

MBP 2017

Applications



Notices

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- Application Notes

Application Notes

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Add Additional Instance Parameter

This application note describes how to add additional instance parameters in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2011.1.0 in August 2011.

Overview

MBP accepts user-defined instance parameters in both model file and measurement data. In this document, the steps required to add new instance parameters in MBP are covered. For more information go to http://www.keysight. com/find/eesof or contact your local Keysight office. The complete list is available at http://www.keysight.com/main/contactInformation.jspx? tmprop=TM&cc=SG&lc=eng.

Steps

You can follow the steps listed below to complete the process of adding additional instance parameters in MBP.

Model File

To begin, you must first edit the model file to which the new instance parameter will be added. For example, assume that you have specified an instance parameter *xxd*; (in this case, *xxd* has no real physical meaning) in one subcircuit model as follows:

```
.param
+xvth0 = 1e5
. subckt macromodel d g s b w=1e-6 l=1e-6 xxd=1e-6
sa=1e-6 sb=1e-6
.param
+dvth0 = _xxd*xvth0_
m1 d g s b nmos w=w l=1 xxd=xxd sa=sa sb=sb
.model nmos nmos
.model nmos nmos
*** Flag Parameter ***
+level = 49 version = 3.2 binunit = 2
+vth0 = _0.7+dvth0_;
.....
.ends
```

In this example, the new instance *xxd*; is added and declared in the model file. The parameter *dvth0* is expressed as the product of *xxd* and *xvth0*.

Instance Configuration File

Open the file inst.ini under

\$MBP_HOME\etc\hspice\mosfet\bsim3v3\inst_core. Append the xxd, item to the file. Here, \$MBP_HOME is the MBP installation path.

```
ml d g s b nmos w=<le-6,W,le-6,0,um> ... ps=<0,PS,1,0,
m> xxd=<le-6,xxd,1,0,m>
```

The file *inst.ini* claims the model name and instance parameter of the certain device. MBP creates a netlist according to this file. In this example, the instance named *xxd* is added with the default value of *0*, a unit scale of *1*, an offset value of *0*, and the unit name *m*.

Measurement File

Next, you must specify *xxd* in the measurement file. For example:

```
condition{mode=forward,type=nmos,modtype=DC}
```

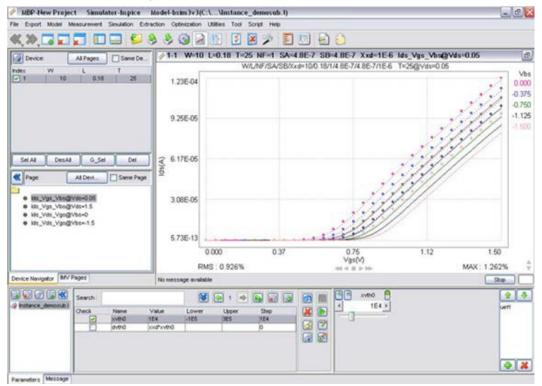
```
Page(name=Ids_Vgs_Vbs,x=Vgs,p=Vbs,y=Ids) { Vds=0.05,W=10
.0,L=0.18,NF=1.0,SA=4.8E-7,SB=4.8E-7,T=25.0,xxd=1e-6}
```

In this example, the new instance *xxd*; is added with the value of *1e-6*;

Simulation

Finally, load the modified model into MBP. Once the user tunes *xvthO*, which is correlated to *xxd*, the change may be observed in the simulation curves, as shown in the following figure.

Add the xxd instance parameter



Advanced Graph Export

This application note describes how to customize a report to be exported in Model Builder Program (MBP).

Overview

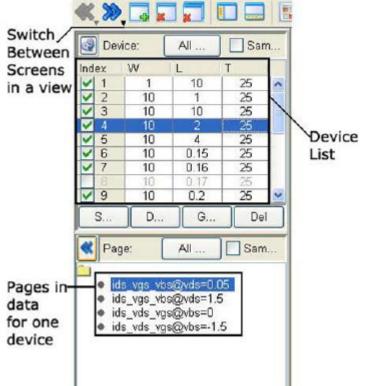
In addition to the basic graph export functions like *All Pages Current View* and *Screen In One* that MBP supports, the software also provides an advanced graph export function that allows you to customize reports according to their specific needs. This document introduces the options and steps for exporting graphs using this advanced mode. For more information go to www.keysight.com or contact your local Keysight office. The complete list is available at www.keysight.com

Basic Concepts

Before introducing MBP's advanced graph export function, a clear and solid understanding of the software's plot category methodology is necessary. To begin, the concepts of Device, Page and View in MBP are defined as follows

- Device: Some measurement data and model simulation results are included under each device. Different devices are included in the device array at the top of the device navigator.
- Page: Page means a set of curves under every device, like Id_Vg and Id_Vd. This information is shown in the page list at the bottom part of the device navigator.
- View : Another plot sequence named view is independent from the device array and page list. View means that all of the plots are contained in the current screen. However, because of space limitations in the display area, MBP cannot display all of the plots at the same time. Instead, MBP displays some plots according to the layout configuration and hides the rest. You can loop the plots in View using the blue arrow buttons in the tool bar. As shown in the figure device list, you can add plots to the current view by clicking the Add screen button beside the blue arrow. The math transform and the log /linear scale will also be memorized in a View. Pay attention to the difference between View and Screen. A View is a kind of extension of Screen and may have more than one screen.





Export Graphics

MBP's advanced export function is based on the Device, Page and View grouping categories. To export graphics, you must first click Export > Export Graph > Advanced from the main menu. This pops up the window called Report Collector, as shown in the following figure:

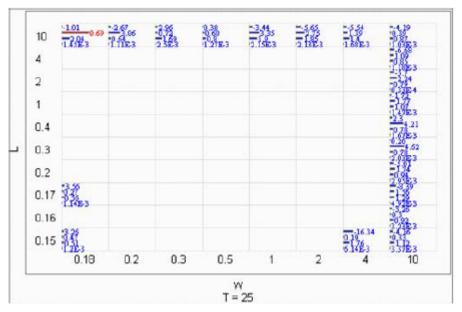
Report Collector

election		0 4 X
 ✓ By device Device ✓ Selected ▲11 	Fage Fage All pages As view	Collector Collector
Dy view		
Current screen	All Screens	
Imper FileBane : report	t Clear	
	t Cleur Brooser	View Graph
FileBane : report Path :		View Graph
FileBane : report Path : Dype DGLF PDF HI MS Diffice Graph Option	Browser RL O PFI O EICEL O NORD	View Graph
FileBane : report Path : Sype SGIF PDF NH	Browser RL O PFI O EICEL O NORD	View Graph
FileBane : report Path : Dype D GIF D PDF HI MS Office Graph Option Word, FPT : D Image Excel : D Image Fage Layout: row x column	Browner ML O PFI O EICEL O WORD O Ercel Object O Chart	View Graph

Choose exported graphs

You must select the graphs to be exported. MBP provides two options in this regard: to export By view or By device You can choose either option. If By view is checked, there are two options you can choose from. One is to export the graphs in the current screen by checking Current screen. The other option is to export the graphs in all screens by checking All screens. If By device is checked, you have more options. First, you must specify the devices to be exported, either choosing all devices by checking All or only the devices selected in device navigator by checking Selected . Then, define the page to be exported for each device. Here, there are two options. All pages exports all of the pages for the selected devices, while the As View option enables you to define a set of plots in a view and export the graphs of the selected devices according to the current view. If you check the Export error monitor option, the error monitor graph as shown in the figure below will also be exported.

Error Monitor graph



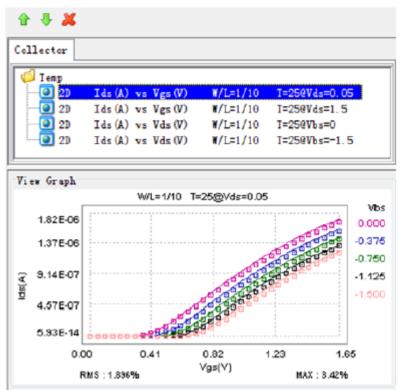
By checking the Export error table option, the error tables as shown in the following figure will be added to the report.

Page	W	L	T	Bias	Math	RMS	MAX
ids_vds_vgs	1	10	25	vbs=0	У	1.96%	4.19%
ids_vds_vgs	1	10	25	vbs=-1.5	у	2.91%	5.50%
ids_vds_vgs	10	1	25	vbs=0	У	1.58%	4.80%
ids_vds_vgs	10	1	25	vbs=-1.5	у	1.28%	3.15%
ids_vds_vgs	10	10	25	vbs=0	У	0.38%	1.73%
ids_vds_vgs	10	10	25	vbs=-1.5	у	1.60%	3.51%
ids_vds_vgs	10	2	25	vbs=0	У	1.22%	3.83%
ids_vds_vgs	10	2	25	vbs=-1.5	у	1.12%	2.67%
ids_vds_vgs	10	4	25	vbs=0	у	0.59%	2.44%
ids_vds_vgs	10	4	25	vbs=-1.5	у	1.52%	3.60%

Error table

Collector

The next step, is to click Import so that all of the graphs to be exported will be placed in the *Collector* section, as shown in the figure below. Here, you can adjust the graph sequence by clicking the Move up or Move down icons. Then, click Remove icon to remove the selected graph from the Collector . When a file is selected in the Collector , its corresponding graph will be plotted automatically in the View Graph section. Collector section



Choose the Exported File Format

MBP allows multiple formats to be exported, including GIF (.gif), PDF (.pdf), HTML (. html), PPT (.ppt or
br/>.pptx), EXCEL (.xls or .xlsx) and WORD (.doc or .docx). You may select any format desired in the Type section. If the exported file type is PPT, Excel or Word, you will have more options to choose from in the MS Office Graph Option section.

- 1. If the file type is PPT or Word, there are three options:
 - Choose Image in Word, PPT to export the graphs only in the generated PPT or Word file.
 - Choose Excel Object in Word, PPT and Image in Excel to export graphs (plotted by MBP) with data in Excel format in the generated PPT or Word file.
 - Choose Excel Object in Word, PPT and Chart in Excel to export graphs (plotted by Excel) with data in Excel format in the generated PPT or Word file.
- 2. If the file type is Excel, there are two options:
 - Choose Image in Excel to export the data and graphs (plotted by MBP) in the generated Excel file.
 - Choose Chart in Excel to export the data and graphs (plotted by Excel) in the generated Excel file.

Choose Exported File Format

After confirming the page layout (row x column), you can then click Save to generate the customized report.

Binned Model Generation and Tweaking

This application note describes how to generate and tweak binned models in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2011.1.0 in July 2011.

Overview

With process variation or when there is a requirement to fit a specific target, tweaking is generally used as a fast way to achieve the corresponding models. For a binned model, the modeling engineer should always pay attention to ensure continuity is kept from bin-to-bin. MBP features an integrated binning tweak capability to meet this need. In this document, we introduce the steps required to generate and tweak binned models. For more information go to www.keysight.com /find/eesof or contact your local Keysight office. The complete list is available at www.keysight.com/find/contactus

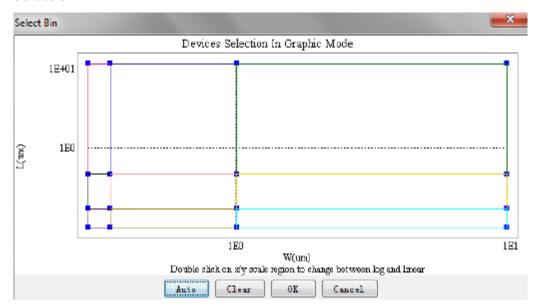
Generate Binned Models

First we introduce how to generate binned models from point models. After all the point models are ready, you can generate the corresponding binned model. To begin, choose Utilities > Binning from the main menu, and then click the Load Point Model button to load the point models. As shown in the figure Load point model a total of 16 point models are loaded.

Binning	linning										
Status	Index	Name	w	L		Load Point Model					
V	1	demo_0.28	0.28	0.12		<u></u>					
1	2	demo_0.28	0.28	0.2		Select Bin					
1	3	demo_0.28	0.28	0.5		Jerect Din					
v	4	demo_0.28	0.28	10	=						
V	5	demo_0.34	0.34	0.12	-	Generate					
V	6	demo_0.34	0.34	0.2							
V	7	demo_0.34	0.34	0.5		Save					
V	8	demo_0.34	0.34	10							
V	9	demo_10_0	10	0.12		Exit					
	10	demo_10_0	10	0.2		Exit					
V	11	demo 10.0	10	0.5	*						

Load point model

Binning region selection is done in a geometry plane. Click Select Bin and the graphical bin selection window will pop up. Press and hold Ctrl, then use the cursor to select the bin region. You can also click Auto to generate the bins automatically. In the example, the 16 devices are divided into nine bins, as shown in the following figure:



Select bin

After the bin selection is done, click Generate. The dialog window shown in the figure below will pop up where you must type in the bin model name. Then, you have an option to expand the bin boundary by checking the Extend Boundary box and inputting the ratio value. For example, after checking Extend Boundary and setting the ratio at 0.01, LMax will become 1.01E-5 from 1E-5. WMax also becomes 1.01E-5 from 1E-5.

Generate binned model

Dialog	×
Bin Name	
Bin Name:	bin
▼ Extend Boundar	y Ratio: 0.01
OK	Cancel

Press the Save button to store the generated binned model.

Three Options Regarding Binned Model

Load the binned model just created. Right-click to open a new window as shown in the following figure:

Three binned model options

🙀 🙀 🖉 S	؛ 🔊 🕄	Search :				۲	0	
bin.	Set bin I	boundary	DW/DL V	TH MOB SUE	Rout Temp	Diode Cap	Stress 🕢 🕨	j 🞽 💽
	To Poin Extend I		Name	Value	Lower	Upper	Step	
			level	49			<u>م</u> 0	
- bin 6			version	3.2			0	
			binuni t	2			0	
- Din 8			lmin	5E-7	0	1	1E-7	
bin. 9			lmax	1.01E-5	0	1	1E-7	
opr bin. 5			mobmod	1			0	
			wmin	1E-6	0	1	1E-7 +	
				Unspecif	ied Paramete	ers		
Parameters Me	ssage							

ameters

There are three options:

1. Set bin boundary

For a binned model, the user often extends the maximum channel width and length a little to verify that the simulation of the WMax/LMax device is correct. For example, given the setting shown below in the figure, the model is extracted from WMax/ LMax=10µm/10µm device. However, in the final binned model, the user will obtain a bin boundary of WMax/LMax =10.1 μ m /10.1µm. Set binning boundary

🥢 Bin	ning Boundary Setti	ng		x
Please	input a new bound	ary for t	he binning m	odel:
WMax:	1.01E-5	LMax:	1.01E-5	
	OK	Cance	1	

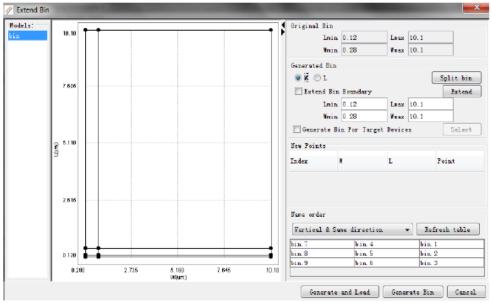
2. To point mode

Convert the loaded bin models to point models. The newly generated point models are to the right of the original bin boundary points. After this operation, you can tune the bin boundary point models directly to meet the target. Finally, right-click and select Back to Binning Back to binning

😨 😰 🙀		Search :				¥ 🔊	•		
🞯 binmode] 🚬									
bin.	Back	To Binning	DW/DL VI	H MOB SUB	Rout Temp	Diode Ca	p Stress	∢ ▶	
									3
		Check	Name	Value	Lower	Upper	Step		
💮 🎲 bin. 4									S 3
💮 🎲 bin. 5			level	49			0	*	
💮 💮 bin. 6			version	3. 2			0		
			binunit	2			0		
	=		lmin	1.01E-5	0	1	1E-7		
			lmax	1.01E-5	0	1	1E-7	Ξ	
💮 💮 bin. 10			nobnod	1			0		
			wmin	1.01E-5	0	1	1E-7		
			capnod	3			0		
			vmax	1.01E-5	0	1	1E-7		
			ngsnod	0			0		
			tox	2 958-9	1 4758-9	4 4258-9	18-10	-	
15 01h. 15	-	AV.		Unspecifi	ed Paramete	rs			

3. Extend bin

In the Extend Bindialog window, shown in the figure extended bin, you can re-scale the bin region or generate a binned model that incorporates all of the target devices, including the new insertion points, bin boundary point devices. Extend bin



Tweak Binned Models

Besides the method of re-extracting the point models and re-generating the binned model, MBP allows you to directly tweak binned models. With this method, you can tweak binned models much like they would tune global models. To implement this model in MBP choose Extraction > Model Tweaking. The window shown in the following figure is displayed.

eeak: It	urget							
largets.								
Add devi	ce Save	- Loud	📝 Show	error calumn	Select :	ous and press (0a)	lete> key to delete	devices
flert		L	I	Feight				
								_
1			-					
1								
-								\rightarrow
-								
-								
- 10								
1								
1								
-								
				10				_

Model tweaking window

- 1. Click the Target tab in the window, as shown in figure target panel. Then:
- 2. Click 中 to add a tweaking target.
- 3. Assign a name to this target, vth for example.
- Choose one built-in algorithm (to achieve the above target) from the dropdown list. Here vth_gm means to calculate the threshold voltage with the maximum transconductance method.
- 5. Input the bias conditions to perform the algorithm.
- 6. Click the Applybutton to confirm. Target panel

Jodel Tweaking				
Iwooks Iarget				
INV Const				
Related Targets:	wth con wth con logid wth	conlin. wth consat		
Fane	Value String	Velue	IsDISens	Description
Icon	1E-7	1.08-7	V	Constant Current 🔺
Vdd	absnax (vds)	1.65		The sax Vds value
12	-1 (I)	+ 0E		The sea only
Iargets	Isrget Definition			
🔽 vth	Target Bane: vth 🤈	1		
	Nethod Bane: wth_gm		- Fresh	
	vth_m			
	vgs: Stepsweep 💌	Start 0 - S	tep 0.01 - Stop vgg	-
	vds: 0.1 👻	4		
	vas. 0.1 •	4		
	vbs: 0 👻			
1				
· ·				
	2		Apply 5	

Next, you can return to the Tweaks tab. Click the icon to expand the hidden Original Devices panel. All of the original devices used to generate the binned model are listed in the panel. Choose the desired target devices by checking the box, and then click the Move Target Devices to Upper Panel button. You can also add new target devices by clicking the Add device button.

Edit the values of instance parameters (W, L, T, etc.) and set the design targets (e. g., vth_Des), as shown in the following figure:

Binned model tweaking

lweaks 1	arget								
Targets									
vth									
optimiza									
error fo	_	olute 🔻							
error I	ADSI ADSI	olute 🔻							
Add dev	ice Save	Los	d 🛛 🖉 Show	error column		Select en	es and press Gelete		
							-	. Key to assist as	
alect	v	L	1	vth_Des	vth_Sin	Error	Weight		
	10.1	10.1	25	0.35	0. 292 495	5.75049E-	2 1		
					0. 2.02.000		••••••••••••••••••••••••••••••••••••••		
<					m1				•
riginal	Devices R	eset Target	Values	Nove Target Dev	vices Io Uppe	r Panel	Save		- 😽
elect	v	L	I	vth_Des	vth_Sin	Error	Veight		
erect		2		A CITO ES	Val_on	51101	act Buc		
	10.1	0.5	25	0.350841	0.350841	0	1		
	1	10.1	25	0.287542	0.287542	0	1		
	1	0.5	25	0.388754	0.388754	0	1		
	10.1	0.2	25	0.380832	0.380832	0	1		
	1	0.2	25	0. 38 499	0.38499	0	1		
12	10.1	0.12	25	0.405094	0.405094	0	1		_
100		0.12	25	0.433189	0.433189		4		

Next, determine the bins to be tweaked. Obtain the geometry of the target devices (the devices selected to be optimized) and check which bins contain these devices. These bins are the ones that will be tweaked later. According to the target values and the bins to be tweaked, you can select the parameters with which to tweak the binned model. In the process of selecting tweaking parameters, you can add, remove and parametrize the non-binable parameters (e.g., tox), bin-core parameters (e.g., vth0) and L/W/P parameters (e.g., lvth0, pvth0 and pvth0).

Automated optimization

Tweaks 1	awara t								
	mgac								
Targets									
New_0									
optinize									
error fo	rmat Absol	ute 👻							
Add dev	ice Save	- Load	🗹 Show e	rror column		Select rows	and press @elete	key to delete devic	es
elect	×	L	т	New_O_Des	New_0_Sim	Error	¥ei ght		
	10.1	10.1	25	0.32	0.292495	2.750498-2	1		
v	10.1	0.5	25	0.38	0.350841	9.159005E-3	1		
7	0.68	0.4	25	0.4	0.367018	3.298218-2	1		
									-
riginal	Devices Rea	et Target Va	lues	ove Target Devi	ces Io Upper	Panel S	ave 🖉		_ ¥
elect	×	L	T	New_O_Des	New_O_Sin	Error	¥eight		
	1	10.1	25	0.287542	0.287542	D	1		
	1	0.5	25	0.368754	0.368754	0	1		
	10.1	0.2	25	0.380832	0.380832	0	1		
	10.1			0.38499	0.38499	0	1		
	1	0.2	25						
	10.1	0.2 0.12 0.12	25 25 25	0.405094	0.405094	0	1		

After selecting the parameters, checking the optimize box and the Select items for the target devices, you can perform automated optimization. Click the optimize button line in the Optimization window and MBP will invoke the internal optimizer to proceed.

After optimization, you can check if the tweaking binned model meets their requirement. If Yes you can save the newly generated model directly. If No then, you can either manually tune the parameters or change the conditions and re-run the optimization.

Call External Simulator

This application note describes how to call an external simulator for simulation in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2010.3.0.1 in May 2011.

Overview

MBP supports the ability to call external simulators, regardless of whether they are installed on a local computer or a remote host. From MBP v2007.2.6 on, all the configurations for calling external simulators can be set on the software's graphical user interface (GUI).

NOTE

To avoid a long simulation time, it is recommended that the internal SPICE in MBP be used for simulation.

This section uses HSPICE as the example to introduce the steps required to call HSPICE in MBP. You can follow these steps to call HSPICE on a local computer or a remote host. For more information, go to www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at www.keysight.com/find /contactus

Call Local HSPICE

To call HSPICE on a local computer, first open a cmd window. Type *HSPICE* in the command line to confirm that HSPICE can be run directly on the local computer. If HSPICE is properly installed, but cannot run directly, right-click My Computer and open System Properties > Advanced > Environment Variables. Add \$HSPICE_HOME\bin to the variable Path . Here, \$HSPICE_HOME is the HSPICE installation path on the computer.

In the MBP main GUI, choose Simulation > Simulator > External Hspice from the main menu to select the simulator.

When doing the simulation, the HSPICE window will flash in the background.

NOTE You may not see the HSPICE window when calling HSPICE on a remote host.

If the simulation results are not correct, choose Simulation > External SPICE from the main menu and deselect the Delete Netlist Files option in the popup window. Redo the simulation to see if the results are what is expected.

NOTE

All netlist files can be found in the $MBP_HOME \ bspice folder (<math display="inline">MBP_HOME \ bspice folder \ when the MBP installation path on the computer). You can use these files when debugging.$

Call Remote HSPICE

When calling HSPICE on a remote host, you must first confirm they have permission to do so. Telnet can be used to log in to the remote service to confirm the permission. In the MBP main GUI, choose Simulation > Simulator > External Hspice from the main menu to select the simulator. Then, choose Simulation > External SPICE from the main menu. The window will pop up as shown in the following figure.

External SPICE options

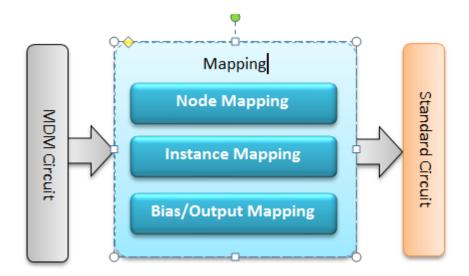
External SPICE op	otions 💌 🗙
Hspice Spectre	ADS Spice3
🔽 Call Remote	
Remote Call	TELNET -
Remote Transfer	FIP -
Remote IP	192. 168. 0. 180
User Name	test
Password	***
Command	hspice
Prompt	\$
Directory	
	Check
🔽 Is Delete Ne	tlist Files
ОК	Cancel

Next, enable the Call Remote option by clicking the box. Enter the necessary information such as Remote IP, User Name and Password. After filling out the settings, you can check whether HSPICE can be called successfully by clicking Check . Finally, click OK to close the window.

DC/CV MDM Loader Configuration

Overview

MDM Loader module is designed for MBP to load ICCAP's .MDM file, by default we have completed the configuration for most conditions so that user can load a MDM file without any modification to the loader, but if user want to load any special MDM files the customization of the LOADER need to be done by the user himself. This material instruct on how to do the customization The overall structure of MDM Loader:



By configure the MDM loader user configure the Mapping to change the circuit in MDM file to a MBP standard circuit, then MBP can parser the file and simulation correctly.

Circuit Standard

Bias/Output Name Standard

Bias/Output Name is composed with type, node1 and node2.

Туре

Type can be one of characters below:

Name	Туре
V	Voltage
I	Current
С	Capacitance
G	Conductance

Node

If node name contains '_', it is a composed node, for example:"d_s_b", this node is connected to 'd','s' and 'b'.

Bias/Output Name Format

Format 1 <Type>_<Node1>#<Node2> The first character is type, and followed by by node1, '#' and node2.

Example

 $Vd_s_b\#g \quad Voltage \ between \ d_s_b \ and \ g$

Vg#d_s_b Voltage between g and d_s_b

Format 2

<Type><Node1><Node2>

If each node contains no more than 1 character, '#' should be omitted.

Example

Vgs Voltage between g and s

Vbs Voltage between b and s

Format 3 <Type>_<Node1># or <Type>_<Node1> If the node2 is "ground", it should be omitted.

Example

Vd_s_b# Voltage between d_s_b and ground

Vg Voltage between g and ground

Vb Voltage between b and ground

Analysis Name Standard

Format

<Output><Sweep1><Sweep2>@<Bias1>,<Bias2>

- 1. Analysis name is composed with output and bias names.
- 2. If there is '_' in output/bias name, it will be replaced with '~'

Example

Analysis Name	Output	Biases
lds_vgs_vbs@vds,vs	lds	Vgs,vbs,vds,vs
Cgc_vb_vdg_vds@vg	Cgc	Vb,vdg,vds,vg
Cg#d~s_vb_vdg_vds@vg	Cg#d_s	Vb,vdg,vds,vg

List of Standard Node Names and Instance Names

Model	Nodes	Instances
/bjt/gp	c,b,e,s	area,areab,areac,temp,l,w
/bjt/hicum	c,b,e,s	area,temp,l,w
/bjt/mextram	c,b,e,s	area,temp
/bjt/vbic	c,b,e,s	area,m,temp,l,w
/capacitor /mimcap	p,n	w,l,temp
/capacitor /mosvar	g,bi,b	w,l,temp,m,M_SEG,NGCON
/diode/diode	p,n	area,pj,temp,l,w,lm,wm,lp,wp,w
/diode/diode3	p,n	area,pj,temp,l,w,lm,wm,lp,wp,w
/diode/juncap2	p,n	area,pj,pgate,temp
/jfet/jfet	d,g,s	w,l,temp
/mosfet/mos2	d,g,s,b	w,l,temp,nf,m,sa,sb,sd,sca,scb,scc,sc,ad,pd,as,ps,nrs,nrd
/mosfet/mos3	d,g,s,b	
/mosfet/mos66	d,g,s,b	
/mosfet /bsim3v3	d,g,s,b	
/mosfet/bsim4	d,g,s,b	w,l,temp,nf,m,sa,sb,sd,sca,scb,scc,sc,ad,pd,as,ps,nrs,nrd,rsc,rdc
/mosfet/bsim6	d,g,s,b	l,w,nf,temp,nrs,nrd,m,rgatemod,rbodymod,geomod,rgeomod,sa, sb,sd,sca,scb,scc,sc
/mosfet /bsimcmg	d,g,s,b	l,d,tfin,fpitch,nf,nfin,ngcon,temp,nrs,nrd,lrsd
/mosfet /bsimimg	d,g,s,b	l,w,nf,temp,nrs,nrd

Model	Nodes	Instances
/mosfet/hisim2	d,g,s,b	w,l,temp,nf,m,sa,sb,sd,ad,pd,as,ps,nrs,nrd,sca,scb,scc
/mosfet /hisim_hv	d,g,s,b	w,l,temp,nf,m,sa,sb,sd,ad,pd,as,ps,nrs,nrd
/mosfet /LayoutConfig	d,g,s,b	w,l,temp,nf,m,sa,sb,sd,sca,scb,scc,sc,ad,pd,as,ps
/mosfet/psp/102 /local	d,g,s,b	
/mosfet/psp/102 /global	d,g,s,b	
/mosfet/psp/103 /local	d,g,s,b	
/mosfet/psp/103 /global	d,g,s,b	w,l,temp,nf,m,sa,sb,sd,sca,scb,scc,sc,ad,pd,as,ps,nrs,nrd
/mosfet /RingOscillator	avin,roa,avdd,qvin, roq,qvdd,s	wp,lp,wn,ln,outtype
/resistor/poly- resistor	p,n	w,l,temp
/resistor/r3	n1,nc,n2	m,l,w,temp,swnoise,sw_et,wd,a1,p1,a2,p2,c1,c2,sw_mman, nsmm_rsh,nsmm_w,nsmm_l
/resistor/resistor	p,n	w,l,temp
/soi/b3soi	d,g,s,e,p	w,l,temp,nrd,nrs,nf,m,sa,sb,sd,ad,pd,as,ps
/soi/b4soi	d,g,s,e,p	w,l,temp,nrd,nrs,nf,m,ad,as,pd,ps,sa,sb,sd
/tmi/bsim4 /default	d,g,s,b	w,l,temp,nf,m,sa,sb,sd,sca,scb,scc,sc,ad,pd,as,ps,nrs,nrd

Mapping

Click File -> Data -> Data Loader -> Config on MBP to start the configuration GUI.

File	
File mosfet bjt diode capacitor induc	tor jfet resistor soi resistor/r3
Var Source	Var Name
MAIN. SCA	sca
MAIN. SCB	scb
MAIN. SCC	scc
MAIN. SC	sc
MAIN.SCC MAIN.SC TEMP Hfin IFIN IFIN I Cap_D_G_Intrinsic::vs_b Cap_D_G_Intrinsic::v_d_g Cap_D_G_Intrinsic::vg Cap_S_G_Intrinsic::vg Cap_S_G_Intrinsic::vs_g Cap_S_G_Intrinsic::vg node(d_s_b) pade(d_s_b)	t
Hfin	Hfin
IFIN	TFIN
NFIN	NFIN
Τ	T
Cap_D_G_Intrinsic::vs_b	vsg
Cap_D_G_Intrinsic::v_d_g	vds
Cap_D_G_Intrinsic::vg	vb
Cap_S_G_Intrinsic::vd_b	vbg
Cap_S_G_Intrinsic::v_s_g	vsb
Cap_S_G_Intrinsic::vg	vd
node (d_s_b)	E
node (d_s)	c
🕂 🕹	
DC/CV Iarget	
Import	Export Reset

There are 3 kinds of Mapping:

1. Instance Mapping(Change the instance name to standard name)

	Var Source	Var Name
Describe	Name in mdm file	Standard Name
Sample	MAIN.SCA	SCA

2. Node Mapping(Change the node to standard name)

	Var Source	Var Name
Describe	node(nodeName)	Standard Name
Sample	node(d_s)	C

This mapping is only for current, capacitor and conductance: For example:cg#d_s -> cgc For voltage source, it doesn't care this mapping: For example:vg#d_s -> vgd, vds=0

3. Bias/Output Mapping(Change the bias/output to standard name for specified setup)

	Var Source	Var Name
Describe	SetupName::VarName	Standard Name
Sample	Cap_S_G_Intrinisic::vg	vgs

Generate and Tweak Corner Model

This application note describes how to generate and tweak corner models in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2011.1.0 in July 2011.

Overview

Device model is relevant to the actual fabrication process. Even a well developed process may have some variations. And these variations are likely to affect the device characteristics and circuit behavior. To account for the variations in semiconductor process, based on an initial set of typical and comer device models, the process dependent model parameters needed to be tweaked. The smart model tweaking module integrated with MBP enables easy model retargeting, adjustment of global or binning models according to new specification. Both model cards and model libraries are well supported.

In this article, we will use global model as an example to introduce the steps to generate and tweak corner models, respectively.

Generate Corner Models

To generate corner models, choose Utilities > Corner Model from the main menu. The window shown in the following figure: Corner model generation--Start

🥢 Corner Model Start	×
Supported SPICE Choose SPICE: hspice -	
Construct corner model lib from tuned models. Details User starts with one or several model cards. This module helps	3 Steps
User starts with one or several model cards. This module helps user to accomplish the process of parameterization, tuning, constructing and final deliver a complete model library. Please follow the flow in the right column.	 ✓ 1. Add Model ✓ 2. Parameterize ✓ 3. Preview And Export
Construct corner model lib from existing lib	
Details	4 Steps
User always starts with an existing model library. User can insert any model including BSIM3v3, Bsim4 etc into the library. It also allows tuning and exporting the model library. Please follow the flow in the right column.	 ♀ 1. Import Lib ♀ 2. Add Model ♀ 3. Parameterize ♀ 4. Preview And Export
Cancel	Previous Next

MBP currently supports two external simulators: HSPICE and Spectre. Choose either one as the SPICE simulator. You have an option to construct the corner model library from either tuned models or an existing library. In this document, we introduce the procedures to Construct corner model lib from tuned modes. The process of Construct corner model lib from existing lib is almost the same, except that it requires the additional step of importing a library.

- Click Next.
- Select Add Model to load the model card.
- Click Add default in the popup Set Group window.
- Select OK.
- Check the Typical box and click Next , as shown in following figure.

Corner model generation-Step 1

broup Iree	Add Mo	del Renov	e Model	Set Gron	up		
Root	ITMOS				- 2		
MDS	Group	Model Name	Merge Nane	Туре	Corner	Typi cal	File Name
• IMOS	NOS	IMOS	IMOS	bsin3v3	IT		B3_nmos.1
ia <mark>.</mark> SS i∰ FS ia SF	A.V.						
🕀 🔒 FS	▲▼ PMOS						
🕀 🚽 🗄		Model Name	Merge Jane	Туре	Corner	Typi cal	File Name

In the popup window shown in following figure, choose the parameters (e.g., vth0, u0 and ags) and click Next.

Corner model generation-Step 2

Group:	105 👻	Merge: [MOS 👻							
Name	SkewName	Type	Expres	II	FF	SS	FS	SF		
VTHO	dvth0_n	Delta	0.3817	0.0	0.0	0.0	0.0	0.0		
U O	du0_n	Delta	0.0279	0.0	0.0	0.0	0.0	0.0		
AGS	dags_n	Delta	0.4604	0.0	0.0	0.0	0.0	0.0		
NLX	dnlx_n	Delta	2. 4433	0.0	0.0	0.0	0.0	0.0		
A.					Ex	port Excel	De	-parameter	ize	
Search:			Parameter	ize		Set D	ef)	Apply D		
Name					Value					
- K1					0.549529					
K2					-0.002053457					
11/2					-0.002977076					
pk2					0.0					

The corresponding corner model structure will now be built, as shown in following figure. Click Export to save the library.

Corner model generation-Step 3

řrevi ew			
.lib SF			
.param			
$+dvth0_n = 0$	$du0_n = 0$	$dags_n = 0$	
$+dnlx_n = 0$			
lib 'preview_path'	MOS		-
endl SF			
lib MOS			
model NMOS NMDS			
*** Flag Parameter ***	k.		
+level = 49	version = 3.2	binunit = 1	
+mobmod = 1	capmod = 3	ngsmod = 0	
*** Geometry Range Par	rameter ***		
			10

Tweaking Corner Models

Choose Utilities > Lib Parser from the main menu. A warning message window will pop up. Click Yes to continue. In the Lib Parser tab, click Load to load the library just created. The tree structure of the library and the model parameters to be tweaked are listed as shown in following figure. Corner library and model parameters

Load	66A	Remo	va 🗌	Save	Ex	i t hsj	pice 🔻		
Search:									
V Select Model	🔤 Add Model						\rightarrow		
B3_nms_corner.l compact MDSFET MDSFET FF FF FF FF FS FS FF									
RF_Device DC_De	evice Lib Parse	er							
	K Search :				8 🔒 🗲	•			
yaram IMOS	Check	Nane	Value	Lower	Vpper	Step			
	V	dvth0_n	0	-1	1	1E-3			
	V	du0_n	0	-1	1	1E-3	S 🔊		
	V	dags_n	0	-1	1	1E-3			
	V	dnlx_n	0	-1	1	1E-3			
Parameters Mess	sage								

Define Tweaking Target

To define the tweaking target choose Extraction > Model Tweaking from the main menu and switch to the Target panel. The window shown in Figure: Target panel will appear. In this window:

- 1. Click 中 to add a tweaking target.
- 2. Assign a name to this target, for example vth.
- **3.** Choose one built-in algorithm (to achieve the above target) from the dropdown list. Here, vth_gm means to calculate the threshold voltage with the maximum transconductance method.
- 4. Input the bias conditions to perform the algorithm.
- 5. Click the Apply button to confirm.
- 6. Repeat steps 1 to 5 to add Idsat as another tweaking target.

Target panel

Model Tweaking		-		—X —
Iweaks Target				
IMV Const				
Related Targets: vth	con, with con logid with a	onlin, wth consat		
Name	Value String	Value	IsDISens	Descripti on
Icon	1E-7	1.0E-7		Constant Current 🖍
Vdd V	abamaz (vds)	1.65		The max Vds value
Iargets	Target Definition	14 120		17L
⊽ vth	Target Hame: vth 2 Method Hame: vth_gn vdh_gn vgs: Stepsweep v S vds: 0.1 v vbs: 0 v	3 Start () - Start () 4	▼ Fresh	•
			Apply 5	

Define Target Devices

After defining the tweaking targets, switch to the Tweaks panel. Press the Add device button to add target devices to the list. You can edit the instances such as W , L and T, in this case. Right-clicking on the table will pop up the instance parameter list. MBP allows you to save or load device information, as shown in Figure: Tweaks panel.

Following the instances, the design target (suffixed by Des, e.g., vth_Des), simulated value (suffixed by Sim, e.g., vth_Sim), and their differences (e.g., Error) are listed. You can choose the error format as either Absolute or Relative. Type in the value of the design target. The simulated value and Error will respond instantly once you tune the model parameters.

Model Tweaking

Select the proper parameters from the Optimization/Parameter_ window. You can then start tweaking the model. MBP provides both manual and automated tuning. For the latter, make sure that the design targets are set, parameters are selected, the optimize items for tweaking target are checked, and the Select items for the target devices are checked (Figure: Automated optimization). Then, click the

Optimize button in the Optimization window. MBP will invoke its internal optimizer to proceed.

Tweaks panel

Aodel Twee	aking										x
Iveaks [arget										
largets vth optimize error fo			Idset optimize error Ecrmet	Absolute	•]						
Add devi	ice Save	Losd	Show err	or column		Select ro	ws and press 🔇	Delete> key to	delete d	vices	
Select	W	L	τ	vth_Des	vth_Sim	Error	Idsat_Des	Idsat_Sin	Irror	Weig	ght
	10	10	25		0.398437			1.58527E-4		1	۰.
	10	0.15	25		0.470556			5.528082E-3		1	1
	0.18	10	25		0.334154			3. 455915E-8		1	
	0.18	0.15	25		0.427272			1.630918E-4		1	
1											
											_
				_							-
											-1
											-
											-1
1											
											-1
		1									

Automated optimization

Model Twe	aking									le l	x
Iweaks]	arget										
Targets											
optimize error fo		olute	Idnat optim ▼ error	ize 🔽	Lative V						
Add dev	ice Sav	e 🔍	Load 🔽	Show error co	lunn	Selec	trows and y	oress (Delete)	key to del	te devices	
Select	¥	L	Т	vth_Des	vth_Sim	Error	Idsat_Des	Idsst_Sim	Error	Weight	
	10	10	25	0.4	0.399858	1.422387E-4	4E-5	4.030159E-5	-0.748344	1	
1	10	0.15	25	0.5	0.498284	1.716409E-3	2.3E-3	2.345332E-3	-1.932849	1	
1	0.18	10	25	0.34	0.337684	2.315939E-3	9E-7	8.948829E-7	0.56857	1	
V	0.18	0.15	25	0.45	0.450092	-9.18024E-5	6.6E-5	6.556111E-5	0.664991	1	

If more than one target device is selected for automated tuning, you can differentiate the importance between devices by specifying different Weight values. The device with the higher weight value normally generates higher accuracy.

Implementing Verilog-A Model

This application note describes how to implement Verilog-A models in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2009.1.0 in July 2011.

Overview

Verilog-A is an industry standard modeling language for analog circuits. MBP initiated support of Verilog-A models with MBP v2009.1.0.

This application note describes how to implement Verilog-A models in MBP. For more information, go to www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

Preparation

To implement Verilog-A models, you must first ensure that MBP v2009.1.0 or a later version has been properly installed on the computer. Also, the Verilog-A license feature is needed.

Windows users must add \$MBP_HOME\win32\mingw\bin to the environment variable Path. Here, \$MBP_HOME stands for the directory where MBP is installed, for example C:\Keysight\modelbuilder. Then, reboot the computer.

For Linux users, run which gcc and which g++ in the command line to make sure both gcc and g++ have been installed properly on the machine. Otherwise, contact your IT administrator.

Sample Models

There must be a subcircuit model to define which Verilog-A model is to be called and which parameters are to be tweaked. MBP allows you to load this subcircuit model and tweak the parameters in the same way as any other model parameters in MBP.

Sample models are listed below for the HSPICE and SPECTRE simulators.

HSPICE

The following model, ekv.l, is an example of a model that is simulated by HSPICE:

```
hdl ekv.va // Define Verilog-A model to use: ekv.va.
model verilog1 ekv // Define new model named verilog1.
Use Verilog-A odel ekmv from ekv.va.
+VTO=0.5 // Define model parameters to be tweaked in
MBP.
+GAMMA=1
+PHI=0.5
.subckt rf_nch d g s b W=10E-6 L=10E-6
x3 d g s b verilog1 L=L W=W // The user could use the
new model named verilog1,
x2 d g s b ekv L=5E-6 W=10E-6 // or use the original
model named ekv.
.ends
```

SPECTRE

The following model, ekv.l, is an example of a model that is simulated by SPECTRE:

```
simulator lang=spectre
ahdl_include ekv.va // Define Verilog-A model to use:
ekv.va.
model verilog1 ekv // Define new model named verilog1.
Use Verilog-A model ekv from ekv.va.
+VTO=0.5 // Define model parameters to be tweaked
in BP. M
+GAMMA=1
+PHI=0.5
subckt rf_nch (d g s b)
parameters W=10E-6 L=10E-6
x3 (d g s b) verilog1 l=l w=w // The user could use the
new model named *verilog1*,
x2 (d g s b) ekv l=5e-6 w=10e-6 // or use the original
model named *ekv*.
ends rf nch
```

NOTE

The element using Verilog-A must start with **x** even in SPECTRE. Only the parameters declared in **verilog1**, such as VTO, GAMMA and PHI, can be tweaked in MBP. The original Verilog-A model (e.g., ekv) can be called and simulated in the subcircuit. However, the parameters in ekv not declared in verilog1 cannot be tweaked in MBP.

MBP Supported Functions and Keywords

MBP supports most of the common functions and keywords defined in Verilog-A, including:

- Basic operation: supports most of the basic operation in Verilog-A.
- Syntax: supports if/else, for loop, while loop, etc. Does not support repeat.
- Simulation system function: supports \$stop, \$temperature, \$vt, \$vt(temp), and strobe(express).
- Function: supports user-defined function.

For additional details, refer to the following table:

Support Table

Category	Туре	ltem	Example	Support Status	Description
Basic Operator	Mathematic	/		Supported	Attention: res = 1/5; //The resulte of this integer division is zero,res = 0.

Category	Туре	Item	Example	Support Status	Description
Basic Operator	Mathematic	+		Supported	
Basic Operator	Mathematic	-		Supported	
Basic Operator	Mathematic	*		Supported	
Basic Operator	Mathematic	sqrt	sqrt(x)	Supported	
Basic Operator	Mathematic	ln	ln(x)	Supported	
Basic Operator	Mathematic	log	log(x)	Supported	
Basic Operator	Mathematic	abs	abs(x)	Supported	
Basic Operator	Mathematic	pow	pow(x,y)	Supported	
Basic Operator	Mathematic	min	min(x,y)	Supported	
Basic Operator	Mathematic	max	max(x,y)	Supported	
Basic Operator	Relational Operators	<	a>b	Supported	
Basic Operator	Relational Operators	>	a <b< td=""><td>Supported</td><td></td></b<>	Supported	
Basic Operator	Relational Operators	<=	a<=p	Supported	
Basic Operator	Relational Operators	>=	a>=b	Supported	
Basic Operator	Logical operators	!=		Supported	
Basic Operator	Logical operators	==		Supported	
Basic Operator	Logical operators	&&		Supported	
Basic Operator	Logical operators			Supported	
Basic Operator	Conditional Operator	?:	(a <b)?a:b< td=""><td>Supported</td><td></td></b)?a:b<>	Supported	

Category	Туре	ltem	Example	Support Status	Description
Basic Operator	access	Ι()	I(branch) I(node1,n ode2) I(node1)	Supported	Attention : I(node1) means the current from the node1 to the ground
Basic Operator	access	V()	V(node1,n ode2) V(node1)	Supported	
Basic Operator	contribution	I(a,b)<+V(c,d)		Supported	
Basic Operator	contribution	V(c,d)<+variable or constant	V(in,mid)<+0.5;V(in, mid)<+x;	Supported	
Basic Operator	contribution	l(c,d)<+variable or constant		Supported	
Basic Operator	contribution	V(c,d)<+I(a,b)		Supported	
Basic Operator	contribution	l(a,b)<+l(c,d)		Not Supported	
Basic Operator	ddx	Y=ddx(z,x);		Supported	
Basic Operator	ddx	Y=ddx(z,x);		Supported	Attention : Y= k*ddx(z,x); is
Basic Operator	ddx	Y=k* Y;			unacceptable
Basic Operator	ddx	Y= ddx(func(x), x);	Fun(x) is the function of x. And fun is maybe	Supported	
Basic Operator	ddx	Y=ddx(Y,x);	Y is a var	Not Supported	Attention : But z=ddx(Y , x); Y=z; that is right

Category	Туре	ltem	Example	Support Status	Description
Basic Operator	ddx	ddx (Userdefined function,x)		Supported	
Basic Operator	ddx	l()<+ddx(y,x)		Not Supported	Attention : But ,z=ddx(y, x) I()<+z Is right
Basic Operator	ddx	More than 2th derivate	ddx(ddx(a,b),b)	Not Supported	
Basic Operator	idt			Not Supported	
Basic Operator	assignment	y=V(p,n);		Supported	
Basic Operator		z=l(p,n);		Not Supported	
Syntax		lf else			
Syntax		Forloop		Supported	
Syntax		case		Supported	
Syntax		whileloop		Supported	
Syntax		repeat		Not Supported	
Syntax	Defining Macros	`define		Supported	
Syntax	Conditional Compilation	`ifdef `else `endif		Supported	
syntax	including	`include	`include "discipline s.vams"	Supported	
	Simulation control	\$stop		Supported	

Category	Туре	ltem	Example	Support Status	Description
Simulation System Function					
Simulation System Function	Simulation control	\$finish		Supported	
Simulation System Function	Environment Parameter Functions	\$realtime	Current simulation time in seconds.	Not Supported	
Simulation System Function	Environment Parameter Functions	\$temperature	Ambient temperature in kelvin.	Supported	
Simulation System Function	Environment Parameter Functions	\$vt	Thermal voltage ().	Supported	
Simulation System Function	Environment Parameter Functions	\$vt(temp)	Thermal voltage at given temperature	Supported	
Simulation System Function	Environment Parameter Functions	\$abstime	Returns the simulation time, in seconds	Not Supported	
Simulation System Function	Input/output	\$fopen		Not Supported	
Simulation System Function	Input/output	\$fclose		Not Supported	
Simulation System Function	Input/output	\$fwrite		Not Supported	
Simulation System Function	Input/output	\$strobe ("express")		Supported	

Category	Туре	ltem	Example	Support Status	Description
Function	Userdefined Function			Not Supported	
Analog	Initial Step	@(init_s)		Not Supported	
Events		tep())			
	Final Step	@(final_step())		Not Supported	
	Cross	cross()		Not Supported	
	Timer	timer()		Not Supported	
Hierarchical	Basic_ hierarchical			Not Supported	
	Port_connect			Not Supported	

Reference: Accellera Verilog-AMS Language Reference Manual, Analog & Mixed-Signal Extensions to Verilog HDL, Version 2.3.1

Implementing MOSRA Models

This application note describes how to implement a MOSRA model in Model Builder Program (MBP).

NOTE This document was originally released for MBP V201.1.0 in July 2011.

Overview

Device models are relevant to the actual fabrication process. MBP offers an environment for MOS reliability analysis in general and MOSRA in particular. With this environment, you can measure device performance degradation over time and evaluate stress effects. This section provides information on the raw data format and MOSRA simulation and parameter extraction. For more information go to www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at www.keysight. com/find/contactus.

Raw Data Format

The data format for MOSRA analysis is similar to that of general measurement data in MBP. A sample of MOSRA data is as follows:

```
condition {corner = tt,date = oct_20_02,instrument=
(hp4145, probe_station),
mode=forward, datatype= mosra, version=1.0, type=nmos}
Page (name=ids_vgs_vbs,x=vgs,p=vbs,y=ids) { vds=0.05, w=
10.0, L=0.13, T=25.0}
stress ( time=0.0, vds=2.0, vgs=1.0, vbs=0.0)
curve { 0.0}
0.0 5.000E-14
0.05 5.002E-14
0.1 5.010E-14
0.15 5.055E-14
0.2 5.315E-14
```

Here, the keyword datatype should be specified as mosra and version=1.0 corresponds to the MOSRA level. The keyword stress defines the bias condition and the duration of the aging test.

MBP also supports another kind of MOSRA data, which allows you to take the aging span as the variable. For example:

```
condition{corner = tt,date = oct_20_02,instrument=
(hp4145, probe_station),mode=forward} Datatype
{S_target} Version{2.1}
type{nmos} Delimiter{,}
Instance{L, W, T}
Strss_Condtion{S_vgs=1, S_vds=2, S_vbs=0, S_time}
Input{Vgg=2, Vdd=2, Vbb=-1,Vdlin=0.05}
Data{ w, 1, t, S_vgs, S_vds,S_vbs, S_time, vth_lin,
vthsat, Idlin, Idsat, Ioff, gm }
10, 2, 125, 1, 2, 0, 0, 0.728628, 0.697769, 7.348435E-5,
8.848617E-4, 2.029162E-12,
4.2957E-4
10, 2, 125, 1, 2, 0, 1e5, 0.728985, 0.698127, 7.343337E-
5, 8.8407E-4, 2.028872E-12,
4.2903E-4
```

Here, Datatype{S_target} means the data type is DP data.

NOTE All of the variables in this kind of MOSRA data need to start with S. For example, the gate-to-source voltage(vgs) during an aging test should be named as **S_vgs**.

All of the data, including instance parameters, bias conditions, timing nodes, and physical quantities, is stored in the Data session.

As shown in figure Pre-defined IMV pages for stress data, several IMV pages have been pre-defined in MBP to help you to better understand stress data trends.

Pre-defined IMV pages for stress data

MV	~
🕀 🚞 GM/GDS	
🗉 🧰 VTH	
🗉 🦲 Idlin	
E 📋 Idsat	
E MOSRA	
Vth_time	
Vth_L_time	
Vth_VV_time	
Idlin_L_time	
Idlin_VV_time	
Idsat_L_time	
Idsat_VV_time	*

MOSRA Simulation and Parameter Extraction

MBP invokes the external simulator (Synopsys HSPICE) for MOSRA model simulation.

NOTE Ensure that HSPICE has been installed properly before the simulation.

Choose Model Type

Choose Model > Select Model from the main menu and select Reliability in the pop up window. Then, select one core model in the upper Core Model Selection section and MOSRA in the lower Reliability section. Selecting MOSRA analysis

Project Ty			
0	© RF	💭 Statistical 🔘 Reliabilit	y
Core Model	Selection		
🖯 🍐 hspi			*
8-1	osfet V bsin3v3		
	bsin4		
-	hisim2		Ę
	hisim_hv LayoutConfig		
	nos2		
	mos3		
	mos66		
Reliabilit	y .		
8-1 eosr			
	level1		
			_

Model Parameters Panel

After setting up the model type, MBP merges the selected core model and MOSRA model. For example, as shown in the Parameters panel of following figure, the upper model (mosra model) is a MOSRA level 1 model and the lower one (nmos) is a BSIM3V3 core model. By clicking any model, the corresponding parameters will show on the right-side of the window.

Model viewer for MOSRA

s	Check	-				
		llane	Value	Lower	Upper	Step
		level	1			0
		relmode	2		-	0
			2			0
			Unspecif	ied Paramete		

Parameters Message

Load Model

In the main menu, choose File > Model > Load to load the model. A window named MOSRA Compose Dialog is displayed.

MOSRA compose dialog window

		e model card and l card and a mosr Mosra		a Mosra model car
Load		Load	• Default	Compose & Load
Renove	Save	Renove	Save	Compose & Add
/ model_mmos.l		🗹 model_nbti.	a	

A complete MOSRA model consists of two parts: the core model and the MOSRA model. You can deal with these two parts separately. Click Remove to delete the existing models and click Load to load other models. After loading the models, click Compose & Load to replace the current MOSRA model.

Then, choose File > Data > Load from the main menu to load the data file. The window with the MOSRA model and data.

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Load data

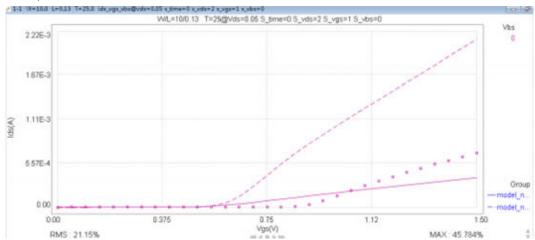
Now, you can select model parameters and adjust them to fit the measurement data.

MBP allows you to compare two MOSRA models. Simply, click Compose & Add to append a MOSRA model for comparison. Select the two models and click the Compare icon to compare them.

Compare two models

Firmer:		All Pages	El ber Byrten		1-1 W-10.0 L-0.13 T-25.0 ids.ygc.dis@vdi=5.05.1,time=8.c.vdi=2.c.yg=1.c.dis=0	(at)
lader	1 minut	Lim)	1		WIL-100.13 T-250Vide=0.05 5_bite=0 5_vide=2 5_vide=0	1.4
1	. 10	0.12	5		2.226-3	~
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3	10		25		16763	1
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The result is shown in the following figure.



Comparison result

Run Task Tree

MBP also provides a built-in automatic extraction flow (task tree) for the MOSRA model. Task tree can be enabled by choosing Extraction > Task Tree from the main menu. After loading the task tree, you could run the flow automatically, or step by step. Task tree will select devices, region and parameters for optimization automatically. The task tree optimization window is shown in the following figure:

Task tree of a MOSRA model

				10 4 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	R Serve	2 P 			al Lingvury		***		در (اسطن ب	دهرور موروم ۱	nangenaany n	in all the second
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Load Multi-Die Data

This application note describes how to set up the script-based environment so that MBP can load and utilize ET data.

NOTE This document was originally released for MBP V2011.1.0 and above in October 2011.

Overview

Besides the single sweep data (.mea) and single point data (.dp), there is also a multi-die data structure called ET data. This kind of multi-die data is important for retargeting the final SPICE model and monitoring final corner models.

MBP has the ability to deal with this type of ET data. In this document, we describe how to set up the script-based environment so that MBP can load ET data and use it to run simulation. For more information go to www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at: www.keysight. com/find/contactus.

Script-based Environment Setup

You can complete the script-based environment setup by following these steps:

Step 1. Un-Zip

The default.7z is actually the sample script code package for loading ET data. It can be un-zipped in any appropriate path. It contains the folders and files shown in the following figure.

Script code package

? Unknown Attachment

script_code.gif

Step 2. Start a New Project

Choose File > Project > New from the main menu. Doing so will start a new project.

Step 3. Load the Script Project File

You must choose Script > Script Project from the main menu to pop up the MBP Script window. Click the Open icon. Then, load the file jt.prj in the folder where the the project is just un-zipped.

MBP Script window

? Unknown Attachment

script_window.jpg

Step 4. Run the Script Project

After loading, choose the *load_etdata* item by clicking Project > default > sys > gui > menu > load_etdata.

load_etdata

? Unknown Attachment

load_etdata.jpg

Step 5. Load ET Data

A new menu ERData > Load should now be added under Script from the main menu. Choose to load the ET data (multi-die data), as shown in following figure.

Load ETData

? Unknown Attachment

load_ETData.gif

Step 6. Plot ET Data

Go to the IMV page and refresh the IMV tree. Here, you will find the Idsat_l_et example, as shown in the following figure:

IMV tree

? Unknown Attachment

imv_tree.jpg

Click this IMV item. The multi-die plot will appear as shown in the following figure:

Multi-die plot

? Unknown Attachment

multidie_plot.jpg

Customization

You can also modify the source script to hide/show the mean (or median) value of the multi-die data. Let's use the above Idsat_l_et plot as an example. Choose Script > Script Project from the main menu to pop up the MBP Script window. In the Project tab, click default > imv >; imv > idsat > idsat_l_et . Double click the idsat_l_et item to display the code window.

Script for the Plot

? Unknown Attachment

script_plot.jpg

In the script, there are variables to show/hide the mean and median value: isshow_mean and isshow_median. Set it to true (or false) to show (or hide) the curve.

Mismatch Modeling

This application note introduces the basic components of Model Builder Program's (MBP's) mismatch module. The steps to run the built-in extraction flow and how to configure and plot an IMV graph in MBP are also demonstrated.

NOTE This document was originally released for MBP V2011.1.2 in December 2011.

Overview

Two devices in design that are the same (e.g., exactly the same property, geometry, etc.) may show different electrical behavior on the Silicon due to mismatch. The main reason for the difference is the local process variance across the wafer. Mismatch affects the yield and reliability of the final products. An accurate mismatch model is therefore, necessary to ensure the robust design of many analog and digital circuits.

MBP supports mismatch modeling and simulation for all major semiconductor devices such as MOSFETs, bipolar transistors, resistors, and capacitors. In this document, we first introduce the data format supported, plot configuration and Monte Carlo (MC) simulation in MBP. Examples of running the built-in extraction flow, and configuring and plotting an IMV graph are also demonstrated. For more information go to www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus.

Data, Plot and MC Simulation

Data Format

For mismatch, MBP supports two kinds of data formats. The first one is based on the actual measurement data, while the other allows you to input the mean and sigma value of the target.

Data Format I

Here is an example of the first data format supported in MBP:

```
miscondition {date=,type=NMOS}
Page (name=vth_gm,target=vth_gm,scale=1.0,p=(L,W))
{vds=0.1,Vgs=1,Vbs=0,icon=1E-7,T=25}
{0.18,2.0}
0.002604200182343308 0.015163779612074824 -0.00163863082
04789923
0.0012339958926110839 0.008895426625025848 -0.0048731228
537369775
....
{0.18,10.0}
0.0011114374468496058 0.007055480752867993 -7.
450025621094092E-4
4.969414898894353E-4 0.003966458228031433 -0.00242138927
38844667
....
```

The first line of the data file begins with the keyword miscondition and contains information like date and device type. The second line defines all page-related information. The information within the round bracket () contains Page name, target, scale, and P variable. The information within the brace {} declares Page constants, including the bias/current condition and temperature.

The latter part is the data block information. Every curve block always begins with $\{L W\}$. All data information is then listed behind it. In this example, the data information is the threshold voltage difference (Δv th_gm) between two adjacent devices with the same geometry.

Data Format II

You can also choose the other format. As an example:

```
condition {corner = tt,date = oct_20_02} Datatype
{mismatch}
Version{1.0}
type{nmos} Delimiter{,} Instance{L, W, T}
Input{vds=0.05, Vgs=1, Vbs=-1,icon=1e-7} Targets{Ids}
Data{ L, W, T, vds, vgs, vbs, ids}
40, 5, 25, 0.05, 3, 0, 0, 6.448e-4
40, 2, 25, 0.05, 3, 0, 0, 9.836e-4
```

30, 2, 25, 0.05, 3, 0, 0, 9.6235e-4 20, 2, 25, 0.05, 3, 0, 0, 1.28e-3 20, 1, 25, 0.05, 3, 0, 0, 1.889e-3 20, 0.5, 25, 0.05, 3, 0, 0, 2.448e-3 6, 1, 25, 0.05, 3, 0, 0, 3.4727e-3 10, 0.5, 25, 0.05, 3, 0, 0, 3.503e-3 6, 0.5, 25, 0.05, 3, 0, 0, 4.1108e-3

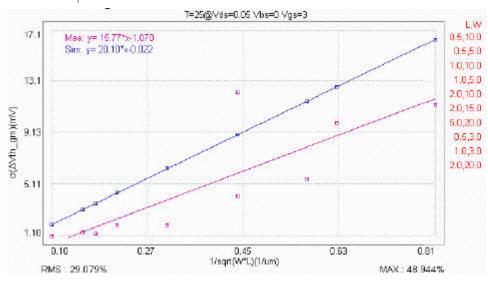
In this format, the first part of the data file contains general information such as corner type, date, data type, device type, instance, bias condition, and target. The second part of the data file includes the data block information. The first line begins with the keyword Data following the variables. All data is then listed from the second line. Note that the last two values in every line correspond to the mean and sigma of the target.

For example:

40,5,25,0.05,3,0,0,6.448e-4 means L=40um,W=5um, T=25C, Vds=0.05V, Vgs=3V, Vbs=0, Δlds(mean) =0, Δlds(sigma)=6.448e-4A.

Plot

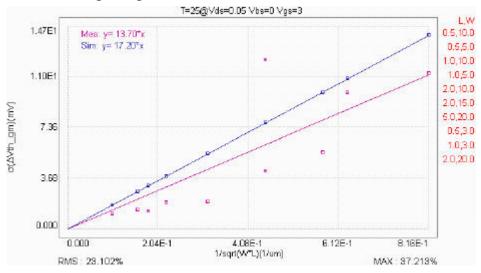
As shown in the following figure, the plot shows the value of σ (Δ Vth_gm) versus *1 /sqrt (W*L), and the trend slope lines. The simulation point and trend line are plotted in blue and the measurement data and trend line are plotted in purple.



By clicking on the legend L, W you can disable/enable the geometries to be plotted. Right click on the plot and check the item Fit Line through Origin from the popup menu. MBP then forces the trend lines through the origin, as shown in the following figure:

Mismatch plot

Fit Line through Origin



MC Simulation

MBP's internal engine supports Monte Carlo analysis of mismatch models. You can right-click on the plot and select Set Monte Count , as shown in the following figure. Then, set an appropriate number. A large number may lead to a more accurate result, but it can also cause a longer simulation time.



Set Mon	te Count
?	Please input the monte 100
	OK Cancel

You have an option to execute a fast MC simulation by choosing Simulation > Fast-MC from the main menu.

Extraction Flow

We can use a demo to describe the steps required to run a mismatch model extraction through the built-in flow.

Demo Files

The demo folder is \$MBPHOME\demo\Mismatch\mosfet Here, \$MBPHOME is the MBP installation path. There are a total of three files in the folder:

- demo_model: the initial model card.
- param.txt: the parameter list used in the extraction flow.
- mis_data.mea: the demo data.

You can follow the steps below to complete the whole process.

Set Model Type

First, set the mode type. Choose Model > Select Model from the main menu. In the popup Model Type window, choose Statistical as the Project Type. Then choose mosfet as the device type, as shown in Figure: Model Type.

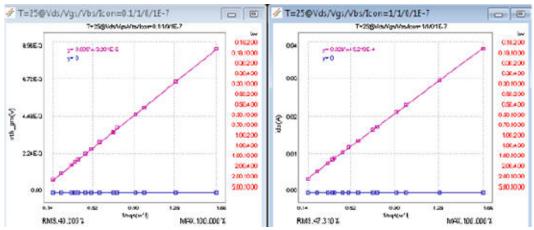
Click the OK button to close the window.

Model typ	De		
Model Type			-
Project Iy DC	je ORF	🖲 Statistical 🔘 Raliability	
Statisti Statisti Capsc Capsc Mosfe Mosfe Soi Soi	itor t sfet		
hepice Statistical I Statistical definition of the second seco	© spectre Mosfet efault project of	mosfet.	
<i>v</i>	OX	Cancel	1

Load Data and Model

Choose File > Data > Load from the main menu and load the data file mis_data.mea as shown in the following figure:





Then, choose File > Model > Load from the main menu and load the model file model_nmos.l. Here, MBP supports the ability to load the model with or without mismatch information.

Extraction Flow

Choose Extraction > Extraction Flow from the main menu. The extraction panel is shown in the following figure:

Extraction Flow panel

traction_Flow		 		
🗿 GlobalKviraction				
(WismatchExtractio	<u>n</u>			

Double-click the Mismatch Extraction button to expand the flow, as shown in the following figure:

Global Extraction flow

Extraction_Flow MismatchExtraction	
<pre>select mismatch params select_mismatch_targets mismatch_extraction</pre>	A III
	-
Press <ctrl> to drag and link tasks</ctrl>	
Device Navigator Statistical Extraction	

There are three steps in the flow: select_mismatch_params,

select_mismatch_targets and, mismatch_extraction. Click the run icon to run the mismatch extraction flow. The Select Parameters window pops up as shown in the following figure.

V	paran		nan	NaN	0.0	NaN

Select Parameters window

Click the Load button to load the parameter list file param.txt. The parameters used for mismatch extraction are shown in the following figure.

Load Parameter list

elect	type	nane	random	signa	step	min	max
	param	dt cx_nis		มงม	1. CE-12	0.0	NaN
1	par am	dvth_nis		NaN	1. OE-4	0.0	NaN
1	param	ddl_mis		NaN	1. OE-4	0.0	Nall
	param	ddw_mis		Hall	1. OE-4	0.0	Nall

Some comments on the column names in the figure above are as follows:

- select: when it is checked, the parameter gets re-extracted. If it is unchecked, then the parameter depends on the sigma value. If the sigma value is given, the final value of the parameter is the sigma value. If sigma value is not given, the current value of the parameter remains as the final one.
- name: mismatch parameter name. When *select* is unchecked, the parameter name can be blank. At the same time, both random and sigma must have correct values.
- random: random variable name. If in the current model file there is a random variable for the parameter, then put the name of the random variable here. If in the current model file there is no random variable for the parameter, you can either input a new name here, or keep it blank. For the latter case, a new name is created automatically. Note that the names of random variables cannot be repeated.
- sigma: sigma of the mismatch parameter. You can input the value here. The extraction flow then bypasses this parameter and uses the predefined value instead.
- step: the step for BPV calculation. It is used to calculate the sensitivity of the parameter to the target. Click the OK button to continue. The Select Targets window pops up as shown in the following figure.

Select targets - slope

_gii	weight	I	vds	7gs	Vbs	icon
	1	25	0.1	1	0	13-7

In this window, you can select the data group for the following extraction and the corresponding weight. Click the target tab in the window as shown in the following figure.

Select targets - target

slope target					
vth_gm]=25.0, vd ids I=25.0, vds=1		weight	w	1	
		1	2E-6	1.8E-7	
	V	1	18-5	1.8E-7	
	1	1	2E-6	3E-7	
	1	1	4E-6	3E-7	
	1	1	1E-5	3E-7	_
	1	1	2E-6	5E-7	=
	1	1	4E-6	5E-7	
	1	1	18-5	5E-7	
	V	1	12-5	7E-7	
	1	1	2E-6	1E-6	1
	1	1	4E-6	1E-6	
4 III +	1	1	1E-5	1E-6	-

All the specific targets corresponding to the data group in as shown in Figure: Select targets-slope are listed here. You can also change the weight values, which affects the final value of the slope.

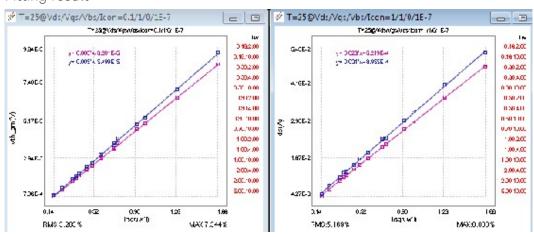
Close the window to continue. In the last step, the Save dialog window pops up. Input a file name to save the extracted model file. Then, the following mismatch parameters that have been extracted are found:

.param +s_dtox_mis = 8.320052E-10 s_dvth_mis = 6.310913E-4 s_ddl_mis = 9.80127E-2

```
+s_ddw_mis = 6.175251E-3
.param
+random5 = agauss(0.0,1.0, 1)
+random6 = agauss(0.0,1.0, 1)
+random7 = agauss(0.0,1.0, 1)
+random8 = agauss(0.0,1.0, 1)
.param
+dtox_mis = â0.0+s_dtox_mis*random5'
+dvth_mis = â0.0+s_dvth_mis*random6'
+ddl_mis = â0.0+s_ddl_mis*random7'
+ddw_mis = â0.0+s_ddw_mis*random8'
```

The fitting result is shown in following figure.

You can continue to fine tune the parameters manually. They can also modify some settings and rerun the flow until a satisfying result is obtained.



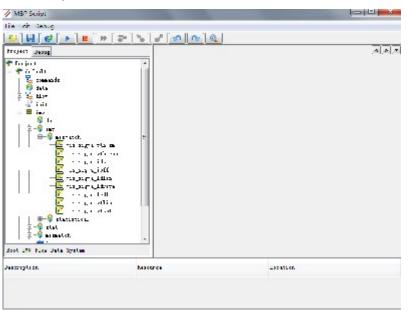
Fitting result

Mismatch IMV

Lastly, we use a demo case to illustrate how to customize mismatch IMV and plot it in MBP. After loading the data and model, choose Script > Script Project from the main menu to pop up the MBP Script interface.

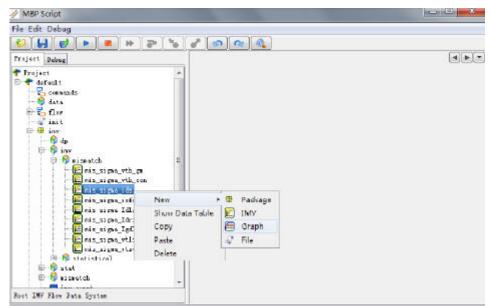
In the left Project tab window, click default > imv > imv > mismatch to expand the folder, as shown in the following figure:

MBP script



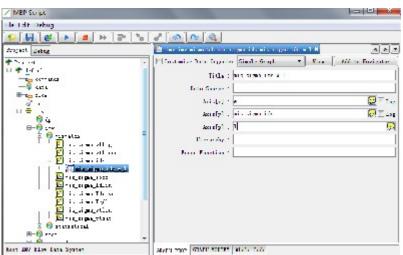
Right-click the IMV mis_sigma_ids and choose New > Graph (see following figure).

Create new graph



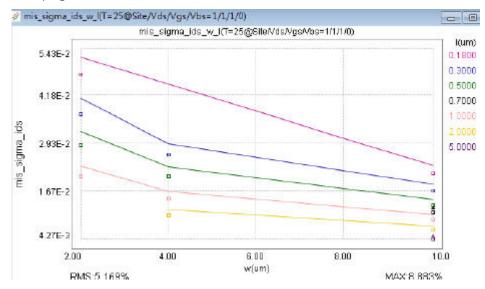
Input mis_sigma_ids_w_l as the code name. In the GRAPH_PROP tab, choose w as Axis[x], mis_sigma_ids as Axis[x] and l as Axis[x] as shown in the following figure.

Configure graph



Click the icon to save the current code. In the main menu of MBP, choose Extraction > IMV > IMV Pages to open the IMV page. Click the icon to refresh. You can then view the customized IMV page (mis_sigma_ids_w_l) as shown in the following figure:





Multiple Simulations

This application note describes how to compare two or more different models in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2011.1.0 in July 2011.

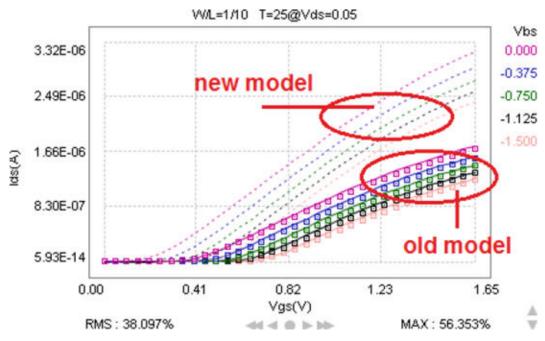
Overview

MBP provides an option to plot two or more models (including binning models) on screen at the same time. This feature is specifically designed for modeling engineers tuning or comparing different models.

This document introduces the steps and options to running a multiple simulation. For more information go to www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus.

Double Simulation

MBP features a double simulation function that can be used to compare two models— the models before and after tuning— by plotting their simulation results on screen at the same time.



Double simulation result

This function is enabled by clicking Simulation > Double Sim from the main menu or pressing the Ctrl and R buttons on the keyboard at the same time. After that,

two new icons (Cancel and Confirm 2) are added to the optimization pane, as shown in the figure cancel and confirm icons. You can then easily compare the results of the two models.

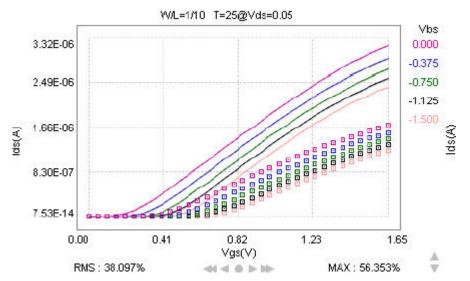
Cancel and confirm icons

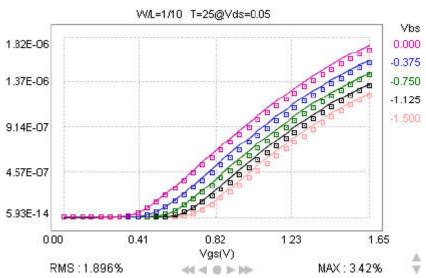
Search :			😻 🔒	• • •		🔞 👩 🔊
💡 General	DW/DL V	IH MOB SUB	Rout Iem			
Check	Name	Value	Lower	Cancel a Confirm		
	LEVEL	49				
	VERSION	3.2		0		
	BINNNII	1		0		
[17]	LMIN	1.485E-7	0	1 11	E-7	E

The old (original) model is represented by the solid line and cannot be modified. When one tunes a parameter, the new (current) model, which is represented by the dotted lines, becomes active and changes with the parameter.

On clicking the Confirm icon 💐, the new model is kept. MBP then updates the old model using the parameters of the new model, as shown in the Figure: Confirm to use the new model. On clicking the Cancel icon 🔎, MBP reverts back to the old model as the current model, as shown in Figure: Cancel to use the old model as the current.

Confirm to use the new model





When the double simulation functionality is in use and you want to save the model, only the new model gets saved. In case you quit the double simulation after some adjustment, MBP deletes the old model (solid one) and uses the new one (dotted one) as the current model.

Multiple Models Comparison

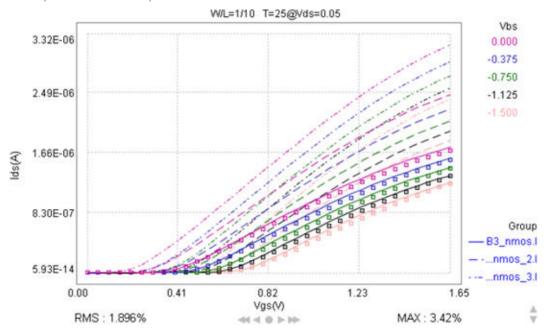
In addition to performing double simulation, MBP also allows you to compare multiple models. The model manager interface is located at the bottom-left corner of the main graphical user interface (GUI), as shown in figure Model manager interface. There are five icons at the top of this model manager. From left to right, they are: Add Model,Remove Model,Compare,Save Version,and Hide. A model list is located under these icons. All models added to MBP can be found here. Model cards can be loaded into the model manager. In case you want to load a model library, it can be done by choosing Utilities > Lib Parser from the main menu. Figure 4. Model manager interface

	DW/DL VIH	MOB SUB F	lout Iemp	Diode Cap S	tress WPE	1
Check	Nane	Value	Lower	Upper	Step	
	LEVEL	49	1		0	-
	VERSION	3.2			0	
	BINUNII	1			0	
100	LMIN	1.4852-7	0	1	1E-7	E
	LMAX	1	0.5	1.5	0.1	
	MOBMOD	1			0	
	WMIN	1.782E-7	0	1	1E-7	
	CAPMOD	3			0	
	IANN	1	0.5	1.5	0.1	+

Cancel to use the old model as the current

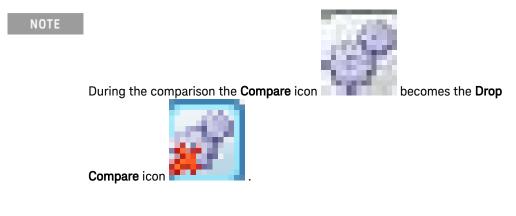
The Hide icon $\overline{\mathbb{S}}$, as the name indicates, is used to minimize the model manager interface. The Add Model and Remove Model icons are for loading/removing models into/from the model manager. The Compare icon $\overline{\mathbb{S}}$ is used to compare models in the model manager.

You can select multiple models (at least two) by clicking the models while pressing the Ctrl button on the keyboard. Next, click the Compare icon. The results can be viewed on the plot panel as shown in following figure.



Multiple models comparison

You can then observe the simulation results of three different models. The legend showing line symbols and the corresponding model names can be found at the bottom right corner of the screen.



Optimization Weight Setting

This application note describes how to set weight in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2011.1.0 in August 2011.

Overview

In MBP, weight can be separately assigned to device and curve. The weight setting takes effect when calculating root-mean-square (RMS) and thus, affects the final optimization result. When weight is set on one curve, all points on that curve inherit the weight value. In MBP, the default value of weight is always "1"; In this document, we introduce the steps to set weight for device and curve, respectively. For more information go to www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus.

Device Weight Setting

MBP allows you to set different weights for different devices when running the optimization. Here, weight means the part's weight in the whole integration. For example, the default weight for every device in MBP is 1, so the RMS values of all devices are multiplied by 1 (e.g., they remain unchanged). Since the built-in optimizer implements optimization according to the RMS value, it treats all devices with the same importance. However, if you set the weight value of one device as 2, then the RMS value of this device will be multiplied by 2 and the optimizer will treat it with much more importance than ordinary devices with a weight of 1.

To enable this feature, choose Extraction > Weight Setting from the main menu. The weight setting dialog will pop up as shown in the following figure:

Apply		🛛 Mamual Opti	mization		
Multi	setting				
weight	a		Apply to Sele	cted 🔻 Apply	Reset All
Index	w	L	T	Weight. Value	Weight.Exp
V 1	1	10	25	1	
V 2	10	1	25	1	
73	10	10	25	1	
V 4	10	2	25	1	
V 5	10	4	25	1	
V 6	10	0.15	25	1	
77	10	0.16	25	1	
8	10	0.17	25	1	
V 9	10	0.2	25	1	
7 10	10	0.3	25	1	
V 11	10	0.4	25	1	
12	2	10	25	1	
V 13	4	10	25	1	
V 14	4	0.15	25	1	
V 15	0.18	10	25	1	
12 16	0.19	0.15	ne -	1	

Weight setting for device

At the top of this dialog window there are two check boxes that allow you to apply the weight settings to either Task Tree or Manual Optimization. You can also check both options. In the Multi-setting panel, you can chose to apply the weight setting to the Selected devices or All devices. As for weight, you can either directly input the value or use the expression.

For example, as shown in figure Weight expression, weight is set as an expression given by W/L*T. After clicking the Apply button, the values and expressions in the column Weight.Value and Weight.Exp will be updated. Device instance parameters (such as W, L and T) may be employed in the expression.

Apply to: 25 25 25 25 25 25 25 25		2.5 250 25	Reset All Weight.Exp W/L*I W/L*I W/L*I	
I 25 25 25 25 25		t. Value 2.5 250 25	Weight.Exp W/L*I W/L*I	
25 25 25 25	Weigh	2.5 250 25	W/L*I W/L*I	
25 25 25		250 25	W/L*I	
25 25 25		250 25	W/L*I	1
25			W/L*I	
the second se				
25		125	W/L*I	
		62.5	W/L*I	
25	1	,666.667	W/L*I	
25		1,562.5	W/L*I	1
25	1	470.588	W/L*I	
25		1,250	W/L*I	
25		833.333	W/L*I	
25		625	W/L*I	
25		5	W/L*I	-
25		10	W/L*I	
25		666.667	W/L*T	
25		0.45	W/L*T	
los.		20	WITAT	
	25 25 25 25 25 25	25 25 25 25 25 25 25	25 625 25 5 25 10 25 666.667 25 0.45 25 20	25 625 W/L*I 25 5 W/L*I 25 10 W/L*I 25 666.667 W/L*I 25 0.45 W/L*I 25 20 X/L*T

Weight expression

MBP supported operator and functions are listed in Tables 1 and 2, respectively.

Support operator

Support Operator	Symbol
Power	^

Support Operator	Symbol
Boolean Not	ļ
Unary Plus, Unary Minus	+X, -X
Modulus	%
Division	/
Multiplication	*
Addition, Subtraction	+,-
Less or Equal, More or Equal	<=, >=
Less Than, Greater Than	<, >
Not Equal, Equal	!=, ==
Boolean And	&&
Boolean Or	
Support function	

Support function

Support Function	Symbol
Sine	sin()
Cosine	cos()
Tangent	tan()
Arc Sine	asin()
Arc Cosine	acos()
Arc Tangent	atan()
Hyperbolic Sine	sinh()
Hyperbolic Cosine	cosh()

Support Function	Symbol
Hyperbolic Tangent	tanh()
Inverse Hyperbolic Sine	asinh()
Inverse Hyperbolic Cosine	acosh()
Inverse Hyperbolic Tangent	atanh()
Natural Algorithm	ln()
Algorithm base 10	log()
Angle	angle()
Absolute Value / Magnitude	abs()
Random number (between 0 and 1)	rand()
Modulus	mod()
Square Root	sqrt()
Sum	sum()

Curve Weight Setting

The weight can also be set in curve level. To do so, click the Curve tab to switch to the interface as shown in the following figure:

Weight setting for curve

State of the second	ge Res	Reset Page	y •	s=1.5 🔻 Math	_vgs_vbs@vd	Page: ids
					ds	Y Name: i
. 5	-1.5	-1.125	-0.75	-0.375	0	vbs
0	1.0	1.0	1.0	1.0	1.0	Weight
-						vbs Weight

First, you need to define a plot. As shown in following figure, this is done by choosing one page from the drop-down list, for example, ids_vgs_vbs@vds=1.5

	eight setting ds_vgs_vbs@vds=1.5 🔹	ath: y 🔹	Reset Page	Reset All
	ds_vgs_vbs@vds=1.5			
	ds_vgs_vbs@vds=0.05	-0.75	-1.125	-1.5
eigh i	ds_vds_vgs@vbs=-1.5	1.0	1.0	1.0
	ds_vds_vgs@vbs=0			

Set page

Next, select a math transform from the drop-down list as shown in figure Set Math. This is important because the user may be interested in Id_Vg_Vb or Gm_Vg_Vb (the derivative of Id_Vg) during the optimization. Choosing different math transformations can distinguish between these two plots.

Curve wei	ght setting			`	
Page: ids	_vgs_vbs@vdi	s=1.5 🔻 Matl	h: y 🔹	Reset Page	Reset All
Y Name: i	ds		у		
vbs	0	-0.375	1/y	-1.125	-1.5
Weight	1.0	1.0	y'	1.0	1.0
			y''' dx/dy)	

Set math

The weight setting can also be accomplished by editing the value directly in the table. Note, however, that the final weight value of one curve needs to be multiplied by the weight of its device. So, the total weight of one curve is equal to device_weight*curve_weight.

After all settings are done, click the OK button to save and close the window. All of the selected settings will be immediately activated.

Parameter Boundry

This application note describes how to compare two or more different models in Model Builder Program (MBP).

NOTE This document was originally released for MBP V2011.1.0 in July 2011.

Overview

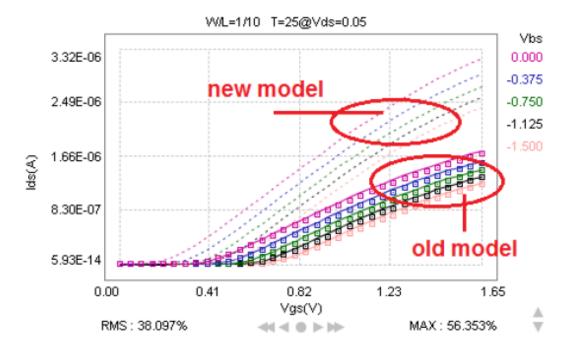
MBP provides an option to plot two or more models (including binning models) on screen at the same time. This feature is specifically designed for modeling engineers tuning or comparing different models.

This document introduces the steps and options to running a multiple simulation. For more information go to http://www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at http://www.keysight.com/find/contactus.

Double Simulation

MBP features a double simulation function that can be used to compare two models' the models before and after tuning – by plotting their simulation results on screen at the same time (see following figure).

Double simulation result



This function is enabled by clicking Simulation > Double Sim from the main menu or pressing the Ctrl and R buttons on the keyboard at the same time. After that, two new icons (Cancel and Confirm a) are added to the optimization pane, as shown in following figure. You can then easily compare the results of the two models. Cancel and confirm icons

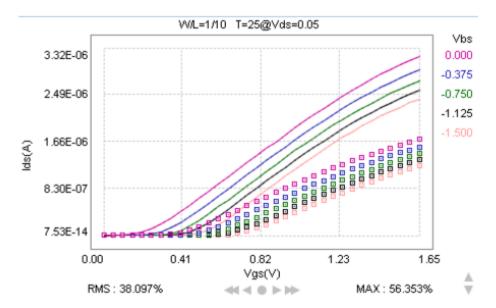
Search :			😻 🚯	• • •	
💡 General	DW/DL VIH	MOB SUB	Rout Temp		
Check	Name	Value	Lower	Cancel and Confirm but	
	LEVEL	49		0	
	VERSION	3.2		0	
	BINUNIT	1		0	
	LMIN	1.485E-7	0	1 1E-7	=

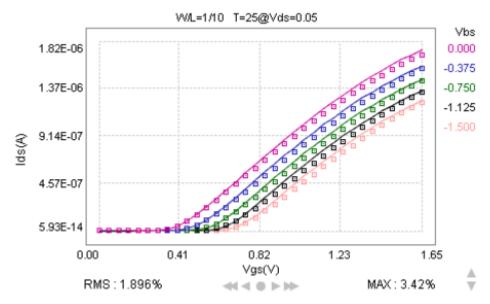
The old (original) model is represented by the solid line and cannot be modified. When one tunes a parameter, the new (current) model, which is represented by the dotted lines, becomes active and changes with the parameter.

On clicking the Confirm icon is, the new model is kept. MBP then updates the old model using the parameters of the new model, as shown in Figure: Confirm to use

the new model. On clicking the Cancel icon ^[S], MBP reverts back to the old model as the current model, as shown in Figure: Cancel to use the old model as the current.

Confirm to use the new model





Cancel to use the old model as the current

When the double simulation functionality is in use and you want to save the model, only the new model gets saved. In case you quit the double simulation after some adjustment, MBP deletes the old model (solid one) and uses the new one (dotted one) as the current model.

Multiple Models Comparison

In addition to performing double simulation, MBP also allows you to compare multiple models. The model manager interface is located at the bottom-left corner of the main graphical user interface (GUI), as shown in Figure 4. There are five icons at the top of this model manager. From left to right, they are: Add Model, Remove Model, Compare, Save Version, and Hide. A model list is located under these icons. All models added to MBP can be found here. Model cards can be loaded into the model manager. In case you want to load a model library, it can be done by choosing Utilities > Lib Parser from the main menu.

🙀 💭 🔐 🔛 候	Search :			😻 🙆	0		
	💡 General	DW/DL VTH	NOB SUB Ro	ut Temp Di	ode Cap Str	ess WPE∢ →	🞽 💽
B3_nmos_2.1	Check	Name	Value	Lower	Upper	Step	
I3_nmos_3.1		LEVEL	49			• 0	
		VERSION BINUNIT	3.2			0	
		LMIN	1.485E-7	0	1	1E-7 ≡	
		LMAX	1	0.5	1.5	0.1	
		MOBMOD	1 1.782E-7	0	1	1E-7	
		CAPMOD	3			0	
		XAMX	1	0.5	1.5	0.1 +	
			Unspeci fi	ed Parameter	5		
Parameters Message							



interface. The Add Model 😨 and Remove Model 题 icons are for loading

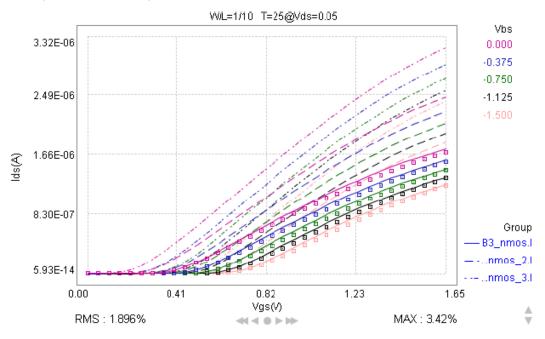
/removing models into/from the model manager. The Compare icon 🧰 is used to compare models in the model manager.

You can select multiple models (at least two) by clicking the models while pressing the Ctrl button on the keyboard.

Next, click the Compare icon. The results can be viewed on the plot panel as shown in Figure: Multiple model comparison.



Multiple models comparison



From above figure, you can then observe the simulation results of three different models. The legend showing line symbols and the corresponding model names can be found at the bottom right corner of the screen.

Statistical Modeling

Overview

Incorporating process variability into models is critical for IC design. Moreover, statistical modeling is today playing an ever important role in ensuring high product yield in the design phase. MBP supports Monte Carlo simulation with statistical modeling. In this document, we first describe the data format supported, plot configuration and Monte Carlo simulation in MBP. Additionally, the built-in flow used to run statistical model extraction with the Backward Propagation of Variance (BPV) method is elaborated. Finally, we use a demo to introduce the steps to configure and plot statistical IMV. For more information go to http://www.keysight.com/find/eesof or contact your local Keysight office. The complete list is available at: http://www.keysight.com/find/contactus.

Data, Plot and Simulation

Data Format

MBP supports two kinds of data formats for statistical modeling. The first is based on actual measurement data, while the second allows you to input the mean and sigma value of the target.

Data Format I

Below is an example of the first format (based on measurement data) supported in MBP:

```
staccondition{mode=forward,type=nmos}
Page(name=Ids,target=\{Ids(vds=0.05,vgs=1.1)\},p=vbs)\{w=0.
18, L=0.15, T=25
curve{0.0}
* sitel
                 1.863622E-5
* site2
                1.859326E-5
* site3
                1.826478E-5
* site4
                1.79857E-5
* site5
                1.857634E-5
* site6
                1.89573E-5
                 1.831234E-5
* site7
 site8
                1.895472E-5
* site9
                1.901374E-5
 site10
                1.882349E-5
```

The first line of the data file begins with the keyword staccondition and contains working mode and device type information. From this example, we know that its a NMOS device in forward working mode.

The second line defines all page related information. The information within the round bracket contains page name, target and P variable. The information within the brace declares the page constants, including geometry and temperature. For any assistance, mail to: mbp_pdl-eesof@keysight.com

The latter part is the data block information. For every curve block, it always begins with the keyword curve and the corresponding P value (vbs, in this example). All data information is listed behind it. There are two values in every line: the site number and the target value (Ids, in this example).

Data Format II

You can also choose the other format for the statistical data, allowing to input the mean and sigma value of the target. An example is as follows:

```
condition{corner = tt,date = oct_20_02} Datatype
{statistical}
Version{1.0} type{nmos} Delimiter{,} Instance\{L, W, T}
Input{vds=0.05, Vgs=1, Vbs=-1,icon=1e-7} Targets{Vth_gm,
Idsat}
Data{L, W, T, vds, vgs,vbs, ids}
0.6, 0.27 , 25 , 5.5, 5.5 , 0, 1.94e-4, 2.44e-6
0.6, 10 , 25 , 5.5, 5.5 , 0, 1.94e-4, 2.44e-6
....
Data{L, W, T, vds,vgs,vbs, vth_gm}
0.6, 0.27 , 25 , 5.5, 5.5 , 0, 0.83, 8.95e-3
0.6, 10 , 25 , 5.5, 5.5 , 0, 0.83, 8.95e-3
....
```

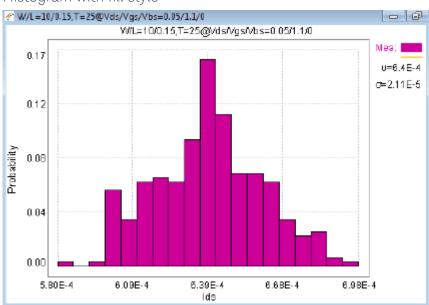
In this format, the first part of the data file contains the general information such as corner type, time, data type, device type, instance, bias condition, and target. The latter part of the data file is the data block information. Every block begins with the keyword Data following the variables. All data is listed from the second line of each block. Note that the last two values in every line correspond to the mean and sigma of the target. In this example, line 0.6, 0.27,25, 5.5, 5.5, 0, 1.94e-4, 2.44e-6 means L=0.6um, W=0.27um, T=25C, Vds=5.5V, Vgs=5.5V, Vbs=0, Ids(mean)=1.94e-4A, Ids (sigma)=2.44e-6A.

Data Plot

Depending on the number of targets, there are two kinds of plots: histogram and scatter.

Histogram for Single Target

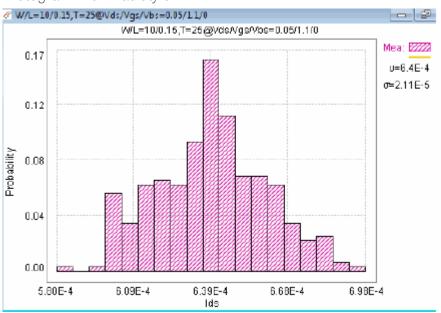
Using the target Ids_ as an example, the data plot(histogram) is shown in following figure.



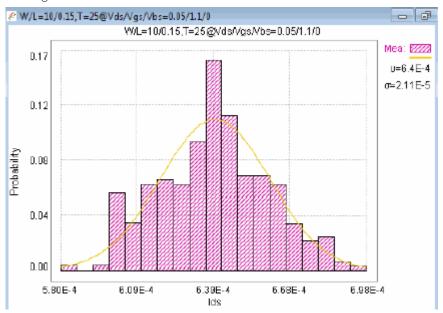
Histogram with fill style

Two styles are available for the histogram: the fill style as shown in Figure 1 and the bias style as shown in following figure. For the Bias style, simply right-click the plot and in the popup menu choose Bar Styles > Bias.

Histogram with Bias style



You can also add a distribution line on the histogram. To do so, right-click on the plot and check the item Draw Distribution(Figure3).



Histogram with distribution line

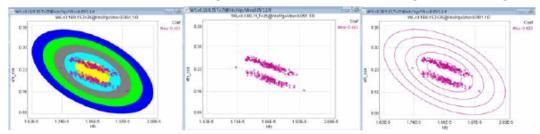
Scatter Plot for a Pair of Targets

The scatter plot is used for a pair of targets. In this example, the pair of targets are defined as ids and vth_con. A scatter plot can be configured by the user on MBPs graphical user interface (GUI). Simply choose Tool > GUI Options > Statistical Graph Config from the main menu to open the Statistical Graph Configuration window as shown in Statistical graph configuration. MBP automatically parses the targets (e.g., ids, vth_con, vth_gm, Ion, and Ioff, etc.). These targets can be freely chosen as X- or Y-axis values on the scatter pages. In this example, we choose ids as X scale and vth_con as Y scale. Next, click the Add Page button.

Statistical graph configuration

Statistical Graph Config	1 Acres	1		×
Scatter pages Pages ids_Scatter_vth_con				
		I Scale:	i	da 👻 👻
	:	Scale:	×	th_con +
			d Fage	
		1.	1 Page	
🖉 Set to default				
Contour				
Contour Stylex:	Outline		• 🔽 s.	t to default
Contour Humber:	5		• 👽 Se	t to default
Color				
Histogram				
🐨 Draw Distribution			V Sa	at to defealt
Bar Styles:	Fill		• 🔽 s	t to default
Bin Dunber:	20		V Se	et to default
NC count			_	
🔽 Vse	default :	number: 10	0	
	OK	Cencel		

The contour of the scatter plot is also set in this window. Currently, MBP allows you to set the contour number up to 5 (corresponding to the case of five sigma). There are three contour styles available to choose from: fill, null and outline. The corresponding scatter plots are shown in following figure.



Scatter Plots: fill (left-most image), null(center) and outline(right-most image)

MC Simulation

MBPs internal engine is capable of performing Monte Carlo analysis. You may also call an external simulator for verification purposes.

Statistical Model

To enable Monte Carlo analysis in MBP, you need to first build a statistical model. The models key parameters must be set to Gaussian distribution as follows:

```
.param
+p1=AGAUSS(0.37,0.01,1)
.param
+p2=GAUSS(1.21038E-1,0.03,1)
.....
+vth0=p1
+u0=p2
.....
```

To begin, first load a compact model into the statistical module. Since no Monte Carlo analysis has yet been set, you will get only one point as a simulation output on each plot. MBP supports the ability to load the statistical model with a global or binning core model, or a macro model. It also allows the statistical model to be loaded directly from the model library using Lib Parser.

Set Monte Carlo Count

You can set the Monte Carlo simulation number by right-clicking on the plot and selecting Set Monte Count. You must set an appropriate number here. Note that a large number may lead to a more accurate result, but will also require a longer simulation time.

Fast MC Simulation

MBP provides an option to run fast MC simulation. To achieve this, choose Simulation > Fast-MC from the main menu. This method speeds up the simulation using a unique methodology to deal with the statistical model.

BPV Extraction Flow

A demo case is used here to describe the steps required to run a statistical model extraction through the built-in flow.

Demo Files

The demo folder is \$MBPHOME\demo\Statistical\mosfet. Here, \$MBPHOME is the installation path of MBP.

There are a total of three files in this folder:

- model_nmos.l, the initial model card;
- param.txt, the parameter list used in the BPV extraction flow; and
- sta_data.mea, the demo data.

You can follow the steps presented below to complete the extraction process.

Set Model Type

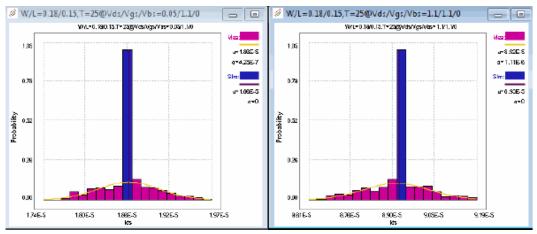
First, You must set the mode type. Choose Model > Select Model from the main menu. In the popup Model Type window, choose Statistical as the project type. Then choose mosfet_ as the device type, as shown in following figure.

Model t	уре		
Model Type			×
Project ly DC	De 🕖 XF	Statistical	🔘 Reliability
Statisti G-Statisti G-Statisti capac capac b-Statisti mosfs 	itor 1 osfet		
(e) hspice	🖲 spectre		
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	30	Cancel	

Click the OK button to close the window.

Load Data and Model

To load the data, choose File > Model > Load from the main menu. Load the model file model_nmosl. Since there is no statistical information in the initial model, only one blue column indicating the simulation result is visible (see following figure).



Initial model versus measurement data

MBP also supports the ability to load a model with existing statistical information. You can use the flow to optimize the previously tuned model.

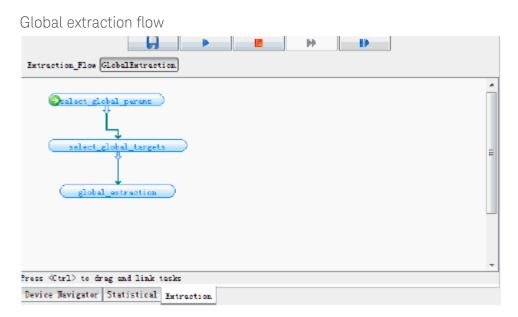
Run Extraction Flow

To run the extraction flow choose Extraction > Extraction Flow from the main menu. The extraction panel shown in following figure.

Extraction flow panel

	+	Ð	
Extraction_Flow			
			*
			=
ClobalEntraction			=
MismatchExtraction			
- mishacchild et al. (con			
Press (Ctrl) to drag and link tasks			•
Device Favigator Statistical Extraction			

Double click the Global Extraction button to expand the flow as shown in following figure.



There are three steps in the flow:

- select_global_params,
- select_global_targets and global_extraction.

 Click the run icon to automatically run the global extraction flow. The Select Parameters window will pop up as shown in Figure: Select Parameters window Select Parameters window

	t Paramet						
elect	type	name	random	sigma	step	min	max
1	param			NaN	NaN	0.0	NaN
			-				
		Add	Del	Loa		ve as	

Click the Load button to load the parameter list file param.txt. The parameters are arranged as shown in Figure-Load parameter list. Load parameter list

aram	dtox		NaN	1.0E-12	0.0	NaN
aram	dxl		NaN	1.0E-9	0.0	NaN
aram	dzw		NaN	1. OE-9	0.0	NaN
aram	dvth		NaN	0.0010	0.0	NaN
aram	dlvth		NaN	1.0E-9	0.0	NaN
aram	dwvth		NaN	1.0E-9	0.0	NaN
aram	dpvth		NaN	1.0E-9	0.0	NaN
aram	du0		NaN	0.0010	0.0	NaN
aram	dpu0		NaN	1.0E-9	0.0	NaN
aram	dvsat		NaN	10.0	0.0	NaN
	aram aram aram aram aram aram aram	aram dxl aram dxw aram dvth aram dlvth aram dwvth aram dpvth aram du0 aram dp0	aram dxl aram dxw aram dvth aram dlvth aram dwvth aram dpvth aram du0 aram dpu0	aram dxl NaN aram dxw NaN aram dvth NaN aram dlvth NaN aram dwvth NaN aram dwvth NaN aram dvth NaN aram du0 NaN aram du0 NaN	ar am dxl NaN 1.0E-9 ar am dxw NaN 1.0E-9 ar am dvth NaN 0.0010 ar am dvth NaN 0.0010 ar am dlvth NaN 1.0E-9 ar am dlvth NaN 1.0E-9 ar am dwvth NaN 1.0E-9 ar am dpvth NaN 1.0E-9 ar am dp0 NaN 0.0010 ar am dp0 NaN 1.0E-9	aram dxl NaN 1.0E-9 0.0 aram dxw NaN 1.0E-9 0.0 aram dxw NaN 1.0E-9 0.0 aram dvth NaN 0.0010 0.0 aram dvth NaN 1.0E-9 0.0 aram dlvth NaN 1.0E-9 0.0 aram dwvth NaN 1.0E-9 0.0 aram dpvth NaN 1.0E-9 0.0 aram dpvth NaN 1.0E-9 0.0 aram dp0 NaN 1.0E-9 0.0

The parameter list window is now visible and can be used to select parameters for statistical calculation.

Some comments on the column names are follows:

- Select. When it is checked, the parameter will be re-extracted. If it is unchecked, the parameter will depend on the sigma value. If a sigma value is given, the final value of the parameter will be the sigma value; while if a sigma value is not given, the current value of the parameter will remain as the final one.
- Name: parameter name. When select is unchecked, the parameter name may be blank. At the same time, both random and sigma must have correct values.

- Random: random variable name. If there is a random variable for the parameter in the current model file, you must enter the name of the random variable here. If there is no random variable for the parameter in the current model file, you may either input a new name here or keep it blank. In the latter case, a new name will be automatically created. Note that not all names of random variables can be repeated.
- Sigma: sigma of the parameter. An example here is the dtox parameter. If you know the sigma of the TOX (normally the information can be obtained from fabrication), then the value can be input into it directly. The extraction flow then bypasses this parameter and uses the predefined value instead.
- Step: the step for BPV calculation. The step is very important for the extraction flow and is used to calculate the sensitivity of the parameter to the target. You must input a suitable value; one that is not too big or too small. Here, you can carefully monitor the change in IdVd or IdVg plots while adjusting the step number.

Click the OK button to continue. The Select Targets window will pop up as shown in following figure. You must then select the targets for the BPV extraction. Normally, the user will select the targets that are important or you care most about it.

con		weight	w	L	T	vds	vgs	vb
	V	1	1.8E-7	1.5E-7	25	0.05	1.1	0
	v	1	1.8E-7	1.5E-7	25	1.1	1.1	0
	v	1	1.8E-7	1E-5	25	0.05	1.1	0
	v	1	1.8E-7	1E-5	25	1.1	1.1	0
	v	1	11-5	1.5E-7	25	0.05	1.1	0
	v	1	11-5	1.5E-7	25	1.1	1.1	0
	V	1	1E-5	1E-5	25	0.05	1.1	0
	V	1	11-5	1E-5	25	1.1	1.1	0

Select Targets

Select targets Next, you can set different weights for different targets. The default value is 1. Close the window to continue. In the last step, the Save dialog window will pop up. Here, the user inputs a name to save the model file. You will then find that the following statistical parameters have been extracted and added into the generated model file:

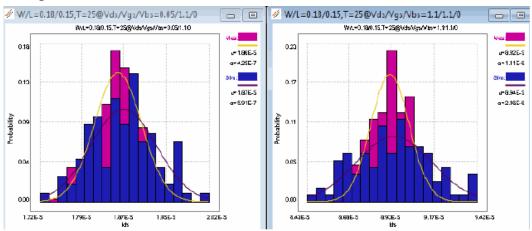
```
.param||
+s_dtox = 4.759276E-14
s_dxl = 2.757199E-13
```

 $s_dxw = 3.874035E-9$ $+s_dvth = 1.16912E-2$ $s_dlvth = 8.878411E-7$ dwvth = 3.014865E-7 $+s_dpvth = 3.740674E-9$ $s_du0 = 1.47506E-3$ $s_dpu0 = 2.144652E-8$ $+s_dvsat = 2.016329$.param +dtox = 0.0+s_dtox*random1* $dxl = 0.0+s_dxl*random2*$ $dxw = 0.0+s_dxw*random3*$ +dvth = 0.0+s_dvth*random4* dlvth = 0.0+s_dlvth*random5* $dwvth = 0.0+s_dwvth*random6*$ +dpvth = 0.0+s_dpvth*random7* du0 = 0.0+s_du0*random8* $dpu0 = 0.0+s_dpu0*random9*$ +dvsat = 0.0+s_dvsat*random10* .param +random1 = agauss(0.0, 1.0, 1)+random2 = agauss(0.0, 1.0, 1)+random3 = agauss(0.0, 1.0, 1)+random4 = agauss(0.0, 1.0, 1)+random5 = agauss(0.0, 1.0, 1)+random6 = agauss(0.0, 1.0, 1)+random7 = agauss(0.0, 1.0, 1)

```
+random8 = agauss(0.0,1.0, 1)
+random9 = agauss(0.0,1.0, 1)
+random10 = agauss(0.0,1.0, 1)
```

The fitting result is shown in following figure.





You may continue to fine tune the parameters manually, or simply modify the step number as previously mentioned and rerun the flow until a satisfactory result is obtained.

Statistical IMV

Finally, we use a demo to illuminate how to customize statistical IMV and plot it in MBP. After loading the demo data, choose Script > Script Project from the main menu to pop up the MBP Script interface. In the left Project tab window, click default > imv > imv > statistical to expand the file structure, as shown in Figure MBP Script.

MBP Script

MBP Script			x
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Right click the IMV sta_sigma_ids and choose New > Graph(see following figure).

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Create new graph

Input sta_sigma_ids_w_l as the code name. In the GRAPH_PROP tab, choose w as Axis[x], sta_sigma_ids as Axis[x] and l as Axis[x], as shown in see following figure.

Configure graph

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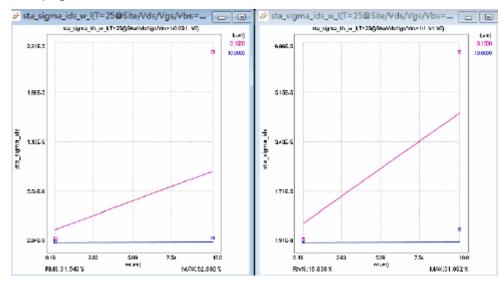
Click the icon **IMV** to save the current code. In the main menu of MBP, choose **Extraction** > **IMV** > **IMV Pages** to open the IMV page.

Click the icon

to refresh.

Then, you can view the customized IMV page (sta_sigma_ids_w_l) as shown in following figure.

IMV pages



Tmi Aging Model Application

TMI Aging Model Application

This application note describes how to implement a TSMC Modeling Interface (TMI) aging model in Model Builder Program (MBP).

NOTE

This document was originally released for MBP V2011.1.0 in August 2011.

Overview

TMI or TSMC Modeling Interface is a C-based modeling application programming interface (API) developed to support extensions of standard compact models. TMI is an add-on to standard models. Therefore, the compatibility and robustness of standard models dictated by the Compact Model Council (CMC) is retained when applied to different simulators and platforms.

MBP V2011.1.0 offers an environment for TMI reliability aging model simulation. With it, you can measure the device performance degradation over time and evaluate the effects of stress.

This document provides information on how to run a TMI aging model simulation and optimization in MBP. For more information go to http://www.keysight.com/find /eesof or contact your local Keysight office. The complete list is available at http://www.keysight.com/find/contactus.

Preparation

In preparation for using the TMI aging model application, all configuration files regarding TMI models must be placed under \$MBP_HOME\etc\hspice\tmi where \$MBP_HOME is the MBP installation path. You need to specify one directory as the TMI library path (TMIPath) on the computer. Then, a subfolder under TMIPath must be created to store the compiled, shared library file (libTMImodel.dll_) according to different operating system (OS) platforms. For example, if the OS is a 32-bit version of Microsoft & Windows & , the library file should be placed under TMIPath/WIN/.

See following figure for more information on the directory structure for shared libraries of different platforms.

Directory structure for shared libraries of different platforms

TMIPath

- RH/ libTMImodel.so (RedHat LINUX 32bit)
- RH_64/ libTMImodel.so (RedHat LINUX 64bit)
- SUN/ libTMImodel.so(SUNOS 32bit on SPARC)
- SUN64/ libTMImodel.so (SUNOS 64bit on SPARC)
- SUSE/ libTMImodel.so (SUSE 32bit)
- SUSE_64/ libTMImodel.so (SUSE 64bit)
- X86SUN/ libTMImodel.so (SUNOS 32bit on X86)
- X86SUN_64/ libTMImodel.so (SUNOS 64bit on X86)
- WIN/ libTMImodel.dll (MS Windows 32bit)
- WIN_64/ libTMImodel.dll (MS Windows 64bit)

In MBP, the data format for TMI aging analysis is the same as the MOS Reliability Analysis (MOSRA) data format. For more details, refer to the *MBP user guide* or *The MOSRA Model Support in MBP Application Note*.

Simulation and Parameter Extraction

MBP invokes the external simulator (Synopsys HSPICE) for TMI aging model simulation. You must ensure HSPICE has been installed properly prior to the simulation. Then, the following steps must be followed.

Choose Model Type

Choose Model > Select Model from the main menu and select Reliability in the Project Type. Then, select one core model (bsim4 in this example) in the upper Core Model Selection section and tmi-default in the lower Reliability section, as shown in following figure.

Choose model type

Model Type	•		×
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Reliabil	ity		
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	0K	Cancel	

Set TMI library path

Choose Extraction > Options > SPICE Options from the main menu to set the TMI library path (&TMIPath) in the Spice Options window, as shown in following figure.

TMI path setting

Spice Options	×				
Default Option(s)					
GminDc	1.0E-12				
Scale	1.0				
GeoShrink	1.0				
TempAsOption					
IMIPath	\model_core\tmilib				
User Option(s)	User Option(s)				
Original File					
📃 isUseOriginalFil	Le				
OK	Cancel				

In this example, we set

~\etc\hspice\tmi\bsim4\default\model_core\tmilib as the TMIPath_ Finally, click OK.

Model Parameters Panel

As shown in following figure, the TMI aging parameters are sorted out in the TMI Age tab of the model card.

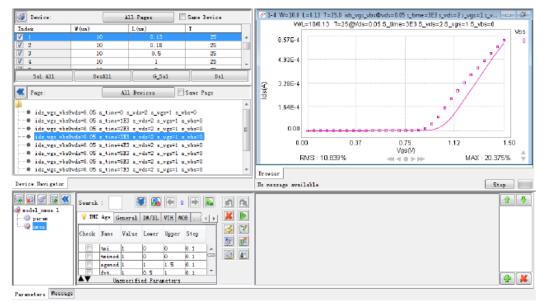
TMI aging parameters

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		tmimod	1	0	0	0.1		<u> 2</u>	
		agemod	1	1	1.5	0.1			
		fvth0_age	1	0.5	1	0.1			
		dagetime	dagetime	0	20	0.01			
		Vgsdmax	5	2.5	7.5	0.1	Ŧ		
			Unspecif	ied Paramet	ers		_		

Parameters Message

Load Model and Data

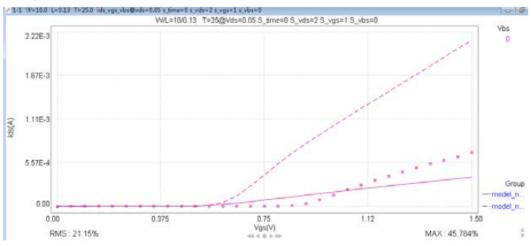
In the main menu, choose File > Model> Load to load the model file. Next, choose File > Data > Load from the main menu to load the data file. The window with the TMI aging model and data is shown in following figure.



Load model and data

You can now select model parameters and adjust them to fit the measurement data. MBP also allows to compare two different models. To do so, simply click the Add icon append another model for comparison. Select the two models by pressing the Ctrl button and clicking Compare icon to compare them. The resulting window is shown in following figure.

Compare two models



Microsoft is a U.S. registered trademark of Microsoft Corporation. Windows and MS Windows are U.S. registered trademarks of Microsoft Corporation.

Transient Simulation

Transient Simulation

Overview

MBP Supports transient simulation for both internal engine and external simulator (hspice , spectre). And build the demo case for this application.

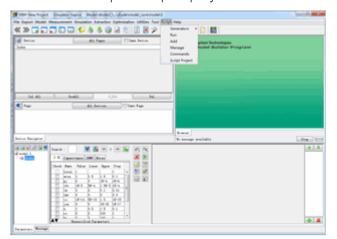
Ring oscillator demo case

MBP takes Ring oscillator as an example, which is a widely used test circuit.

1. Load the model for demo\DC\mosfet\RO

De Export Model Measurer	ar-hapice Model-docket(), Udockronodel, continuedel) met Simulation Estantion Optimization Utilities Tool Stript Help III 😜 🍮 🕭 🌚 🗃 🐑 🗵 🗷 🎾 🦧 🛐 🗐 👜	
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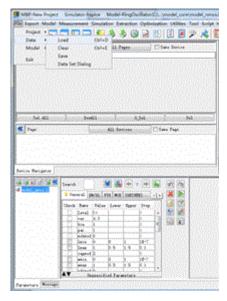
Load the script project.
 Select from script > script > project



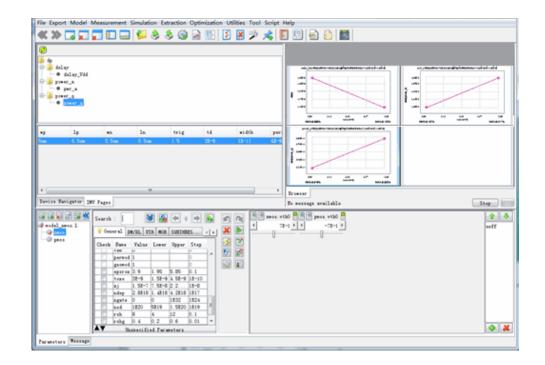
Click the Open button, and load script project from demo\DC\mosfet\RO

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Root IMV Flow Data System			
Description	Resource	Location	

3. Load measurement data from demo\DC\mosfet\RO



4. Check the interesting targets and tweak the parameter



PCA Model Extraction

PCA Model Extraction

Overview

PCA (Principal Component Analysis), is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. It uses major, independent components to describe the majority of variations of a larger number of characteristics and their correlation. In MBP, the PCA flow has two steps:

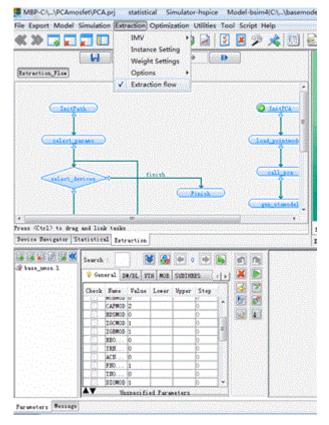
- 1. The first one extracts the point models from measurement data.
- 2. The second one generates the statistical model from the generated point models at last step.

Democase

1. Open the project from \demo\Statistical\PCAmosfet

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2. Load the task tree



There are two task trees, the left one is the first step of PCA flow. It will extract the point models. And the right one is the second step of PCA flow. It will generate the statistical model from the point models.

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3. Initial Setting

Select the InitPath , and click run button. An input table window will be popped.

- Modeltype: pmos or nmos.
- BaseModel: The path of base model, the base model is the initial model for the point models extraction.
- MeaData: The path for measurement data.
- Pointmodel: The path for the point model saving.
- Logfile : The path for the log file saving. Close this window and the tree will run to next step(Parameter select).

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Click the Load button, and select the demo\Statistical\PCAmosfet\ opt_nparam.txt for nmos and demo\Statistical\PCAmosfet\ opt_pparam.txt for pmos (

point models extraction). The point models will be automatically generated, and all the point models will be saved to the specified fold. We can repeat this flow for nmos if necessary.

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1. Load Point Model

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2. Initial setting for statistical model setting

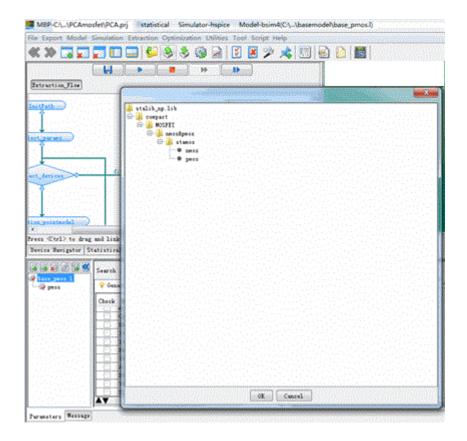
Select InitPCA and click run button, a input table window will be poped. PCAorder: The order-number for PCA algorithm.

BaseModelPath: The path of base model, the base model is the initial model for the point models extraction.

Savepath: The path for generated statistical model saving.

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3. Load the generated statistical model A select window will be popped



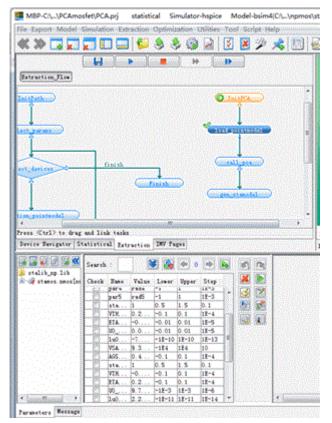
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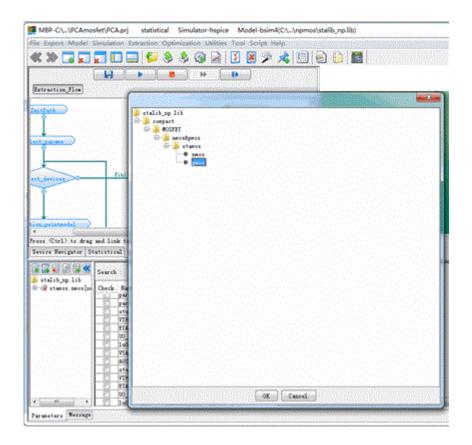
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To see N,P correlation plot, go to Tool > GUI Options > Statistical Graph Config, user is able to choose targets for NMOS and PMOS, and then add the page.

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Statistical Model Extraction Module

Introduction

MBP's statistical model extraction module is fully developed for generating SPICE model with Monte Carlo simulation capability, a capability of both local mismatch and global statistical.

The module is designed to satisfy any input model format: both a single model card and a model library can be the start point of a statistical model extraction process, and the whole extraction progress is fully automatic, customizable.

It contains a comprehensive data dispose procedure which can separate the global variation from the total variation, and the re-centering feature allow user tweaking either the model or the data before go further into the statistical model extraction progress.

Final fitting result is very good, take not only the variation itself but also the correlation between NMOS and PMOS into account.

Start the statistical model extraction module

Follow below four steps:

- 1. Switch to MOSFET statistical project model Select Model Statistical mosfet.
- 2. Load the statistical modeling package under: MBP_HOME\demo\Statistical\GUIBasedSolution\mosfet\demo_case_baseban
- 3. A drop-down menu named "Navigator" appears in the menu bar then



4. Click the menu "Statistical Model Extraction Panel" in the drop-down menu to show/hide the Statistical Model Extraction Panel.

File Export Model S	imulation Extraction Optimization Utilities Tool Script Help Navigator
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Global Model	1MOS: C\keysight\workspace\sta\demo_ca : Browse
	PMOS: C\keysight\workspace\sta\demo_ca : Browse
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	PMOS File: C\keysight\workspace\sta\demo_ca
	NMOS Name: nmos_mac PMOS Name: pmos_mac
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Setup the statistical model extraction progress

There are five buttons in the panel: *Setup, Data Analysis, Re-targeting, Local model*, , *Global model*, Stand for the five main steps to complete a Statistical Model Extraction Progress.

Setup

User need setup the original data and model in follow four steps.

- Set up Raw Data Path
- Input Model Information

- Select Simulation Method
- Add Comments

Set up Raw Data Path

Two parts of this step:

- Total Data (refer to statistical data)
- Local Data (refer to mismatch data)

User may only fill in one of them, if you want to extract either global model or local model.

User could also fill in NMOS or PMOS only.

	Setup
Setup	Input Measurement Data
Data Analysis	IMOS: C\keysight\workspace\sta\demo_ca Browse
Re-centering	PMOS: C\keysight\workspace\sta\demo_ca : Browse
Local Model	Local Data
Global Model	IMOS: C\keysight\workspace\sta\demo_ca : Browse
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	IMOS File: C\keysight\workspace\sta\demo_ca : Browse
	PMOS File: C\keysight\workspace\sta\demo_ca : Browse
	NMOS Name: nmos_mac PMOS Name: pmos_mac
	Simulation -

Input Model Information

MBP statistical module accept either model library or single model card.

	Setup
Setup	Input Measurement Data
Data Analysis	IMOS: C\keysight\workspace\sta\demo_ca Browse
Re-centering	PMOS: C\keysight\workspace\sta\demo_ca Browse
Local Model	Local Data
Global Model	IMOS: C\keysight\workspace\sta\demo_ca : Browse
	PMOS: C\keysight\workspace\sta\demo_ca Browse
	Input Model
	🔘 Lib File
	Lib Path: Browse
	Lib Name:
	NMOS Name: PMOS Name:
	Stat Flag: Mis Flag:
	Model File
	IMOS File: C\keysight\workspace\sta\demo_ca : Browse
	PMOS File: C\keysight\workspace\sta\demo_ca Browse
	NMOS Name: nmos_mac PMOS Name: pmos_mac
	Simulation'

- By using model library, please input library path, library name, NMOS model name, PMOS model name, *stat flag, Mis flag.*
 - Stat flag: the switch parameter in the model card, to switch on/off the statistical function of the model.
 For example, we set Stat flag as "staflag", if staflag=1, all statistical parameters works; if staflag=0, all statistical parameters disabled.
 - *Mis flag*: the switch parameter in the model card, to switch *on/off* the mismatch capability of the model.
 For example we set *Mis flag* as "misflag", if misflag=1, all mismatch parameters works, if misflag=0, all mismatch parameters disabled.
- By using baseband model, you need to fill in nmos model path or PMOS model path, or both of them.
 - The model must be a sub-ckt model and here must input the sub-ckt model name.

Select Simulation Method

MBP provides three simulation methods in its internal engine: *Normal-MC simulation* method, *RSM simulation* method and *FMC simulation* method.

- 1. Normal-MC: traditional Monte Carlo simulation method
- 2. *RSM simulation*: speed-up the mc-simulation with Response-Surface Method
- 3. FMC simulation: speed-up the mc-simulation with linear approximation

Add Comments

Any comments can be filled into the text box. Click "Update" after all the steps accomplished,.

CAUTION Without completing "*Setup*", user cannot go to "*Data Analysis*".

Data Analysis

There are five steps in this section, four of them are optional.

	Data Statistical Analysis
Setup Data Analysis	Data Pruning Delete the data beyond the 3 sigma Data Sampling
Re-centering Local Model Global Model	Group Size: 1
	Global Data Generation Global data from total and local data
	Mean Value Check Model Re-centering Data Re-centering
	Create Mismatch Dummy Data Create Mismatch Dummy Data Through origin point
	Not through origin point Use Last Data Generate Data

Data Pruning

This option is to eliminate the data points beyond 3-sigma.

Data Sampling

This option is to minimize the data with "Group Size". For example, if "Group Size" is set to 10, MBP will select data every ten sites. If the entire data amount is too huge, user can sped up the progress by using this option.

Global Data Generation

This option is to generate global data from total and local data.

Mean Value Check

In case measurement total data's mean value is not equal to simulation total data's mean value, user could use this option to do data tweaking. Two methods for the tweaking:

- 1. *Tweak model*: Tweak the baseband model to fit the measurement, user need go to next step "Baseband Model" to select parameters for tweaking.
- 2. *Tweak measurement total data*: MBP will adjust measurement data to fit model simulation. The tweaked data will be used in following steps.

Create Mismatch Dummy Data

This step is to create mismatch dummy data:

- The dummy data is a straight line, replace the original point data.
- User can choose the straight line through origin point or not before the dummy data generation.
- The dummy data line will be the optimization target during following steps; it can give better trend fitting result than original data points.

Click "Generate Data" button after all the steps to execute data dispose. If user are working on an existing project and want to reuse the data generated in the last data dispose operation, user can click the button "Use Last Data".

Re-centering

Must finished "Data Analysis" the can go to this step. Re-centering is used when "*Tweak model*" is selected at "*Mean Value Check"* steps, if user select "*Tweak data to fit model*", user could skip this step.

The step is used to select parameters for model tweaking, as below.

Model Re-centering Default Load device nmos_v pmos_v nmos_i pmos_i nmos_v pmos_v nmos_i pmos_v nmos_v pmos_v nmos_i pmos_v nmos_v pmos_v nmos_i pmos_v nmos_v pmos_v nmos_v pmos_v nmos_i pmos_v nmos_v nmos_v pmos_v nmos_v nmos_v pmos_v nmos_v	Default Load Save as i nmos_v pmos_v nmos_i pmos_i 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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Target Weight Setting

Click "Default", a weight table will appear. The left side of the table is device column, the upside of the table is target row, and all the default weights are set to 1.0.

User can set one value to the entire column or the entire row. By set the first column(or the first row)'s weight and then right-click on this column(or row) select "Set value to the whole column" or "Set value to the whole row".

User can load pre-defined configuration file by "*Load*", also can save the configuration file by "*Save as*".

Model Parameter Setting

Fill in the parameters for model tweaking in this table, together with parameter's type ("nmos" or "pmos"), step, min/max value.

Pre-defined configuration file can be loaded by "*Load*". A new configuration file can be saved by "*Save as*".

Click "*Baseband Model Generation*", then the model will be tweaked automatically to fit measurement data

Local Model

Note: Make sure you've finished "Data Dispose" before go to this step.

Local Model contains two parts:

- Target Weight Setting

- Model Parameter Setting

Target Weight Setting

								H	
				Local	Model Ge	neration			
Setup	-Target Wei	ght Setting				D	efault	Load	Save as
ata Analysis	device	nmos_I	pmos_I	11mos_v	pmos_v	nmos_I	pmos_I	nmos_v	pmos_v
e-centering	w_1.8E	1	1	1	1	1	1		1 1
	w_2E-6		1	1	1	1	1		1 1
local Model	w_1E-5		1		1	1			1 1
Lobal Model	w_1.8E				1				1 1
	w_2E-6	1	1		1	1	1		1 1
	w 1E-5	1	1	1	1	1	1		1 1
							C		
	type	р	arameter	stej	,	min		max	
	type nmos	-	arameter h0	stej	2	min		max	
		vt		ste	2	min		max	
	nmos	vt	h0 h0	ste	9	min		max	
	ım os pm os	vt vt u0	h0 h0	ste	2	min		max	
	numos pmos numos pmos numos	vt vt u0 to	h0 h0 xe	ster	2	min		max	
	nmos pmos nmos pmos	vt vt u0 to	h0 h0	ster	,	min		max	

You can load your pre-defined configuration file by clicking "Load". And you can save the configuration file by clicking "Save as".

Model Parameter Setting

Two different table formats will appear depend on what format of model we start with: model library or single model card.

- For model library, the table shows as below:

									👂 🛛
				Local	Model Ger	neration			
	Target Weig	ht Setting							
						D	efault	Load	Save as
	device	nmos_I	pmos_I	. nmos_v	pmos_v	nmos_I	pmos_I	nmos_v	pmos_v
	w_1.8E	1			1 1	1		1	1
	w_2E-6	1			1 1	1		1	1
	w_1E-5	1		1	1 1	1	1	1	1
1	w_1.8E	1		1	1 1	1	1	1	1
	w_2E-6	1		1	1 1	1	1	1	1
	w 1E-5	1		1	1 1	1	1	1	1
			ام	-	-	-			
	misrad_mis.		0		vth0_misnm				
	misrad_mis.		0		u0_misnmos_k0				
	misrad_mis. misrad_mis.		0		toxe_misnm vthO_mispm				
			0		uO_mispmos_kO				
	misrad mis.								

Fill in this table with user-defined mismatch model parameters and corresponding random parameters, the mean and sigma value of the parameter are "1" and "0" by default respectively.

- If single model card is used, the table is as below:

									👂 🛛 😢
				Local	Model Ge	neration	L		
	Target Wei	ght Setting							
Setup						D	efault	Load	Save as
Data Analysis	device	nmos_I	pmos_I	nmos_v	pmos_v	nmos_I	pmos_I	nmos_v	pmos_v
Re-centering	w_1.8E	1	1	1	1	1		-	
Local Model	w_2E-6	1	1	1	1				
	w_1E-5 w_1.8E	1	1	1	1		-	-	1
Global Model	w_2E-6	1	1	1	1		-		
	w 1E-5	1	1	1	1	-	-		
	type	p	arameter	stej	,	min		max	
				stej	,	min		max	
	nmos pmos	vt vt							^ ^
	nmos	u0							=
	pmos	u0							
	nmos	to	xe						
	pmos	to	xe						T
				Loca	L Model Gen	eration			

The table is very similar to "Baseband Model".

User need fill this table with parameters for tweaking, and specify parameters' polar type, polar type can be "NMOS" or "PMOS".

User can also assign parameter's step, min value and max value. After setting up all the target weights and model parameters, click "*Local Model Generation*" button, then the mismatch model will be generated automatically.

IOTE		e setup your model library as the MBP's demo example. Below are some trick in the model parameter setting:
	1.	Add ":" after parameter name, it means this parameter's input value will be the initial value for next step
	2.	Add "=" after parameter name, it means this parameter's value will always keep constant
	3.	If the input lib is complex, and the relation between the random and parameter is not very clear, please add "?" at first line and add the tuning parameters in the following lines.

Global Model

NOTE

Before go to this step, make sure "Data Dispose" is done.

Target Weight Sett							
	ing						
				D	efault	Load	Save a
device nmos	. pmos	nmos	pmos	nmos	pmos	nmos	pmos
w_1.8E	1	1 1	1		1	1	1 :
w_2E-6	1	1 1	1		1	1	1 :
w_1E-5	-	1 :	-		1	-	1 1
w_1.8E	1	1 1	-		1	-	1
w_2E-6	1	1 1	1		•		
					1		1 1
W_22-0 W IE-5 Correlation Weight	1 Setting	1	1	D	1 efault	Load	1 Save a
w 1E-5 Correlation Weight device	1 Setting	1	1	D	1 efault	1	1 Save s
<pre>x 1E-5 Correlation Weight device x_1.8E-7_1_1.5E-7</pre>	1 Setting	1	1	 nmos 1	1 efault	1 Load nmos_i	1 Save :
<pre>w 1E-5 Correlation Weight device w_1.8E-7_1_1.5E-7 w_2E-6_1_1.5E-7</pre>	1 Setting	1	1	D rumos_ 1 1	1 efault	1 Load nmos_i (1 1	1 Save a flin & p
<pre>w 1E-5 Correlation Weight device w_1.8E-7_1_1.5E-7 w_2E-6_1_1.5E-7 w_1E-5_1_1.5E-7</pre>	1 Setting	1	1	D nmos 1 1 1	1 efault	1 Load rmos_i (1 1 1 1	1 Save a
<pre>w 1E-5 Correlation Weight device w_1.8E-7_1_1.5E-7 w_2E-6_1_1.5E-7 w_1E-5_1_1.5E-7 w_1.8E-7_1_2E-6</pre>	1 Setting	1 n & nm a 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1	D rmos_ 1 1 1 1 1	1 efault	1 Load rumos_i (1 1 1 1 1 1	1 Save :
<pre>w 1E-5 Correlation Weight device w_1.8E-7_1_1.5E-7 w_2E-6_1_1.5E-7 w_1E-5_1_1.5E-7</pre>	1 Setting	1	1	D nmos 1 1 1	1 efault	1 Load rmos_i (1 1 1 1	1 Save a

This section is used to generate global statistical model automatically.

Three steps to complete a "Global Model" table:

- Target Weight Setting
- Correlation Weight Setting
- Model Parameter Setting

Target Weight Setting

User is suggested to use the default setting by click "*Default*" button. Different weight can be set to different target, MBP will put more effort on the target with high weight

Configuration file can be save and load by "*Save as*" and "*Load*" button.

									📁 🤯
				Global	Model Ge	nerati	on		
	-Target Weig	ht Setting							
Setup							Default	Load	Save as
Data Analysis	device	nmos v	pmos v	nmos i	pmos_i	nmos v.	pmos v.	nmos i	pmos i
Re-centering	w 1.8E	1	1	1			1	1	1 1 4
	w_2E-6	1	1	1			1	1	1 1
Local Model	w_1E-5	1	1	1	l 1		1	1	1 1 =
Global Model	w_1.8E	1	1	1	l 1		1	1	1 1
orobar model	w_2E-6	1	1	1			1	1	1 1
	w 1E-5	1	1	1	l 1		1	1	1 1 7
	- C - D - 1	* 11.0.							
	Correlation	Weight Set	ting			_			
							Default	Load	Save as
	device	IUN	os_vthlin &	ž rum o	os_idsat & p.	nmos	_vthsat & .	nmos_i	dlin & p
	w_1.8E-7_1_1			1		1		1	1 🔺
	w_2E-6_1_1.9			1		1		1	1
	w_1E-5_1_1.9			1		1		1	1
	w_1.8E-7_1_2 w_2E-6_1_2E-			1		1		1	1
	w_2E-6_1_2E w 1E-5 1 2E-			1		1		1	1
	Model Param		g					Load	Save as
	random	mean	sigm	a j	parameter	step	min		nax
	par1		0		th0_stanm				
	par1		0		th0_stapm				
	par1		0		0_stanmos_k1				
	par1		0		0_stapmos_k1				
	par1 par1		0		sat_stamm sat stapm				
	LE dE L	1	01		al Model Gen	eration]		

Correlation Weight Setting

If both NMOS and PMOS data is loaded within one extraction progress, user are enabled to set weight for NMOS and PMOS correlation.

MBP put more effort to the correlation with higher weight, may have better fitting accuracy normally.

] 🚺	
			Global	Model Ge	neratio	n				
	ght Setting									
						Default		Load	Sa	ve as
device	nmos v	pmos v	nmos i	pmos_i	nmos v	pmos v		nmos i	pmos	
w_1.8E			_	1	_	1	1	_	1	1
w_2E-6			-			1	1		1	1
w_1E-5			1	1 1		1	1		1	1
w_1.8E		:	1	L 1		1	1	:	1	1
w_2E-6	1		1	L 1		1	1	1	1	1
w 1E-5			1	1 1		1	1		1	1
Correlatio	n Weight Se	tting								
						Default		Load	Sa	ve as
device	TU	nos_vthlin	& nm	os_idsat & p.	nmos	_vthsat &	٤	nmos_id	lin & p	••••
■_1.8E-7_1	_		1		1			1		1
*_2E-6_1_1			1		1			1		1
*_1E-5_1_1			1		1			1		1
			1					1		1
*_1.8E-7_1			-		1			-		-
_2E-6_1_2	E-6		1		1			1		1
	E-6		-		-			-		-
*_2E-6_1_2 * 1E-5 1 2	E-6	ng	1		1			1		1
*_2E-6_1_2 * 1E-5 1 2	E-6 E-6	ng	1		1			1	Sa	1
*_2E-6_1_2 * 1E-5 1 2	E-6 E-6	sig	1 1 1	parameter	1 1 step	mi	In	1 1 Load	Sa ax	1
*_2E-6_1_2 * 1E-5 1 2 Model Para	E-6 E-6 meter Settin	sig	1 1 ma 1	- th0_stanm	1 1 step	mi	n	1 1 Load		1
*_2E-6_1_2 * 1E-5 1 2 Model Pars random par1 par1	E-6 E-6 meter Settin	5 5 sig 0 0	1 1 ma 1 v	- th0_stanm th0_stapm	1 1 step	mi	n	1 1 Load		1
*_2E-6_1_2 * 1E-5 1 2 Model Para random par1 par1 par1	E-6 E-6 meter Settin	0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1	- th0_stanm th0_stapm 0_stanmos_k1	1 1 step	mi	n	1 1 Load		1
*_2E-6_1_2 * 1E-5 1 2 Model Para random pari pari pari pari pari	E-6 E-6 meter Settin	0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	- th0_stanm th0_stapm d0_stanmos_k1 d0_stapmos_k1	1 1 step	mi	n	1 1 Load		1
<pre>*_2E-6_1_2 * 1E-5 1 2 Model Para random par1 par1 par1</pre>	E-6 E-6 meter Settin	0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	- th0_stanm th0_stapm 0_stanmos_k1	1 1 step	mi	n	1 1 Load		1

Model Parameter Setting

The table has two forms depending on the input model format.

- Library model, the table is as below:

] 👂	C		
		Glo	bal Model Gen	neration					
Target Weig	ght Setting								
				Defa	ult Lo	ad Save	as		
device	nmos v pm	os v nonos i	pmos_i	nmos v pm	os v numos	i pmos i.			
w 1.8E	1	1	1 1	1	- 1	1	1		
w_2E-6	1	1	1 1	1	1	1	1		
w_1E-5	1	1	1 1	1	1	1	1		
w_1.8E	1	1	1 1	1	1	1	1		
w_2E-6	1	1	1 1	1	1	1	1		
w 1E-5	1	1	1 1	1	1	1	1		
	5E-7	1		1	1		-		
w_1.8E-7_1_		1		1	1		1		
w_2E-6_1_2E w 1E-5 1 2E		1		1	1		1,		
	eter Setting			-		ad Save			
random	mean	sigma	parameter	step	min	max Save	as		
par1		0	1 vth0_stanm						
par1		0	1 vth0_stapm				-6		
par1		0	1 u0_stanmos_k1						
par1		0	1 u0_stapmos_k1						
par1		0	1 vsat_stanm						
par1		0	1 vsat stapm						
			- Flobal Model Gene	ration					

User need fill in this table with user-defined statistical model parameters and corresponding random parameters.

Parameters' mean and sigma value are "1" and "0" by default respectively. User can also assign parameter's step, min/ max value.

The configuration file can be save and load by "*Save as*" and "*Load*" button.

- If single model card is used, the table is as below:

] 💕	
			G10	bal	Model Ge	ener	ation	1				
Target Weight	Setting											
							Default			Load	S	ave as
device no	105_ v	pmos_v	nmos_i	i	pmos_i	nmos	5_ v	pmos_v	I	umos_i	pmos	i
w_1.8E	1	1	-	1	1		1	1	1	_	1	1
w_2E-6	1	1		1	1		1		1		1	1
w_1E-5	1	1		1	1		1		1		1	1
w_1.8E	1	1		1	1		1		1		1	1
w_2E-6	1	1		1	1		1		1		1	1
w 1E-5	1	1		1	1		1		1		1	1
w_2E-6_1_1.5E w_1E-5_1_1.5E			1			1			1			1
w_1.8E-7_1_2E			1			1			1			1
w_2E-6_1_2E-6			1			1			1			1
w 1E-5 1 2E-6			1			1			1			1
Model Paramet	er Setti:	ng								Load	S	ave as
type	P	arameter		step			min			max		
nmos	vt	h0										
pmos	vt	h0										
pinos												
nmos	u 0											
-	u0 u0											
nmos	u0											

User need fill in this table with parameters for tweaking, and specify parameters' corresponding polar type.

User can also assign parameter's step, min/max value.

The configuration file can be save and load by *"Save as*" and "*Load*" button. Click "*Global Model Generation*" button after completed all setups, then the global statistical model will be generated automatically.

SRAM Solution Operation Note

SRAM solution is an integrated solution in MBP for SRAM application. With this solution, the customer can check both SRAM and MOSFET device at the same time. All the details will be introduced in the following sections.

1. Load project

From the toolbar, click the File button and then select Project > Open...

File	Export	Model	Simulatio	n Extrac	tion	Opti	mizatic
	Project	•	New	Ctrl+N		٨	😹 (
	Data	1	Open	Ctrl+O			
	Model I		Reopen		•		
	Exit		Save Save As	Ctrl+S	-		
			Save Asia				

Select a project from the pop-up window. A demo example has been included at :\$MBP_home\demo\SRAM\sram.prj.

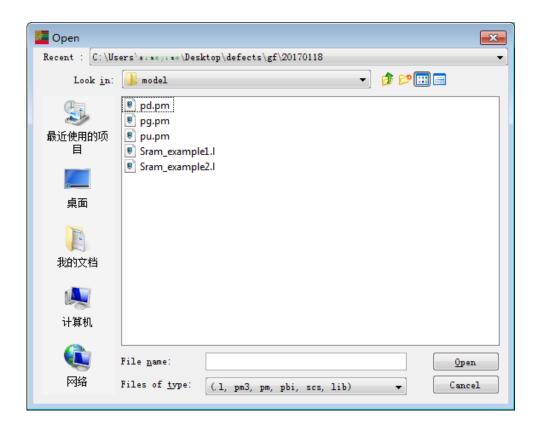
🚾 Open		EX
Recent : Look in		• • • • • • • • • • • • • • • • • • •
最近使用的项 目 原面 我的文楷	 data model normal_config_file sram sram.prj 	
计算机 计算机 网络	File name: Files of type: (,prj)	Open Cancel

2. Load model

Click Load Model button.



Then load the model from the browser window:



After model selection, a model mapping window will pop-up. Map the input model with the Template Model categorization correctly.

Model Mapping								
Models								
Click the table cell to edi	<u> </u>							
Template Model	Input Model	Device Type						
sram	icrit 📃	subckt						
pd	icrit	mosfet						
pg	xpd	mosfet						
pu	xpg	mosfet						
	xpu							
	pd							
	pg							
	pu							
	OK Cancel							

Actually, in SRAM application, any customer input model can be categorized as SRAM,pd, pg,pu (pull-down, pass-gate, and pull-up MOSFET), just like the "Template Model" column list.

In the example, "icrit" in the input model is the SRAM -kind model. With these mapping, it will ensure that MBP script draws and display the correct target plot.

3. Load data

Click the load data button.



Then the loading data window will pop-up.

Solution Information	
Data Model	
sram:	Load Clear
pd:	Load Clear
pg:	Load Clear
pu:	Load Clear
ОК	

Click the **Load** button to load data for every kind of model respectively, and it is ok to select more than one data file at the one time. Click the **Clear** button to empty the data you have selected. After these setting up, click the **OK** button to finish loading data.

4. Parameter tuning

Click model in the model navigator and select model parameters in the parameter navigator to tune like the following picture.

The selected model parameters will be displayed in the parameter panel, and different model's parameter will be set with different colors.



Click the button on the top of parameter panel (pd, pg, pu in the following picture). The selected model's parameters will put into the front of the panel.



5. Double simulation

Double simulation is a power function to check parameter's effect on the circuit or device performance.

Click Double Simulation from the menu.

File Export Mode	el (Simu	ulation Extraction C	ptimization	ιL	Itilities Tool Scri	pt H	elp I	Navigator			
« » 🗔		Simulator Simulate		•			*	× ×			
🔁 😚 Data:		Double Sim	Ctrl+F	2						💴 💱	₿
index		External SPICE Opti	ons				w				
 ✓ ✓ 					1.8E-7 1.2E-6						
		2.4E-7		5	1E-5						
V	✓ 5E-7 2				1.8E-7						
					1.2E-6					-	
Pages:										💴 😥	K

Select some parameters from the parameter navigator and tweak them. And in the plot, square point line is the measurement data, other two curves are simulation result. The solid line represents the simulation result from original parameter value, and dot line is for updated parameters' simulation result.

File Export Model Simulation Extraction Optimization Utilities Tool Script Help	Naviga	jator	
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🔁 😚 Data: 📼 💱 💱			6
index I t w	1	pd_plot(W/L=0.18/0.15,T=25@Vds=0.05)	os(V)
I.5E-7 25 1.8E-7			5000
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▲ Data ▲ → E ids_vgs_vbs@vds=0.05		2.23E-5	7500 3750
Vbs(V)=-1.5 Vbs(V)=-1.125			0000
	ds(A)	₹ 1.48E-5	
Vbs(V)=0 → E ds_vgs_vbs@vds=1.5	5	Se a	
vbs(V)=-1.5		7.43E-6	
Vbs(V)=-0.375 ↓ vbs(V)=0		0.00	
E Ids_vds_vgs@vbs=-1.5		0.00 0.41 0.82 1.23 1.65	
		Vgs(V) MAX:34.620%	
sram pd pg pu	Bro	rowser	
Solution		message available St	x
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Sram example 1	(ueff
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toxe 3.66-9 1.36-9 4.36-9 16-10			
	-		
Unspecified Parameters			÷ ×
			.
Parameters Message			

6. Model Compare

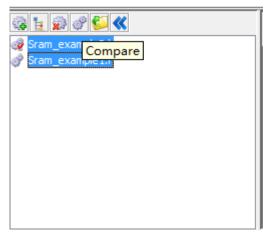
Model Compare can be used to compare two models which have same Electrical Target and different model parameter.

Firstly, click the Add Model button to add a new model into MBP.

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Add Model le2.I	ł
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Model Mapping		— ×
Models Click the table ce	ell to edit	
Template Model	Input Model	Device Type
sram	icrit	subckt
pd		🕳 mosfet
Pg	icrit	mosfet
pu	xpd	mosfet
	xpg	
	xpu	
	pd	
	pg	
	DK Can	cel

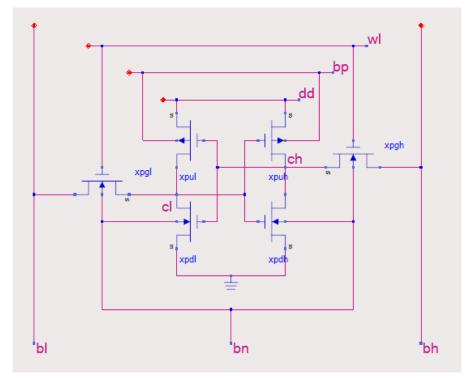
Select both models and click **compare** from the button.



Tweak some parameter to check plots.

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l 😚 C	Data:												🗢 😵 📢					HW/PGHL/PGLW/PGL WPGHL/PGLW/PGLLJ		
lex	pdhl	pdhw	pdl	pdlw	pghi	pghw	pgl	pglw	puhl	puhw	pul	pulw	t	2.	5/0.5/2.5/0	5/10/2/10/2/5/0.	5/5/0.5,T=-50@	@Vbn/Vbp/Vbh/Vbl/Vwl	Vdd=0/0.8/0.8/0.8	0.8/0.9)
V V	SE-7 SE-7	2.5E-6 2.5E-6	SE-7 SE-7	2.5E-6 2.5E-6	2E-6 2E-6	1E-5 1E-5	2E-6 2E-6	1E-5 1E-5	9E-7 5E-7	9E-6 5E-6	9E-7 9E-7	SE-6 SE-6	-50		2.74E-04			Veb=0.900	00.lbl=2.11426E	
1	5E-7	2.5E-6	5E-7	2.5E-6	2E-6	1E-5	2E-6	1E-5	5E-7	5E-6	5E-7	SE-6	25					VCII=0.800	00,01-2.114206	1
V	5E-7	2.5E-6	5E-7	2.5E-6	2E-6	1E-5	2E-6	1E-5	5E-7	SE-6	5E-7	SE-6	175							<i>9</i> ″
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Data																			2	
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E Id	el_Read@V	bn=0,Vbp=0	0.8,Vbh=0.8, 0.8,Vbh=0.8,	Vbl=0.8,Vwl	=0.8,Vdd=	1													. /	
															6.85E-05					
															0.002-00					
																		:/	·	
																		/		
															1.25E-12			/		
															0.	0	0.20	0.40	0.60	0.80
															0.	00 8MS:14.351%	0.20	0.40 Vch	0.60 MAX:2	
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m pt	d pg pu													Brows	0.	RMS:14.351%	0.20			
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tion ram_ icri pd pg	example 2.1	K			neral DW/	DL VTH MC	ne		Value	Temp C	p Diode Lower	RF NOISE	Stress WPE	Brows	0. ser ssage avails	RMS:14.351%	8 8 e	Vch	MAX:2-	5top
tion ram_i iori iori iori iori iori iori iori io	example 2.1	K		💡 Ger	neral DW/	Nan level vers	ne I ion	5	Value 14	Temp Ca	Lower	RF NOISE	Upper	Brows	0. rer ssage avala Step 0 0	RMS:14.351%		Vch	MAX:2-	5top
ition	example 2.1	K		💡 Ger	neral DW/	Nan	ne I ion	5	Value 14	Temp Ca	<u> </u>	RF NOISE		Brows	0. ser ssage availa V (m) Step 0	RMS:14.351%		Vch	MAX:2-	5top
tion ram_i iori iori pd pg pu ram_i iori	example 1.1	K		💡 Ger	neral DW/	Nan level vers	ne I ion	5	Value 14	Temp Ca	Lower	RF NOISE	Upper	Brows	0. rer ssage avala Step 0 0	RMS:14.351%		Vch	MAX:2-	5top
ition	example 1.1	K		💡 Ger	neral DW/	Nan level vers	ne I ion	5	Value 14	Temp Co	Lower	RF NOISE	Upper	Brows	0. rer ssage avala Step 0 0	RMS:14.351%		Vch	MAX:2-	5top

- 7. Appendix
 - a. 6T SRAM circuit



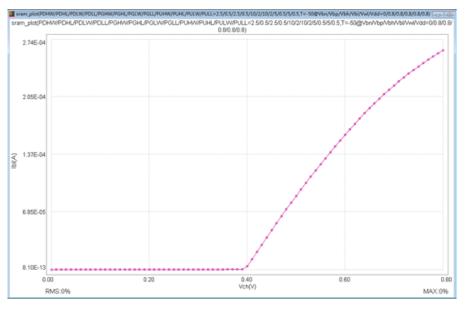
b. Mosfet name

pu: means "pull up"mosfet

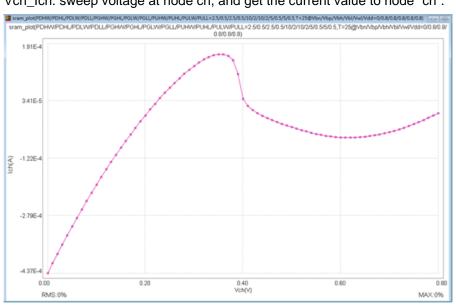
- pd: means "pull down" mosfet
- pg: means "pass gate" mosfet

c. Plot definition

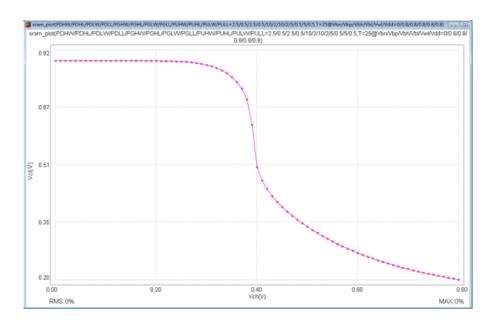
Vch_Ibl: sweep voltage at node "ch", and get the current value to node "bl".



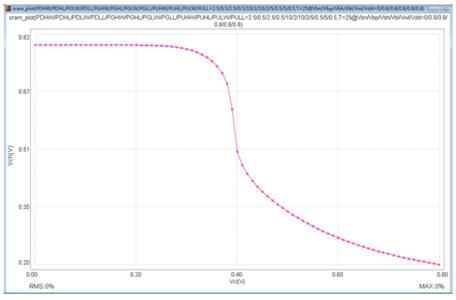
Vch_lch: sweep voltage at node ch, and get the current value to node "ch".



Vch_Vcl: sweep voltage at node ch, and get the voltage value at node "cl".



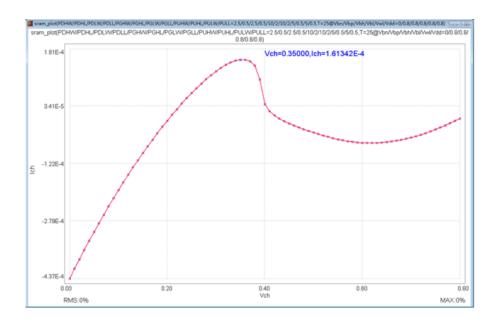
Vcl_Vch: sweep voltage at node cl, and get the voltage value at node "ch".



d. Target introduction

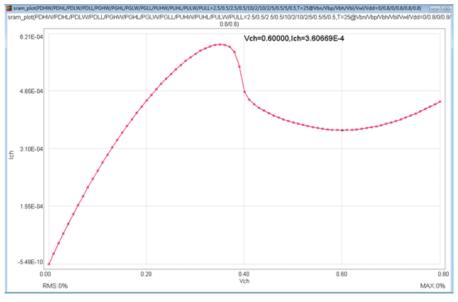
Icrit_RD[1]:

SRAM work at read mode (Vbh=vdd, Vbl=vdd), get the maximum current value at Vch_Ich plot, the graph displays this point's voltage and current value on Vch_Ich plot.



Icrit_WR[1]:

SRAM work at write mode (Vbh=0, Vbl=vdd), get the minimum current value which Vch'svalue is between 0.3*vdd and vddatVch_lch plot, the graph displays this point's voltage and current value on Vch_lch plot.



Butterfly plot and SNM target:

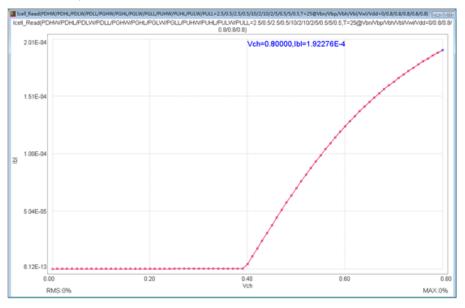
Butterfly plot: The Graph overlays the two plots Vch_Vcl and Vcl_Vch to one plot to get butterfly plot.

SNM target: static noise margin, the graph displays SNM's value on the butterfly plot.



Icell_Read[2]:

SRAM work at the read mode, get the maximum current value on Vch_Ibl plot, the graph displays this point's voltage and current value on Vch_Ibl plot.



Reference:

- 1. Critical Current (ICR1T) Based SPICE Model Extraction for SRAM Cell
- 2. CMOS SRAM Circuit Design and Parametric Test in Nano-Scaled Technologies

Statistical Model Extraction Module

General Introduction

MBP's statistical model extraction module is fully developed for generating SPICE model with Monte Carlo simulation capability, a capability of both local mismatch and global statistical. The module provides GUI-Based Turn-Key solution and its work-flow chart is like following:3

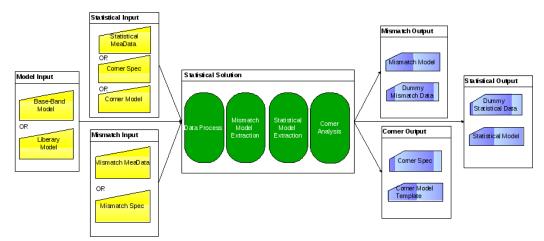


Figure 1: General work-flow chart

In the Module, it supports the following input:

Inputs for this solution

Mismatch Input:

For mismatch model extrication, select one of these two kinds input.

- 1. Mismatch Measurement Data.
- 2. Mismatch Spec, dummy mismatch data will be generated from these specifications and replace the measurement data for mismatch model extraction.

Statistical Input:

For statistical model extrication, select one of these three kinds input.

- 1. Total Measurement Data;
- 2. Corner Spec, dummy statistical data will be generated from these corner spec and replace the measurement data for the statistical model extraction;
- **3.** Corner Model, the statistical model could be generated directly from this corner model;

Model Input:

- 1. Baseband Model, no statistical-equation has been integrated into model card and our solution will generate equations automatically;
- 2. Library Model, it has pre-defined statistical-equation in model card and our solution will tweak the equation's coefficients to match targets;

Output from this solution

With our solution, it can get all kinds of output in the mismatch/statistical model extraction.

Mismatch Output:

- 1. Mismatch Model;
- 2. Generated dummy mismatch Data;
- 3. Mismatch Plot

Statistical Output:

- 1. Statistical Model;
- 2. Generated dummy statistical Data;
- 3. Histogram/Distribution Plot
- 4. Scatter/Contour Plot
- 5. Scatter/Corner Plot

Corner output:

- 1. Corner Spec;
- 2. Corner Model Template;

Typical Application Examples

With proper setup, this solution could be applied widely for various cases. Following table lists some typical application examples. These examples could be good references for quick start. And all the technical details will be presented in following section.

Tab 1. Typical Application Examples

	Input	Solution	Output	Comments
1.	 Mismatch Measurement data; Statistical Measurement data; Baseband Model; 	1.Data Analysis; 2.Mismatch Model Extraction; 3.Statistical Model Extraction	1.Mismatch Model; 2.Statistical Model;	Don't need expertise on the statistical model extraction

	Input	Solution	Output	Comments
2.	1.Mismatch Measurement data; 2.Statistical Measurement data; 3.Liberary Model;	1.Data Analysis; 2.Mismatch Model Extraction; 3.Statistical Model Extraction	1.Mismatch Model; 2.Statistical Model;	Flexible , and designed for specific applications
3.	1.Mismatch Spec; 2.Baseband Model;	1.Dummy Data generation; 2.Mismatch Model Extraction;	1.Dummy Mismatch Data 2.Mismatch Model;	Mismatch model extraction without real measurement data
4.	1.Corner Spec; 2.Baseband Model;	1.Dummy Data generation; 2.Statistical Model Extraction;	1.Dummy Statistical Data 2. Statistical Model;	Statistical model extraction without real measurement data
5.	1.Corner Model; 2.Baseband Model;	1.Dummy Data generation; 2.Statistical Model generation directly;	1.Dummy Statistical Data 2. Statistical Model;	Generate statistical model from corner model directly

Work Flow

Load Project

Load Statistical Project from MBP's demo folder, Select Navigator > Statistical Model Extraction Panel.

Working Flow		mulation Extraction Optimization Utilities Tool Script Help Navigator	Save Import
ListTree	Confg Setup Data Analysis Model Centering Local Model Global Model Corner	Config	Working Space
Message Window		cocal Global Optimization Itermax: Tot: Sec-4 Represent ter: Itermax:	<

Config

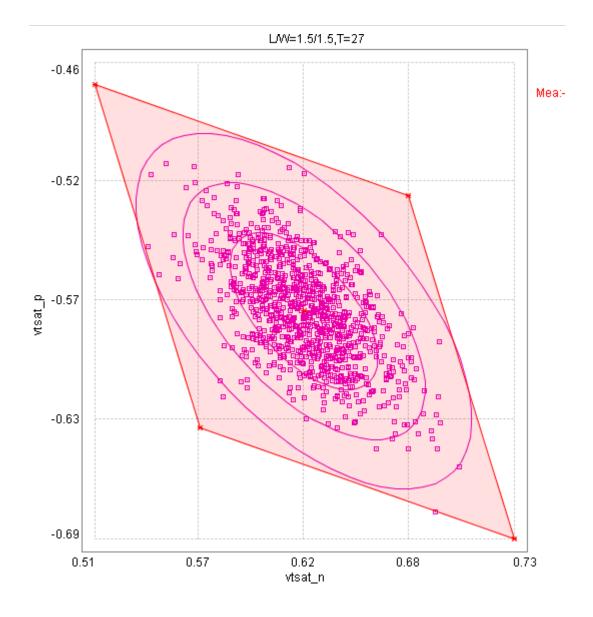
In this window, user can configure the system parameters.

	Config
Config	Simulation Sim Method: Normal-MC Simulation
Setup	
Data Analysis	Parameter Corner/Statistical Scale: 1.3
Model Centering	PCA Number: 3
Local Model	Debug
Global Model	Debug Mode
Corner	Local Global
	Optimization
	Itermax: 2000
	Tol: 5e-4
	Regression Iter: 1
	Mode
	Mode Method: 1-Fast Mode 👻

Simulation: Switch between 3 simulation methods

Normal-MC:	General Monte Carlo simulation, high accurate;
RSM Simulation:	Response surface method simulation, fast speed;
FMC Simulation:	Monte Carlo simulation with linear approximation, fast speed;
Parameter:	
Corner/Statistical Scale:	It is a parameter to define ration scale between corner and statistical; please take table2. 1 as reference;
PCA Number:	It is order number in Principal Component Analysis; Just like following example.

Tab 2. corner/statistical scale



Corner/Statistical Scale=1

Debug Mode:

Debug If Debug Mode is open, the extraction detail information will be printed to the log file for the trouble-Mode: shooting. Usually, the log file is saved to the project_path\ statistical\output\log\statdebug.txt

Local Optimization Parameters: optimization parameters' setting for local model extraction

Itermax:	Max iteration times in optimization ;
Tol:	Target tolerance for optimization convergence criterion;
Regress Iter:	Iteration times for regression calculation;

Local Extraction Method:

Fast Mode: Use linear algorithm for mismatch model extraction, fast speed;

Normal Mode: Use general optimization for mismatch model extraction;

Global Optimization Parameters: optimization parameters' setting for global model extraction

Itermax:	Max iteration times in optimization ;		
Tol:	Target tolerance for optimization convergence criterion;		
Regress Iter:	Iteration times for regression calculation;		
Global Extra	action Method:		
Fast Mode:	Use linear algorithm for statistical model extraction, fast speed];	

Accurate Mode:	Use advanced optimization for statistical model extraction;
Advanced Mode:	Use advanced optimization for statistical model extraction, and user can set optimize-weight for nonlinear characters;
Corner Input Mode:	Input corner model and generate statistical model directly;

Mismatch/Statistical Target Define

Before model extraction, it should be make sure all mismatch and statistical targets have been defined in MBP correctly. MBP has defined some default targets and user also can define customized mismatch or statistical target with script.

Mismatch Target

Select from menu Script > Script Project, MBP Script Windows will pop. Select Default > imv > mismatch in the left panel, right click and select new > mismatch to define new mismatch targets.

MBP Script		_	-			
File Edit Debug						
🗳 📙 🛃 🕨	•	10	,] 🕜 [8	
Project Debug	imv.	misma	atch.ids 🛛 📄 i	imv.imv_con	ist 🔀 📄 imv.mismatc	hx <
🕈 Project	🔺 🔽 Cust	omize	Cache Options		🔽 Enabled Cache	
📄 🕂 🛉 default	Data wi	ill be c	outdated after:			
commands	🗸 🗸 🗸 Dat	a load	ded/removed	Model loa	ded/remo	
🛛 🖓 data 🖓 Flow						
init	=					
acc						
imv 						
imv						
imv_const						
		•	Dealasas	1		
		- · ·	Package			
	Data Table		Data			
Renan	ne	Ø	Mismatch			
Copy		Ø	Group			
Root IMV Flow Dat Paste			Graph			
Description Delete	,	J °	File		Location	
Brows	e			-		
	_					

Set the new target's name in the popped window, and it can be edit in the right panel. How to edit target in MBP Script can reference MBP's help on IMV setting.

MBP supports both absolute and relative difference for mismatch targets.

DP Type			
Expression	👽 Java Algorithm	Script Algorithm	
Page Name:	Ids_vgs_vbs		•
Algorithm Class:	acc/VTH_GM		•
Algorithm Parameters:	vgs,ids,vds		
	Name	Value	*
	vgs	[start=0;stop=vgs;step=0.01]	
	vds	vds	
	vbs	0	
Mismatch Expression:	📝 Absolute 🥅 Relative 🥅 Customize		
	t1-t2		
Use Internal Algorithm			

DP Type			
Expression	📝 Java Algorithm	Script Algorithm	
Page Name:	Ids_vgs_vbs		-
Algorithm Class:	acc/Current		•
Algorithm Parameters:	ids		
	Name	Value	*
-	vgs	vgs	
Deventered	vds	vds	
Page Name: Algorithm Class: Algorithm Parameters: Parameters: Mismatch Expression:	vbs	0	
	Absolute 🔽 Relative 🦳 Customize		
	2*(t1-t2)/(t1+t2)		
	L		

Mismatch Expression: Absolute and Relative

Statistical target

Select from menu Script > Script Project, MBP Script Windows will pop. Select default > imv > stat in the left panel, right click and select new > Statistic to define new statistical targets.

MBP Script	1				
File Edit Debug					
			(2)		
Project Debug					
acc	*				
imv → ⊕ imv → ↔ dp → ↔ imv → ↔ imv_cor ⊕ → ↔ mismate	:h				
	New 🕨	Package	7		
	Show Data Table	📔 Data			
	Rename	📔 Statistic			
	Сору	😚 Group			
	Paste	🗐 Graph			
	Delete	🧊 File			
	Browse				
Calculat → ⊕ calculat → ⊕ sys Root IMV Flow Data					
Description		Resource		Location	

Set the new target's name in the popped window. It can be edit in the right panel. How to edit target in MBP Script can reference MBP's help on IMV setting.

Setup

In "Setup" step, user will setup the input information. Three parts of this step:

- Total Data (refer to statistical data)
- Local Data (refer to mismatch data)
- Input Model

Total Data

User can select one from these three options

- Generate Data From Measurement

Total Data © Generate Data From Measurement	
Cenerate Data From Measurement	
🔘 Generate Data From Corner Model	
Measurement DTMOS: Browse	
PMOS: Browse	
	-
Update	

NMOS: Click the browse button to select measurement data for nmos;

PMOS: Click the browse button to select measurement data for pmos;

- Generate Data From Corner Data

Generate dummy statistical data from input corner data. The Corner/Statistical Scale parameter will be used in the dummy data generation.

Total Data Local Data Input Model			
Total Data			
🔘 Generate Data From Measurement			
◎ Generate Data From Corner Data			
🔘 Generate Data From Corner Model			
Corner Data			
NMOS: C:\Temp\corner_model\cornerdata\nmos	Browse		
PMOS: C:\Temp\corner_model\cornerdata\nmos	Browse		
Corner Model			
◯ With the default model as input			
Input Model			
Path: C:\Iemp\corner_model\mos_6v.lib	Browse		
Lib Name: FF, SS, FS, SF, TT			
Lib names should be in this order:FF,SS,FS,SF,TT, and separated by ',			
Nmos Name: nmos Pmos Name: pmos			
Update			

Corner Data: the corner data file contains corner spec information;

NMOS: Click the browse button to load corner nmos data file;					
PMOS: Click the brows	se button to load corner pmos data file;				
Corner Model: is not used for the model extraction, only for simulation result plot					
With the default model as input:	If customer has no their own corner model, MBP's default corner model will be used in the following work;				
Input Model:	Click browse button to select corner model;				
Corner Model Names:	Corner models name for FF, SS, FS, SF, TT, and separated by comma;				
NMOS Name:	nmos model name				
PMOS Name:	pmos model name				

- Generate Data From Corner Model

Generate dummy statistical data from input corner model's simulation result. The "Corner/Statistical Scale" parameter will be used in the dummy data generation.

Setup				
Total Data Local Data	a Input Model			
Total Data				
🔘 Generate Data Fr	om Measurement			
🔘 Generate Data Fro	Generate Data From Corner Data			
Generate Data From Provide Contract	om Corner Model			
Targets Devices				
Polar	Target	Biases		
nmos	vth_gm	vds = 0.1,vbs = 0.0,vgs = 1.5		
pmos	vth_gm	vds = -0.1,vbs = 0.0,vgs = -1.5		
nmos	idsat	vds = 6.0,vbs = 0.0,vgs = 6.0		
pmos	idsat	vds = -6.0,vbs = 0.0,vgs = -6.0		
Update				
	Opus			

Targets: statistical target definition

Polar: nmos or pmos;

Target: Targets Name;

Biases: bias condition for this target;

Setup						
Total Data	Local Data	Input Model				
Total Data						
Generat	e Data From	Measurement				
Generat	e Data From	Corner Data				
Generat	e Data From	Corner Model				
Targets [Devices					
polar		w				
n&pmos		1.0	2.0			
Update						

		Set	up		
Total Data Local D	Data Input Model				
Total Data					
🔘 Generate Data	🔘 Generate Data From Measurement				
🔘 Generate Data	From Corner Data				
Generate Data	From Corner Model				
Targets Devices	9				
			las de las		
polar	w		corindex		
nmos	1.0	2.0	1.0		
pmos	0.6	1.8	1.0		
L					

Devices: definition for devices instance parameters (w, I, temp, etc.)

Polar: nmos or pmos or n&pmos;

If select n&pmos, it means a pair of devices (both nmos and pmos) will be defined whose w=1 and l=2 as above picture.

the nmos and pmos which has the identical corindex value are a pair of devices, where w=1 and l=2 for nmos, w=0.6 and L=1.6 for pmos;

Local Data

- Get Data From Measurement

Setup	
Total Data Local Data Input Model	
Local Data	
Generate Data From Measurement	
🔘 Generate Data From Spec	
Measurement	
IMOS: C:\TEMP\mc_data\MISDATA\rumos.mea Browse	
PMOS: C:\TEMP\mc_data\MISDATA\pmos.mea Browse	
Update	

Measurement

NMOS: Click browse button and select nmos mismatch measurement data;

PMOS: Click browse button and select Pmos mismatch measurement data;

- Generate Data From Spec

Generate dummy mismatch data from the information in the following table.

		Setup	
otal Data Local	Data Input Model		
Local Data			
🔘 Generate Data	a From Measurement		
Generate Data	From Spec		
Local Spec			
Targets Devic	es		
Polar	Iarget	Biases	Expression
unos	vthlin	vds = 0.1, vbs = 0.0	x*0.02+0.01
pmos	vthlin	vds = -0.1, vbs = 0.0	x*0.02+0.01
		Update	

Targets: mismatch target definition

Polar:	nmos or pmos;
Target:	targets name;
Biases:	bias condition for this target;
Expression:	Target's sigma value= a*x + b; where, x=1/sqrt(w*1); a is slope coefficient; b is intercept value; we will use this express to calculate target value for every devices defined in "Devices" tab

		Setup	
Iotal Data Local	l Data Input Model		
Local Data			
🔘 Generate Data	a From Measurement		
Generate Data	a From Spec		
Local Spec Targets Devic	es		
polar	w	1	
n&pmos	1.0	2.0	
		Update	

fotal Data Lo	cal Data Input M	odel		
Local Data				
🔘 Generate D	ata From Measurem	ent		
Generate D:	ata From Spec			
Local Spec Targets Dev	rices			
polar	w	1	corindex	
num os	1.0	2.0	1.0	
pmos	0.8	1.6	1.0	
		Up da	ite	

Devices: definition for devices instance parameters (w, l, temp, etc.)

Polar: nmos or pmos or n&pmos;

If select n&pmos, it means a pair of devices (both nmos and pmos) will be defined whose w=1 and l=2 as above picture.

the nmos and pmos which has the identical corindex value are a pair of devices, where w=1 and l=2 for nmos, w=0.8 and L=1.6 for pmos;

Input Model Information

MBP statistical module accepts either model library or single model card.

				Setup		
Total Data Loca	al Data	Input Model				
Input Model						
Lib File						
Lib Path:						Browse
Lib Name:						
NMOS Name:			PMOS Nan	ne:		
Stat Flag:			Mis Fla	ag:		
🔘 Model File						
NMOS File:	C:\Tem	np\powerchip\	base_model\b	ase_nmos.l		Browse
PMOS File:	C:\Ter	np \powerchip	base_model\b	ase_pmos.l		Browse
NMOS Name:	nmos_	6v	PMOS Nan	ne: pmos_6v		
			[Update		

Lib File: By using model library, please input library path, library name, NMOS model name, PMOS model name, stat flag, mis flag.

Lib Click browse button, and select the library model; Path:

Lib Library's name; Name:

NMOS Name:	nmos name							
PMOS Name:	Pmos name	;						
Stat flag:	example, w	parameter in the mod e set <i>Stat flag</i> as "staf arameters disabled.						
	The switch	parameter in the mod	del card, to sv	witch <i>on/off</i>	the mism	atch ca	bability	
Mis flag:	example we	set <i>Mis flag</i> as "misfl arameters disabled.	lag", if misflag	g=1, all misr	natch par	ameter	s works,	if misflag=0, a
flag: Model	example we mismatch p	set <i>Mis flag</i> as "misfl arameters disabled. sing baseband n						
flag: Model	example wa mismatch p File: By u pmos nar	set <i>Mis flag</i> as "misfl arameters disabled. sing baseband n	nodel, ple	ase input	t nmos			
flag: Model name,	example wa mismatch p File: By u pmos nar File: Clio	set <i>Mis flag</i> as "misfl arameters disabled. sing baseband n ne.	nodel, ple	ease input	t nmos nodel;			
flag: Model name, NMOS I	example wa mismatch p File: By u pmos nar File: Clio	set <i>Mis flag</i> as "misfl arameters disabled. sing baseband n ne. < browse button, and	nodel, ple	ease input	t nmos nodel;			

In the setup, all generated data can be found at "project_folder\statistical\data".

Data Analysis

There are five steps in this section, four of them are optional.

Data Pruning

This option is to eliminate the data points beyond 3-sigma.

Data Sampling

This option is to minimize the data with "Group Size". For example, if "Group Size" is set to 10, MBP will select data every ten sites. If the entire data amount is too huge, user can speed up the progress by using this option.

Global Data Generation

This option is to generate global data from total and local data.

Mean Value Check

In case measurement total data's mean value is not equal to simulation total data's mean value, user could use this option to do data tweaking. Two methods for the tweaking:

- *Tweak model*: Tweak the baseband model to fit the measurement, user need go to next step "Baseband Model" to select parameters for tweaking.
- *Tweak measurement total data*: MBP will adjust measurement data to fit model simulation. The tweaked data will be used in following steps.

Create Mismatch Dummy Data

This step is to create mismatch dummy data:

- The dummy data is a straight line, replace the original point data.
- User can choose the straight line through origin point or not before the dummy data generation.
- The dummy data line will be the optimization target during following steps; it can give better trend fitting result than original data points.

Click "Generate Data" button after all the steps to execute data dispose. In the Data Analysis, all generated data can be found at "project_folder\statistical\data".

Re-centering

Re-centering is used when "Tweak model" is selected at "Mean Value Check" steps, if user select "Tweak data to fit model", user could skip this step. The step is used to select parameters for model tweaking, as below.

			Mo	odel Re-cen	tering				
Target Weight	Setting								
						Default		oad	Save as
device	nmos_vthsat	pmos_vthsat	nmos_idsat	pmos_idsat	nmos_vthlin	pmos_vthlin	nmos_id	lin pr	nos_idlin
w_1.8E-7_l		1	1	1	1	1		1	1 🔺
w_2E-6_l_1	1	1	1	. 1	1	1		1	1
w_1E-5_l_1	1	1	1	. 1	1	1		1	1 =
w_1.8E-7_l		1	1	. 1	1	1		1	1
w_2E-6_l_2		1	1	. 1	1	1		1	1
w_1E-5_l_2	1	1	1	. 1	1	1		1	1 -
type	P	arameter	ste	p	min		ma	ax	
nmos		h0	540	P				- AA	
pmos		h0							
pinos		10							
			I		I				
			Base	Band Model Ge	neration				
			0030						

Target Weight Setting

Click "Default", a weight table will appear. The left side of the table is device column, the upside of the table is target row, and all the default weights are set to 1.0.

User can set one value to the entire column or the entire row. By set the first

column (or the first row)'s weight and then right-click on this column (or row) select "Set value to the whole column" or "Set value to the whole row". User can load pre-defined configuration file by "Load", also can save the configuration file by "Save as".

Model Parameter Setting

Fill in the parameters for model tweaking in this table, together with parameter's type ("nmos" or "pmos"), step, min/max value. Pre-defined configuration file can be loaded by "*Load*". A new configuration file can be saved by "*Save as*". Click " *Baseband Model Generation*", then the model will be tweaked automatically to fit measurement data

In the Re-Centering, the model can be found at "project_folder\statistical\output\baseband".

Local Model

Local Model contains two parts:

- Target Weight Setting
- Model Parameter Setting

			Loca	l Model Gen	eration		
	Target Weight S	Setting					
nfig					Default	Load	Save as
up							
alysis	device	nmos_Idsat	pmos_Idsat	nmos_vth_gm	pmos_vth_gm	nmos_Idsat1	pmos_Idsat1
	w_4E-7_l_6E-7		1 1	1	1	1	1
וור	w_1E-6_l_6E-7		1 1	1	1	1	1
20	w_2E-6_I_6E-7		1 1	1	1	1	1
	w_5E-6_1_6E-7		1 1	1	1	1	1
511	w_1E-5_l_6E-7]	1 1	1	1	1	1
Model	Model Paramete	r Setting	1 1	1	1	Load	1
	Model Paramete	r Setting				Load	1 Save as
	Model Paramete	r Setting parame		n 1	min		1
]	Model Paramete	r Setting				Load	1 Save as
	Model Paramete type nmos	parame vth0				Load	1
	Model Paramete type nmos nmos	r Setting parame vth0 u0				Load	1 Save as
	Model Paramete type nmos nmos nmos	parame vth0 u0 vsat				Load	1 Save as

Target Weight Setting

You can load your pre-defined configuration file by clicking "Load". And you can save the configuration file by clicking "Save as".

Target Weight S	Setting			Default	Load	Save as
device	nmos_Idsat	pmos_Idsat	nmos_vth_gm	pmos_vth_gm	nmos_Idsat1	pmos_Idsat1
w_4E-7_I_6E-7	1	1	1	1	1	1 🔺
w_1E-6_ _6E-7	1	1	1	1	1	1
w_2E-6_l_6E-7	1	1	1	1	1	1
w_5E-6_l_6E-7	1	1	1	1	1	1
w_1E-5_l_6E-7	1	1	1	1	1	1
w_4E-7_l_1E-6	1	1	1	1	1	1 🔻

Model Parameter Setting

Two different table formats will appear depend on what format of model we start with: model library or single model card.

For model library, the table shows as below:

Model Parameter Setting Load Save as										
random	mean	sigma	parameter	step	min	max				
misrad_misnmos1	0	1	vth0_misnmos_k0							
misrad_misnmos2	0	1	u0_misnmos_k0				1			
misrad_misnmos3	0	1	toxe_misnmos_k0				Ξ			
misrad_mispmos4	0	1	vth0_mispmos_k0				1			
misrad_mispmos5	0	1	u0_mispmos_k0				1			
misrad_mispmos6	0	1	toxe_mispmos_k0				Ŧ			

Fill in this table with user-defined mismatch model parameters and corresponding random parameters, the mean and sigma value of the parameter are "1" and "0" by default respectively.

Setup your model library as the MBP's demo example. Below are some useful tricks in the model parameter setting:

- Add ":" after parameter name, it means this parameter's input value will be the initial value for next step
- Add "=" after parameter name, it means this parameter's value will always keep constant
- If the input lib is complex, and the relation between the random and parameter is not very clear, please add "?" at first line and add the tuning parameters in the following lines.

If single model card is used, the table is as below:

Model Paramete	Load Save a	as			
type	parameter	step	min	max	
nmos	vth0				
nmos	u0				
nmos	vsat				=
nmos	a0				
nmos	ags				
pmos	vth0				

The table is very similar to "Baseband Model". User need fill this table with parameters for tweaking, and specify parameters' polar type; polar type can be "NMOS" or "PMOS". User can also assign parameter's step, min value and max value.

After setting up all the target weights and model parameters, click "*Local Model Generation*" button, then the mismatch model will be generated automatically.

Key points in the local model extraction

Firstly, selecting right parameters for the local model extraction is most important. Parameter selection depends on the mismatch targets and device's dimension. If simulation result is failed to converge, please reset parameter's min/max value and try again.

Secondly, set weight matrix to tradeoff between different optimize targets. Finally, switch extraction methods or tweak optimization parameter to help optimization converge at better result.

Moreover, open debug mode and read log file can help trouble-shooting. The extracted local model can be found at "project_folder\statistical\output\local".

Global Model

Before go to this step, make sure "Data Dispose" is done. This section is used to generate global statistical model automatically. Three steps to complete a "Global Model" table:

- Target Weight Setting
- Correlation Weight Setting
- Model Parameter Setting

Target Weight Setting

User is suggested to use the default setting by click "*Default*" button. Different weight can be set to different target, MBP will put more effort on the target with high weight Configuration file can be saved and load by "*Save as*" and "*Load*" button.

Correlation Weight Setting

If both NMOS and PMOS data is loaded within one extraction progress, user are enabled to set weight for NMOS and PMOS correlation.MBP put more effort to the correlation with higher weight, may have better fitting accuracy normally.

Model Parameter Setting

The table has two forms depending on the input model format. Library model, the table is as below:

Model Parame	ter Setting					Load	Save as
random	mean	sigma	parameter	step	min	max	
par 1	0	1	vth0_stanmos_k1	[
par 1	0	1	vth0_stapmos_k1				
par 1	0	1	u0_stanmos_k1				
par1	0	1	u0_stapmos_k1				
par 1	0	1	vsat_stanmos_k1				
par1	0	1	vsat_stapmos_k1				-

User need fill in this table with user-defined statistical model parameters and corresponding random parameters. Parameters' mean and sigma value are "1" and "0" by default respectively. User can also assign parameter's step, min/ max value. The configuration file can be save and load by "*Save as*" and "*Load*" button. If single model card is used, the table is as below:

Model Paramete	r Setting		Cru	eate Load	Save as
type	parameter	step	min	max	
nmos	vth0				
pmos	vth0				
nmos	u0				=
pmos	u0				
nmos	vsat				3E3
pmos	vsat				1E4 `

User need to fill in this table with parameters for tweaking, and specify parameters' corresponding polar type. User can also assign parameter's step, min/max value. The configuration file can be saved and load by "Save as" and "Load" button.

- Click "*Global Model Generation*" button after completed all setups, then the global statistical model will be generated automatically. There are some different algorithm will be used when the global model generation.
- 1. a. No device is selected in the target weight setting table

All devices will be taken into account in the statistical model extraction. And "global" statistical model will be extracted.

1. a. If only one device is selected in the target weight setting table

Only selected device will be taken into account in the statistical modeling extraction. And "point" statistical model will be extracted.

1. a. All devices are selected in the target weight setting table

All extracted "point" statistical model will be merged into a "global" statistical model

The extracted statistical model can be found at "project_folder\statistical\output\global".

Key points in global model extraction

Firstly, selecting right parameters for the global model extraction is most important. Parameter selection depends on the statistical targets and device's dimension. If simulation result is failed to converge, please reset parameter's min /max value and try again.

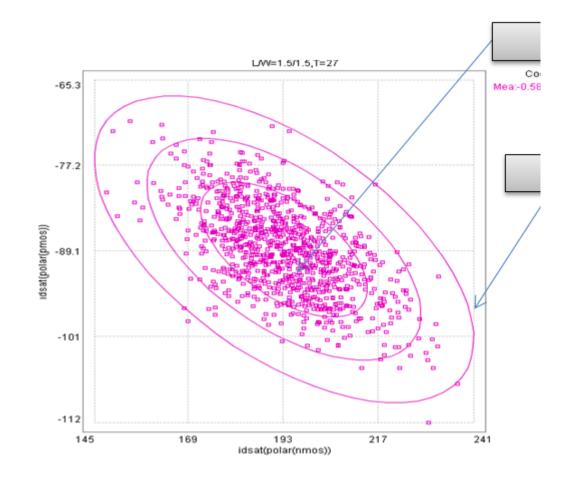
Secondly, set weight matrix to tradeoff between different optimize targets. Finally, switch extraction methods or tweak optimization parameter to help optimization converge at better result. For example, user can select one device and extract point model one by one. It is a good way to find the cause for the problem. Moreover, open debug mode and read log file can help trouble-shooting. Ps: how to de-select the device? Please press "ctrl" button and right click mouse to de-select the specific devices.

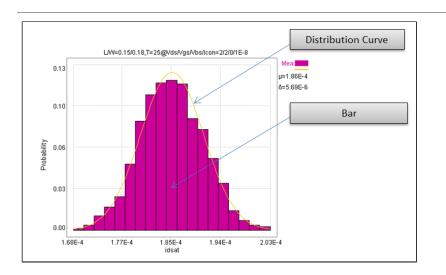
Graph Configure

Statistical Graph Configure

Select from menu Tool > GUI Options > Statistical Graph Config, and a setup window is popped.

Statistical Graph Config			×
Scatter pages			
Pages			
vthlin polar(nmos)_Scatter_			
idsat polar(nmos)_Scatter_i	X Scale:) 🚽
vthsat polar(nmos)_Scatter idlin polar(nmos)_Scatter_id	Y Scale:	✓ polar (pmos)	
Idin [polar (rimos)_scatter_i			
		Add Page	
		Del Page	
	Couple with a	corindex	
Set to default			
Contour			
Contour Styles:	Outline	▼ ▼ Set to default	
Contour orylest	Codume		
Contour Number:	5	 Set to default 	
Color			
Histogram			
_		Cat to default	
Draw Distribution		V Set to default	
Bar Styles:	Fill	 Set to default 	
Bin Number:	20 Split Sepa	arately 🛛 Set to default	
🔲 Shift Mean to Zero			
Mismatch			
Mismatch X: 1/sqrt(w*l*1e12))		
MC count			
Vs	e default number: 100	00	
	OK Cano	el	





Scatter Pages:

X Scale:

Target and polar selection for X-axial;

Y Scale:	Target and polar selection for Y-axial;	
Pages:	Click Add Page, the plot defined by X Scale and Select item in the Page List and click Del Page, list.	
Couple with corindex:	Nmos and Pmos device will be grouped by cori	ndex;
Contour:		
Contour Styles:	Contour Curve Plot Styles;	_
Contour Numbers:	Contour Curve number, default number is 5;	_
Color	Contour Curve Plot Color;	
Histogram:		_
Draw Distribution:	Draw theoretical distribution curve or not	
Bar Styles:		
Bin Number:	Bin Number in the histogram plot	
Shift Mean to Zero:		
Mismatch:		
Mismatch X: Calc	ulation expression for x axial in mismatch plot	_
MC Count:		
MC Count: The ra	andom numbers in Monte Carlo Simulation	

Scatter-Corner Graph Config

Select from menu Tool > GUI Options > Scatter-Corner Graph Config, and a setup window is popped.

Scatter-Corner G	raph Setting
Vth_Scatter_Idsat Ion_Scatter_Ioff	x y y p
ОК	Add Remove

- X: Target and Polar for X-axial
- Y: Target and Polar for Y-axial

Corner Analysis

Make corner analysis for the customer input to generate corner spec and corner model template.

Generate corner spec

Input Corner Spec
Generate From Global Variation
Generate From Total Variation

Generate corner spec from global variation data; Generate corner spec from total variation data;

Model parameter setting

Model parameter setting for corner model template generation.

type parameter step min max nmos vth0
pmos vth0

Demo Examples

Mismatch and Statistical model extraction from data – Baseband Model.

Open the project from

"MBP_home\demo\Statistical\GUIBasedSolution\mosfet\demo_case_baseband"

	Config
Config	Simulation Sim Method: Normal-MC Simulation
Setup Data Analysis Model Centering	Parameter Corner/Statistical Scale: 1.3
Local Model	PCA Number: 3
Corner	Debug Mode Local Global Optimization
	Itermax: 2000 Tol: 5e-4
	Regression Iter: 1 Mode Mode Method: 1-Fast Mode

a. Config 1.

Г

a. Setup 1.

The measurement for this demo case can be found "project_path\MISDATA" and "project_path\STADATA"

Setup
Total Data Local Data Input Model
Total Data
Generate Data From Measurement
🔘 Generate Data From Corner Data
🔘 Generate Data From Corner Model
Measurement IMOS: demo\\Statistical\\GUIBasedSolution\\mosfet\\demo_cas Browse PMOS: demo\\Statistical\\GUIBasedSolution\\mosfet\\demo_cas Browse
Update

1. a. Data Dispose

Data Statistical Analysis
Data Pruning
Delete the data beyond the 3 v sigma
Data Sampling
Select the data from group
Group Size: 1
Global Data Generation
🕼 Generate the global data from total and local data
Mean Value Check
Model Re-centering
Data Re-centering
Create Mismatch Dummy Data
Create Mismatch Dummy Data
Ihrough origin point
Not through origin point
Generate Data

Click the "Generate Data" for data dispose.

1. a. Local Model

			Local J	enerati	on					
Target W	eight Sett	ing								-
					Defaul	t 🗌	Load	a 🗌	Save a	s
device	nmos	pmos	nmos	pmos	nmos	pmos.		05	pmos	
w_1.8	1	1	1	1	1		1	1	1	
w_2E	1	1	1	1	1		1	1	1	
w_1E	1	1	1	1	1		1	1	1	
w_1.8	1	1	1	1	1		1	1	1	
w_2E	1	1	1	1	1		1	1	1	
w 1E	1	1	1	1	1		1	1	1	Ŧ
type	р	arameter	ste	ep	min		Load	max	Save a	<u>s</u>
nmos	vt	h0								
pmos	vt	th0								
nmos	u)								Ξ
pmos	սն)								
nmos	to	xe								
pmos	te	xe								Ŧ
			Local	Model Ge	neration					

Set target weight table and parameter table, and click "Local Model Generation" button to extract local model

1. a. Global Model

			GIO	bal J	Model Ge	ener	ation					
Iarget Weight	Setting						_					
								Default	Los	ad	Save	as
device nm	105_ v	pmos_v	nmos_i.	I	mos_i	nmos	_v	pmos_v	nmos_i		pmos_i	
_1.8E-7	1	1		1	1		1	1		1		1
_2E-6_1	1	1		1	1		1	1		1		1
_1E-5_1	1	1		1	1		1	1		1		1
_1.8E-7	1	1		1	1		1	1		1		1
_2E-6_1	1	1		1	1		1	1		1		1
1E-5 1	1	1		1	1		1	1		1		1
								Default	Los		Save	_
device		nos_vthlin &	pm	nmos_	idsat & pm		nmos_v	thsat & pm.	. nmos	s_idli	n & pm	•
_1.8E-7_1_1.5			1			1			1			1
_2E-6_1_1.5E-			1			1			1			1
_1E-5_1_1.5E-			1			1			1			1
_1.8E-7_1_2E-	6		1			1			1			1
_2E-6_1_2E-6			1			1			1			1
1E-5 1 2E-6			1									1
						1			1			
Model Paramete				sten		1	min		Los	ad	Save	as
type	pa	arameter		step		1	min			ad	Save	
type mos	ps vtl	arameter hO		step			min		Los	ad	Save	85
type mos mos	ps vtl	arameter hO hO		step		1	min		Los	ad	Save	
type mos mos mos	ps vtl vtl u0	arameter hO hO		step			min		Los	ad	Save	
	ps vtl	arameter hO hO		step			min		Los	ad	Save	

Set target weight table, correlation weight table and parameter table, and click "Global Model Generation" button to extract global model.

The generated dummy data and extracted model are saved in the "project_path\mosfet_demo_2\statistical";

Mismatch and Statistical model extraction from data - Model Library.

Open the project from

"MBP_home\demo\Statistical\GUIBasedSolution\mosfet\demo_case_library"

1. a. Configuration

	🤪 😫 🛃
	Config
Config Setup	Sim Method: Normal-MC Simulation
Data Analysis Model Centering	Parameter Corner/Statistical Scale: 1.3 PCA Number: 3
Local Model Global Model Corner	Debug Debug Mode
	Optimization Itermax: 2000
	Tol: 5e-4 Regression Iter: 1
	Mode Mode Method: 1-Fast Mode

1. a. Setup

The measurement for this demo case can be found "project_path\MISDATA" and "project_path\STADATA"

Setup
Total Data Local Data Input Model
Total Data © Generate Data From Measurement
 Generate Data From Corner Data Generate Data From Corner Model
Measurement ITMOS: demo\\Statistical\\GUIBasedSolution\\mosfet\\demo_cas Browse PMOS: demo\\Statistical\\GUIBasedSolution\\mosfet\\demo_cas Browse
Update

1. a. Data Dispose

Data Statistical Analysis
Data Pruning
Delete the data beyond the 3 💌 sigma
Data Sampling
Select the data from group
Group Size: 1
Global Data Generation
🕼 Generate the global data from total and local data
Mean Value Check
Model Re-centering
Data Re-centering
Create Mismatch Dummy Data
Create Mismatch Dummy Data
Ihrough origin point
🔘 Not through origin point
Generate Data

Click the "Generate Data" for data dispose.

1. a. Local Model

Target Weight Setting	1		LOCA	l Model Ger	neration				
	3								
					(Default	Load	Save as	s
device nmos_	Idlin pm/	os_Idlin	nmos_vthlin	pmos_vthlin	nmos_Idsat	pmos_Idsat	nmos_vt	pmos_vt	
w_1.8E-7	1	1	1	. 1	1	1	1	1	
w_2E-6_l	1	1	1	. 1	1	1	1	1	
w_1E-5_l	1	1	1	. 1	1	1	1	1	H
w_1.8E-7	1	1	1	. 1	1	1	1	1	-
w_2E-6_l	1	1	1	. 1	1	1	1	1	- H
w_1E-5_l	1	1	1	. 1	1	1	1	1	Ŧ
							Load	Save as	s
random me	an	sigma	a (parameter	step	min			S
	ean	sigma		parameter	step	min	Load		
misrad_misnmos1	an	0	1 v	th0_misnmos		min			S
misrad_misnmos1 misrad_misnmos2	ean	_	1 v 1 u		•	min			
misrad_misnmos1 misrad_misnmos2 misrad_misnmos3	ean	0	1 v 1 u 1 to	th0_misnmos 0_misnmos_k0		min			
random me misrad_misnmos1 misrad_misnmos2 misrad_misnmos3 misrad_mispmos4 misrad_mispmos5	2an	0 0 0 0	1 v 1 u 1 tc 1 v	th0_misnmos 0_misnmos_k0 pxe_misnmos		min			

Set target weight table and parameter table, and click "Local Model Generation" button to extract local model

1. a. Global Model

			Glo	bal Model Ger	neration				
Target Weigh	t Setting								
						Default	Load	Save a	s
device	nmos_vthlin	pmos_vthlin	nmos_idsa	t pmos_idsat	nmos_vt	pmos_vt	nmos_idlin	pmos_idlin	
w_1.8E-7	1	L 1	L	1 1	1	1	1	1	4
w_2E-6_l	1	L 1	L	1 1	1	1	1	1	
w_1E-5_l	1	L 1	L	1 1	1	1	1	1	Ξ
w_1.8E-7	1	L 1	L	1 1	1	1	1	1	-
w_2E-6_l	1	L 1	L	1 1	1	1	1	1	
w_1E-5_l	1	L 1	L	1 1	1	1	1	1	
device	n	mos_vthlin &	omos n	mos_idsat & pmos	nmos_v	thsat & pmos.	nmos_idlin	& pmos_idlin	
						Default	Load	Save a	2
device	n	mos_vthlin &	omos n	nos_idsat & pmos	nmos_v	thsat & pmos.	nmos_idlin	& pmos_idlin	
w_1.8E-7_l_1			1		1		1	1	1
w_2E-6_l_1.5			1		1		1	1	-11-22
w_1E-5_ _1.5			1		1		1	1	
w_1.8E-7_ _2			1		1		1	1	-11.
w_2E-6_l_2E-			1		1		1	1	-11.
w_1E-5_ _2E·	0		1		1		1	1	
Model Parame	eter Setting								
							Load	Save a	s
random	mean	sigm	a	parameter	step	min	Load		s
	mean	sigm 0		parameter	step	min			
par 1	mean		1	1.	step	min			
par1 par1	mean	0	1	vth0_stanmos	step	min			
par 1 par 1 par 1	mean	0	1	vth0_stanmos vth0_stapmos	step	min			
random par1 par1 par1 par1 par1 par1	mean	0	1 1 1 1	vth0_stanmos vth0_stapmos u0_stanmos_k1		min			s

Set target weight table, correlation weight table and parameter table, and click "Global Model Generation" button to extract global model.

The generated dummy data and extracted model are saved in the "project_path\mosfet_demo_2\statistical";

Statistical model extraction from corner spec

Open the project from

"MBP_home\demo\Statistical\GUIBasedSolution\mosfet\demo_case_cornerspec"

1. a. Config

		Config	
Confia	lation im Method: Normal-MC Simulati	on 🔹	
-	meter Corner/Statistical Scale:	1.3	
Model Centering	PCA Number:		
Local Model Debu	P		
	ebug Mode		
	Global		
Opti	Itermax: 2000		
	Tol: 5e-4		
	Regression Iter: 1		
Mod	e de Method: 1-Fast Mode	•	

1. a. Setup

The demo corner data for this example can be found at "mbp_folder\demo\Statistical\GUIBasedSolution\mosfet\demo_case_fromcornerspe

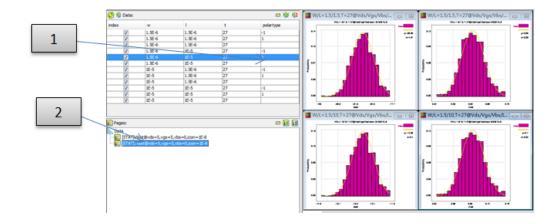
Click setup button, dummy statistical will be generated. And the new generated dummy data can be checked from the plots. Switch to the "Statistical" tab,

Device Navigator Statistical Model Extraction Panel Statistical

]		
	🔁 📦 Data: index				= 🕸 🚯		Annual Train		UNIT BIATUR
	index 🔽	w 1.5E-6	1.92-6	t 27	polartype				
	×	1.92-6	1.92-6	27	1				
	4	1.52-6	1.52-6	27	-		Real Dra		and los and the
	1	1.5E-6	1E+5	27	-1	Ι	Contraction of the local division of the loc		
	v	1.92-6	第-5 第-5	27	1	3.00	Re-		
-	2	1.32-0	1.52-6	27	-4	3.	2.		
	v .	12-5	1.92-6	27	1		Louis Ser.		BO Street Bolds
	2	12-5	1.5E-6	27	~		100.36	X	-
	~	12-5	10-5	27	-1			· \	
	× .	ぼ-5 ぼ-5	近-5 近-5	27	1			-	• L
				100	_	-	19 10 10 100,0		· · 2, · · ·
	Pages:				= 🖬 👪		100-100-0-10		100-12127-27
2	Data					4.4			~
	B E vtsatipo	kar(nmos)_Scatter,	_vtsatipolar(pmos) jdsatipolar(pmos)						
	idsat[poi	lar(nmos)_Scatter_	idsat(polar(pmos)			- Ve	Sand Da		an 10° dante to
	B-E vitatin B-E idsatin	scatter idisatio					Contraction of the second		the second second
		and games				344	18 21		3**
						3	12 20		
							Service and		A CARLENDAR
							0.00	Λ	0 8 8
							-		
								1.7	
						<u> </u>	· · · ·		
	1					-			

Scatter, contour and corner plot checking

First, in the left table, select device whose polar type is blank. It means a pair of devices (a nmos and a pmos with same instance value) will been selected. Second, select plot from the pages' list. The scatter and corner plot can be plotted in the graph region.



Histogram plot checking

First, in the left table, select device whose polar type is 1 or 1 (1 for nmos and -1 for pmos). Second, select plot from the pages' list. The Histogram plot can be plotted in the graph region.

1. a. Data Dispose

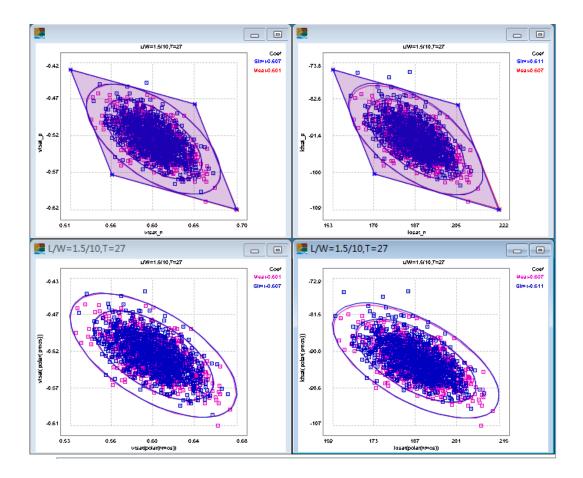
Data Statistical Analysis
Data Pruning
Delete the data beyond the 3 v sigma
Data Sampling
Select the data from group
Group Size: 1
Global Data Generation
Generate the global data from total and local data
Mean Value Check
Model Re-centering
O Data Re-centering
Create Mismatch Dummy Data
Create Mismatch Dummy Data
O Ihrough origin point
Not through origin point
Generate Data

Click the "Generate Data" for data dispose.

a. Global Model Extraction

device	nmos_vtsat		pmos_vtsat	r	umos_idsat		pmos_idsa	at	
w_1.5E-6_1_1.5E-	6	1		1		1			
w_1E-5_1_1.5E-6		1		1		1			
w_1.5E-6_1_1E-5		1		1		3			
w_1E-5_1_1E-5		1		1		2			
Correlation Weig	ht Setting				Default	L	oad	Save as	5
device		nmos_v	tsat & pmos_vtsat		nmos_idsat	& pi	mos_idsat		
w 1.5E-6 1 1.5E-	6	1			1				
1E-5_1_1.5E-6					1				
N IE-5 I I.SE-6									
w_1.5E-6_1_1E-5					1				
w_1.5E-6_1_1E-5	Setting				1	L	.02d)	Save as	
*_1.5E-6_1_1E-5 *_1E-5_1_1E-5	Setting		step	miı	1 1 Create	L		Save as	
1.5E-6_1_1E-5 .1E-5_1_1E-5 Model Parameter type	-		step	miı	1 1 Create			Save as	5
<pre>1.5E-6_1_1E-5 .1E-5_1_1E-5 Model Parameter type pmos</pre>	parameter		step	mir	1 1 Create				5
<pre>1.5E-6_1_1E-5 .1E-5_1_1E-5 Model Parameter type pmos amos</pre>	parameter pvsat		step	miz	1 1 Create			8E3	5
<pre>*_1.5E-6_1_1E-5 *_1E-5_1_1E-5 Model Parameter type pmos pmos pmos</pre>	parameter pvsat wvsat		step	miz	1 1 Create			8E3 8E3	5
*_1.5E-6_1_1E-5 *_1E-5_1_1E-5 Model Parameter	parameter pvsat wvsat wvsat		step	mir	1 1 Create			8E3 8E3 8E3	

Click "Model Generation for Device" button for global model extraction. And extracted model simulation result is plotted in the graph.



The generated dummy data and extracted model are saved in the "project_path\mosfet_demo_2\statistical";

Mismatch Model Extraction from spec

Open the project from

"MBP_home\demo\Statistical\GUIBasedSolution\mosfet\demo_case_mismatchspec'

1. a. Config

	😝 🗳 👘	
	Config	
Config	imulation Sim Method: Normal-MC Simulation	
Data Analysis Model Centering	Corner/Statistical Scale: 1.3 PCA Number: 3	
Local Model Global Model	Debug Mode	
Corner	Decal Global Detimization	
	Itermax: 2000 Tol: 5e-4	
	Regression Iter: 1	
	Mode Method: 1-Fast Mode 🔹	

1. a. Setup

The measurement for this demo case can be found "project_path\MISDATA" and "project_path\STADATA" $\ensuremath{\mathsf{STADATA}}$

		Setup	
otal Data Local	l Data Input Model		
Local Data			
🔘 Generate Data	a From Measurement		
Generate Data	a From Spec		
Local Spec			
Iargets Devic	es		
Polar	Iarget	Biases	Expression
rumos	vthlin	vds = 0.1, vbs = 0.0	x*0.02+0.01
pmos	vthlin	vds = -0.1, vbs = 0.0	x*0.02+0.01
		Update	

1. a. Data Dispose

Data Statistical Analysis
Data Pruning
Delete the data beyond the 3 v sigma
Data Sampling
Select the data from group
Group Size: 1
Global Data Generation
🕼 Generate the global data from total and local data
Mean Value Check
Model Re-centering
Data Re-centering
Create Mismatch Dummy Data
Create Mismatch Dummy Data
Ihrough origin point
Not through origin point
Generate Data

Click the "Generate Data" for data dispose.

1. a. Local Model

			Local J	Model G	enerati	on				
Target W	eight Sett	ing								
					Defaul	t [L	oad	Save a	as 🛛
device	nmos	pmos	nmos	pmos	nmos	pmos.		nmos	pmos	
w_1.8	1	1	1	1	1		1	1		1 🔺
w_2E	1	1	1	1	1		1	1	1	1
w_1E	1	1	1	1	1		1	1	1	1 =
w_1.8	1	1	1	1	1		1	1		1
w_2E	1	1	1	1	1		1	1	:	1
w 1E	1	1	1	1	1		1	1		1 -
type	р	arameter	ste	ep	min			max		
nmos	vt	th0								
pmos	vt	th0								
nmos	u)								Ξ
pmos	սն)								
nmos	te	xe								
pmos	te	xe								Ŧ
					neration					

Set target weight table and parameter table, and click "Local Model Generation" button to extract local model

Statistical Model Extraction from Corner Model

Open the project from

"MBP_home\demo\Statistical\GUIBasedSolution\mosfet\demo_case_cornermodel"

1. a. Configuration

	Config
Config	Simulation Sim Method: Normal-MC Simulation
Setup	Parameter
Data Analysis	Corner/Statistical Scale: 1.3
Model Centering	PCA Number: 3
Local Model	Debug
Global Model	✓ Debug Mode
Corner	Local Global
	Optimization
	Itermax: 2000
	Tol: 5e-4
	Regression Iter: 1
	Mode Mode Method: 1-Fast Mode

1. a. Setup

	Setur	p
Total Data Local Data	Input Model	
Total Data		
Generate Data From N		
🔘 Generate Data From C	orner Data	
🔘 Generate Data From C	Corner Spec	
Targets Devices		
Targets Devices		
Polar	Target	Biases
nmos	vtgm	Vlin = 0.05, Vcc = 1.2, Vbs = 0.0
nmos	vtsat	Vlin = 0.05, Vcc = 1.2, Vbs = 0.0
nmos	idsat	Vlin = 0.05, Vcc = 1.2, Vbs = 0.0
pmos	vtgm	Vlin = -0.05, Vcc = -1.2, Vbs = 0.0
pmos	vtsat	Vlin = −0.05, Vcc = −1.2, Vbs = 0.0 =
pmos	idsat	Vlin = -0.05, Vcc = -1.2, Vbs = 0.0
nmos	gds	Vlin = 0.05, Vcc = 1.2, Vbs = 0.0
pmos	gds	Vlin = -0.05, Vcc = -1.2, Vbs = 0.0
		T
Corner Model		
🔘 With the default mo	odel as input	
0		
Input Model		
Path: C:\Winbo	nd\cornermodel\hvt.l	Browse
Lib Name: FF_hvt, S	S_hvt, FS_hvt, SF_hvt, II_hvt	
Lib names should be in	this order:FF,SS,FS,SF,IT, and sep	arated by ',
Nmos Name: nch_hvt	Pmos Name: pch_hvt	
	Update	2

1. a. Data Dispose

1. a. Global Model

The target weight table is similar as other examples. In the parameter table setting, please click the "create" button at first.

Model Paramet	ter Setting		Create	Load	Save as	
type	parameter	step	min	max		
nmos	k3					
nmos	u0					
nmos	toxe					
nmos	wu0					
nmos	pvsat					Click button
nmos	cgsl				*	Check Button

Then, select tuning parameters from the popped table.

		X	
	type	name	
V	nmos	k3	
V	nmos	u0	
V	nmos	toxe	
	nmos	wu0	
	nmos	pvsat	
	nmos	cgsl	
	nmos	xl	
	nmos	lu0	Ξ
	nmos	vth0	
	nmos	cjswgs	
	nmos	cgdl	
V	nmos	wags	
	nmos	xw	
	nmos	cgdo	
	nmos	cjsws	
	nmos	vsat	
	nmos	lvth0	
	nmos	pu0	
	nmos	ags	
	nmos	cjs	
	nmos	cf	
	nmos	pvth0	
	nmos	cgso	
	pmos	k3	
	pmos	u0	
	omos	toxe	-
	OK		

Finally, click the "model generation" button to generate global model directly.

		Global	Model Gene	eration		
Target Weight	Setting					
				Default	Load	Save as
device	nmos_vtsat	pmos_vtsat	nmos_idsat	pmos_idsat	nmos_vtgm	pmos_vtgm
w_1.2E-7_l	:	1 1	1	1	1	1
w_1E-5_ _1E-7	:	1 1	1	1	1	
w_5E-6_l_5E-6	:	1 1	1	1	1	
w_1.2E-7_l	:	1 1	1	1	1	
w_1E-5_ _1E-5		1 1	1	1	1	
Correlation We	ight Setting					
Correlation we	ight Setting					
				Default	Load	Save as
device	n	mos_vtsat & pmo	s_vt nmos_	idsat & pmos_id	sat nmos_vtgr	n & pmos_vt
w_1.2E-7_ _1E	-7		1		1	
w_1E-5_l_1E-7			1		1	
w_5E-6_1_5E-6			1		1	
w_1.2E-7_ _1E	-5		1		1	
w_1E-5_ _1E-5			1		1	
Model Paramet	er Setting					
				Create	Load	Save as
tures		ter ste	D	min	max	
type	parame					
	k3		r			
nmos			r			
nmos nmos	k3					
nmos nmos nmos	k3 u0					
nmos nmos nmos nmos nmos	k3 u0 toxe					

Q&A

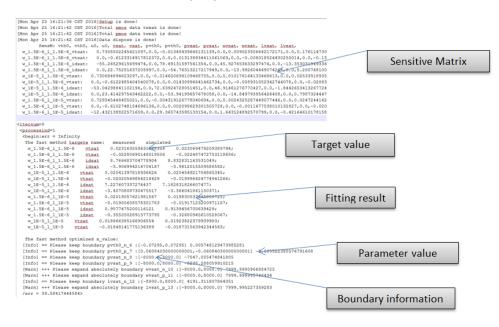
- What's relation between mismatch model/data, statistical model/data, local model/data, and global model/data? In our document, mismatch model/data equals to local model/data. And statistical model/data equals to global model/data
- How to set Monte Carlo Number? Select menu "Tools->GUI Options->Statistical Graph Config->MC count".
- **3.** How to find extracted result? Go to current project folder, and all result and setting configuration file can be found in the "statistical" folder.
- 4. How to import/export configuration files?Save, export, import

						7
		0	Global Model Gener	ation		
Config				Derault	LOAD Save as	
Cornig	device	nmos_vtsat	pmos_vtsat	nmos_idsat	pmos_idsat	
Setup	w_1.5E-6_l_1.5E-6	1	1 1		1 1	

- How to set contour line's number? Select menu "Tools->GUI Options->Statistical Graph Config->Contour Number".
- 6. Usually, a pair of nmos and pmos which has identical dimension value can be checked with scatter plot and the correlation coefficient is calculated. If a nmos and pmos which has different dimension value also need scatter plot and correlation coefficient, how should we do? We can use "corindex" to define a pair of devices. The devices with same

corindex will be paired. If you want to check scatter plot for this pair device defined by "corindex", please select "Tools->GUI Options->Statistical Graph Config->couple with corindex".

7. How to understand the debug log file?



8. How to customize the mismatch plot's x-axis? From Menu "Tool->GUI Options->Statistical GUI Options"Mismatch X-axis

Statistical Graph Config	×
Scatter pages	
Pages	
Vth_Scatter_Idsat	
Ion_Scatter_Ioff	X Scale: 🗸 🗸
	Y Scale: 👻 👻
	Add Page
	Del Page
	Couple with corindex
Set to default	1
Contour	
Contour Styles: 0	utline 🗸 🗸 Set to default
Contour Number: 5	✓ Set to default
Color	
Histogram	
Draw Distribution	V Set to default
Bar Styles: Fi	I
Bin Number: 20	Split Separately 📝 Set to default
Shift Mean to Zero	
Mismatch	
Mismatch X: 1/sqrt(w*l*1e	12)
MC count	
🔽 Use det	ault number: 1000
	OK Cancel

- 9. How to configure different type device? Script-> prog->defaultsetting
- For mismatch spec, how to define x-axis? Default, we can define mismatch sigma by this way. Here, x=1/sqrt(w*l)

		Expression
res	vpn = 1.0	x*0.02

Moreover, we can use instance in the expression for specific applications.

olar	Target	Biases	Expression	
	res	vpn = 1.0	w*0.02	

Targets Devices			
polar	w	1	
r	1.0	1.0	
r	3.0	3.0	
r	5.0	5.0	
r	8.0	8.0	
r	10.0	10.0	
r	1.0	5.0	
r	3.0	5.0	
r	5.0	25.0	
r	8.0	40.0	
r	10.0	50.0	
r	1.0	10.0	
r	3.0	30.0	
r	5.0	50.0	
	8.0	80.0	

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