NOTICE: This document contains references to Agilent Technologies. Agilent’s former Test and Measurement business has become Keysight Technologies. For more information, go to www.keysight.com.
Copyright Notice and Proprietary Information

Copyright © Agilent Technologies, Inc. 2003, 2011. All rights reserved. This software and documentation contain confidential and proprietary information that is the property of Agilent Technologies, Inc. The software and documentation are furnished under a license agreement and may be used or copied only in accordance with the terms of the license agreement. No part of the software and documentation may be reproduced, transmitted, or translated, in any form or by any means, electronic, mechanical, manual, optical, or otherwise, without prior written permission of Agilent Technologies, Inc., or as expressly provided by the license agreement.

Right to Copy Documentation

The license agreement with Agilent Technologies permits licensee to make copies of the documentation for its internal use only. Each copy shall include all copyrights, trademarks, service marks, and proprietary rights notices, if any. Licensee must assign sequential numbers to all copies.

Disclaimer

AGILENT TECHNOLOGIES, INC. AND ITS LICENSORS MAKE NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARD TO THIS MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Registered Trademarks (®)

Agilent, Model Builder Program, MBP, Model Quality Assurance, MQA, Advanced Model Analysis, AMA, Proximity Quality Assurance, PQA are registered trademarks of Agilent Technologies, Inc.
Mismatch Modeling in MBP

Application Note

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.

Introduction

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.agilent.com/find/eesof or contact your local Agilent office. The complete list is available at: www.agilent.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 -0.0016386308204789923
0.0012339958926110839 0.008895426625025848 -0.0048731228537369775
..........................
{0.18,10.0}
0.0011114374468496058 0.007055480752867993 -7.450025621094092E-4
4.96941489894353E-4 0.003966458228031433 -0.0024213892738844667
..........................
```

For any assistance, mail to: mbp_pdl-eesof@agilent.com
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 ($\Delta v_{th, gm}$) 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 "$L=40um,W=5um, T=25C, Vds=0.05V, Vgs=3V, Vbs=0, \Delta Ids(mean) =0, \Delta Ids(sigma)=6.448e-4A$".

Plot
As shown in Figure 1, the plot shows the value of $\sigma (\Delta V_{th, gm})$ 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 Figure 2.

**Figure 1. Mismatch plot**

![Mismatch plot](image1.png)

**Figure 2. Fit Line through Origin**

![Fit Line through Origin](image2.png)

**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 Figure 3. Then, set an appropriate number. A large number may lead to a more accurate result, but it can also cause a longer simulation time.

**Figure 3. Set Monte Count**

![Set Monte Count](image3.png)

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

Step1. Set Model Type

First, set the model 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 4.

Click the OK button to close the window.
**Step 2. Load Data and Model**

Choose File -> Data -> Load from the main menu and load the data file “mis_data.me,” as shown in Figure 5.

![Figure 5. Data VS initial model](image)

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.

**Step 3. Extraction Flow**

Choose Extraction -> Extraction Flow from the main menu. The extraction panel is shown in Figure 6.

![Figure 6. Extraction Flow panel](image)

Double click the Mismatch Extraction button to expand the flow, as shown in Figure 7.
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 Figure 8.

Click the Load button to load the parameter list file “param.txt.” The parameters used for mismatch extraction are shown in Figure 9.
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 Figure 10.
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 Figure 11.

All the specific targets corresponding to the data group in Figure 10 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 = '0.0+s_dtox_mis*random5'
+dvth_mis = '0.0+s_dvth_mis*random6'
+ddl_mis = '0.0+s_ddl_mis*random7'
+ddw_mis = '0.0+s_ddw_mis*random8'
```

The fitting result is shown in Figure 12.

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.
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 Figure 13.

Right-click the IMV "mis_sigma_ids" and choose New -> Graph (Figure 14).
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 Figure 15.

Click the icon to save the current code. In the main menu of MBR, 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 Figure 16.