

❑ LP HVT SRAM Single-Port 0.620um2 Devices:

NHVTLPPDSP620 NHVTLPPGSP620	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	nsramsp620hvtlp_user	**FF**	**SS**

PHVTLPPUSP620	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	psramsp620hvtlp_user	**FF**	**SS**

❑ LP HVT SRAM Dual-Port 0.97um2 Devices:

NHVTLPPDDP NHVTLPPGDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	nsramdphvtlp_user	**FF**	**SS**

PHVTLPPUDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_lp_dtox_user	SS	FF
	nsigma_lp_dcfring_user	no Impact	no Impact
	psramdphvtlp_user	**FF**	**SS**

❑ GP SVT SRAM Single-Port 0.525um2 Devices:

NSVTGPPDSP NSVTGPPGSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	nsramspsvtgp_user	**FF**	**SS**

PSVTGPPUSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	psramspsvtgp_user	**FF**	**SS**

❑ GP SVT SRAM Dual-Port 0.97um2 Devices:

NSVTGPPDDP NSVTGPPGDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	nsramdpsvtgp_user	**FF**	**SS**

PSVTGPPUDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	psramdpsvtgp_user	**FF**	**SS**

❑ GP HVT SRAM Single-Port 0.525um2 Devices:

NHVTGPPDSP NHVTGPPGSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	nsramsphvtgp_user	**FF**	**SS**

PHVTGPPUSP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	psramsphvtgp_user	**FF**	**SS**

❑ GP HVT SRAM Dual-Port 0.97um2 Devices:

NHVTGPPDDP NHVTGPPGDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	nsramdphvtgp_user	**FF**	**SS**

PHVTGPPUDP	Parameter to be defined	Corner direction if >0	Corner direction if <0
	active_cd_user	FF	SS
	poly_cd_user	SS	FF
	nsigma_gp_dtoxold_user	SS	FF
	nsigma_gp_dcfring_user	no Impact	no Impact
	psramdphvtgp_user	**FF**	**SS**

❑ Unsilicided P+ Active Resistor:

RPODRPO	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	nsigma_psd_drshu_user	common_active	P+ OD unsilicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_psd_drsc_user	common_active	P+ OD contact resistance	RMAX	RMIN	+/- 3
	nsigma_psd_drsh_user	common_active	P+ OD silicided sheet resistance	RMAX	RMIN	+/- 3
	rpdiff_user	**resistor**	**Specific variations (ΔL,ΔW)**	**RMAX**	**RMIN**	**+/- 3**

❑ Silicided N+ Poly Resistor:

RNPO	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	poly_cd_user	common_poly	Poly CD	RMIN	RMAX	+/- 3
	nsigma_npoly_drsh_user	common_poly	N+ Poly silicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_npoly_drsc_user	common_poly	N+ Poly contact resistance	RMAX	RMIN	+/- 3
	nsigma_npoly_drshu_user	common_poly	N+ Poly unsilicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_poly_dcap_user	common_poly	Specific capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	nsigma_poly_dcf0p_user	common_poly	Fringe capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	rpolys_user	**resistor**	**Specific variations (ΔL,ΔW)**	**RMAX**	**RMIN**	**+/- 3**

❑ Unsilicided N+ Poly Resistor:

RNPORPO	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	nsigma_npoly_drsh_user	common_poly	N+ Poly silicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_npoly_drsc_user	common_poly	N+ Poly contact resistance	RMAX	RMIN	+/- 3
	nsigma_npoly_drshu_user	common_poly	N+ Poly unsilicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_poly_dcap_user	common_poly	Specific capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	nsigma_poly_dcf0p_user	common_poly	Fringe capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	rpolyn_user	**resistor**	**Specific variations (ΔL,ΔW)**	**RMAX**	**RMIN**	**+/- 3**

❑ Unsilicided P+ Poly Resistor:

RPPORPO	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	nsigma_ppoly_drsh_user	common_poly	P+ Poly silicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_ppoly_drsc_user	common_poly	P+ Poly contact resistance	RMAX	RMIN	+/- 3
	nsigma_ppoly_drshu_user	common_poly	P+ Poly unsilicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_poly_dcap_user	common_poly	Specific capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	nsigma_poly_dcf0p_user	common_poly	Fringe capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	rpolyp_user	**resistor**	**Specific variations (ΔL,ΔW)**	**RMAX**	**RMIN**	**+/- 3**

❑ High Resistive Poly Resistor:

RHIPORPO	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	nsigma_npoly_drsh_user	common_poly	N+ Poly silicided sheet resistance	RMAX	RMIN	+/- 3
	nsigma_npoly_drsc_user	common_poly	N+ Poly contact resistance	RMAX	RMIN	+/- 3
	nsigma_poly_dcap_user	common_poly	Specific capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	nsigma_poly_dcf0p_user	common_poly	Fringe capacitance (Poly/Bulk)	RMAX	RMIN	+/- 3
	rpolyh_user	**resistor**	**Specific variations (ΔL,ΔW)**	**RMAX**	**RMIN**	**+/- 3**

❑ 2.5V Poly/Well capacitors:

CPOLYN25	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	CMAX	CMIN	+/- 4
	poly_cd_user	common_poly	Poly CD	CMAX	CMIN	+/- 3
	nsigma_go2h_dtox_user	common_go2	Oxide Thickness for 50Angst. devices	CMIN	CMAX	+/- 4
	nsigma_go2h_dcfring_user	common_go2	Fringe Capacitance for 50Angst. devices	no Impact	no Impact	+/- 4
	cpolyn25_user	**cpoly25**	**Specific variations (Vfb, ...)**	**CMAX**	**CMIN**	**+/- 4**

CPOLYP25	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	active_cd_user	common_active	OD (or Active) CD	CMAX	CMIN	+/- 4
	poly_cd_user	common_poly	Poly CD	CMAX	CMIN	+/- 3
	nsigma_go2h_dtox_user	common_go2	Oxide Thickness for 50Angst. devices	CMIN	CMAX	+/- 4
	nsigma_go2h_dcfring_user	common_go2	Fringe Capacitance for 50Angst. devices	no Impact	no Impact	+/- 4
	cpolyp25_user	**cpoly25**	**Specific variations (Vfb, ...)**	**CMAX**	**CMIN**	**+/- 4**

❑ BE Fringe Capacitor:

cfrm1m5shx, cfrm1m5shy, cfrm1m5shz	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	nsigma_m1_drsh_user	common_be	Metal1 sheet resistance	CMAX	CMIN	+/- 3
	nsigma_mx_drsh_user	common_be	Metalx sheet resistance	CMAX	CMIN	+/- 3
	nsigma_rviax_user	common_be	Viax resistance	CMAX	CMIN	+/- 3
	cfringe_user	**cfringe**	**Specific variations (**coeffa, coeffb**)**	**CMAX**	**CMIN**	**+/- 3**

❑ BE Striped Stacked Plate Capacitor:

CMSTRSTK	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	nsigma_m1_drsh_user	common_be	Metal1 sheet resistance	CMAX	CMIN	+/- 3
	nsigma_mx_drsh_user	common_be	Metalx sheet resistance	CMAX	CMIN	+/- 3
	nsigma_rviax_user	common_be	Viax resistance	CMAX	CMIN	+/- 3
	cstrip_user	**cstrip**	**Specific variations** **(**specific capacitance**,** parasitic resistance**)**	**CMAX**	**CMIN**	**+/- 3**

❑ BE Elementary Plate Capacitor:

CM1Mx, CMxMx, CMxMz, CMzMz	Parameter to be defined	Library file	Number of Sigma Definition	Corner direction if >0	Corner direction if <0	Maximum variation
	cplate_user	**cplate**	**Specific variations** **(**ΔL,ΔW, specific capacitance**)**	**CMAX**	**CMIN**	**+/- 3**