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Modella -PNP Bipolar Model Released in *SmartSpice*

Introduction

The ***Modella*** lateral PNP bipolar model was developed by Philips Electronics N.V. and first released to the public domain in 1990 [1,2]. A release of this model has been implemented within ***SmartSpice***, and can be accessed by setting the LEVEL parameter of the BJT model card to 500.

Description

Modella stands for MODEL-LAteral and is a PNP lateral bipolar model. Since most processes use the conventional lateral PNP as a standard, it was necessary to take its specificity in account with a new model. It is intended to provide physically-based equations, instead of using inaccurate vertical models such as Ebers-Moll or Gummel-Poon with modified parameters to represent the lateral behavior of the device. The physical effects of this lateral transistor lead to a totally new model that accounts for the complex bi-dimensional structure of this device.

Usual models for NPN transistors use the Gummel concept of computing majority charge in the neutral base to express collector current. This one-dimensional concept cannot be applied to ***Modella***, because it needs a bi-dimensional physical description. Therefore, ***Modella*** has been developed using another approach, based on a physical analysis of the transistor. Most major modeling equations are derived for the forward active case.

Both lateral and vertical currents flow through the device, modeled by four current sources. The symmetry of the structure is reflected by the model, as well as its vertical and lateral elements (Figure 1).

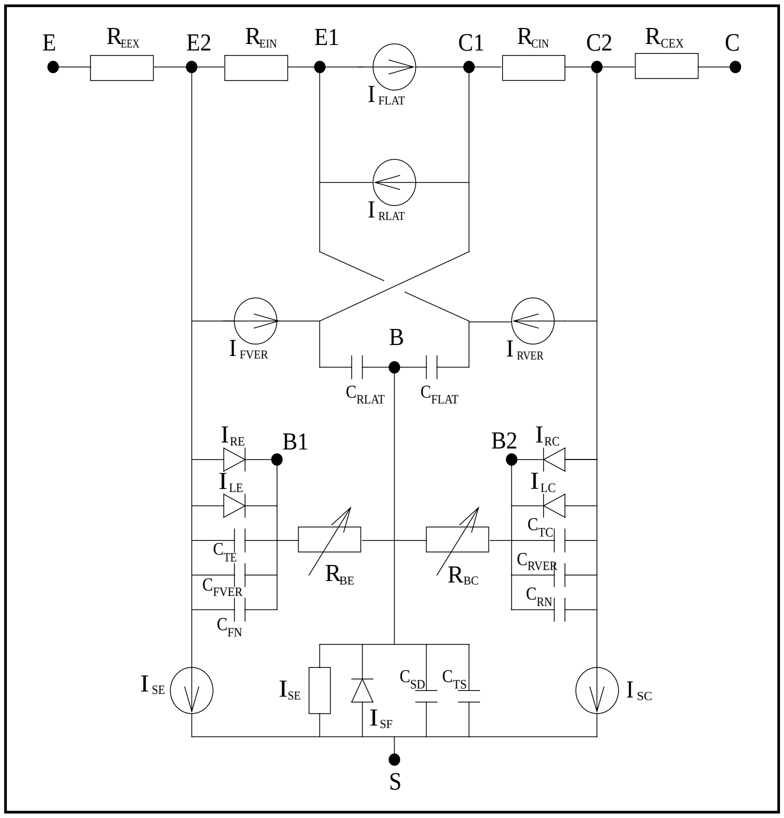

Figure 1. Large signal equivalent circuit.

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Volume 12, Number 1, January 2002

SILVACO INTERNATIONAL

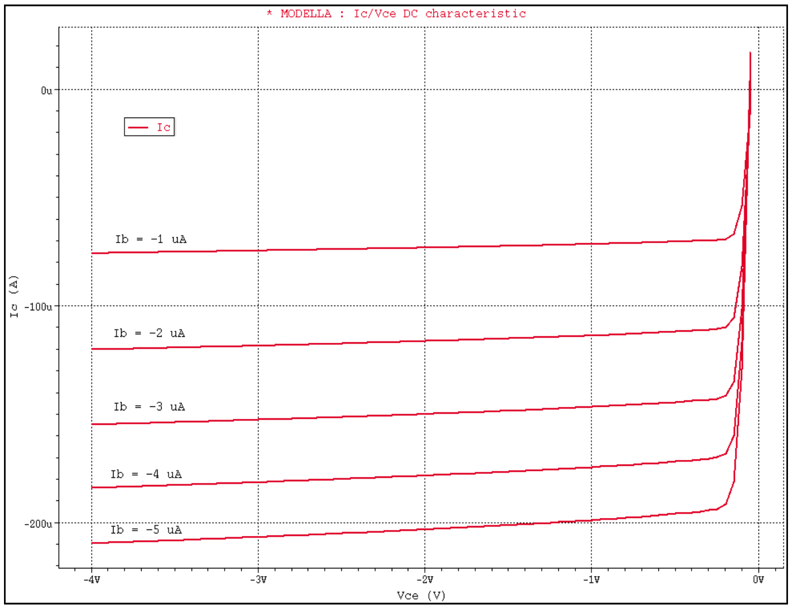


Figure 2. Forward IC vs Vce characteristics.

Modeled effects are :

- Temperature (without self-heating)
- Charge storage
- Excess phase shift for current and storage charges
- High-injection
- Built-in electric field in base region
- Bias-dependent Early effect
- Low-level non-ideal base currents
- Hard and quasi-saturation
- Weak avalanche
- Current crowding (DC, AC and transient) and conductivity modulation for base resistance
- Hot carrier effects in the collector epilayer
- Explicit modeling of inactive regions
- Split base-collector depletion capacitance

Validation

In order to validate ***SmartSpice*** results, values were compared with Philips own in-house simulator output. PStar was used with test circuits for operating point, DC and AC analysis. Outputs for DC simulations match between PStar and ***SmartSpice***.

Examples

Modella is more complex than Gummel-Poon models, because it is composed of as much as 6 internal nodes. However its symmetry and the nature of the equations used lead to convergence with the same performance as other models do.

Typical characteristics for the ***Modella*** device are presented in Figure 2.

Modella also accounts for advanced effects, such as excess phase.

The basic Gummel-Poon model is a one-pole model, but in fact a bipolar device has two poles. This results in simulation errors, estimating cutoff frequency and gain too high and also predicting smaller phase shift. The EXPHI parameter of the ***Modella*** model allows the designer to add the second pole phase contribution, expressed in radians. Figure 3 presents the small-signal gain hFE for an inverter circuit using one ***Modella*** device.

References

[1] ‘Nat. lab Unclassified Report No. 2001/804, Physically based compact modeling of lateral PNP transistors.’ F.G. O’Hara B.E.

[2] ‘Nat. lab Unclassified Report No. 6131, A new physical compact model for lateral PNP transistors’, F.G. O’Hara, J.J.H. van den Biesen, H.C. de Graaff and J.B. Foley.

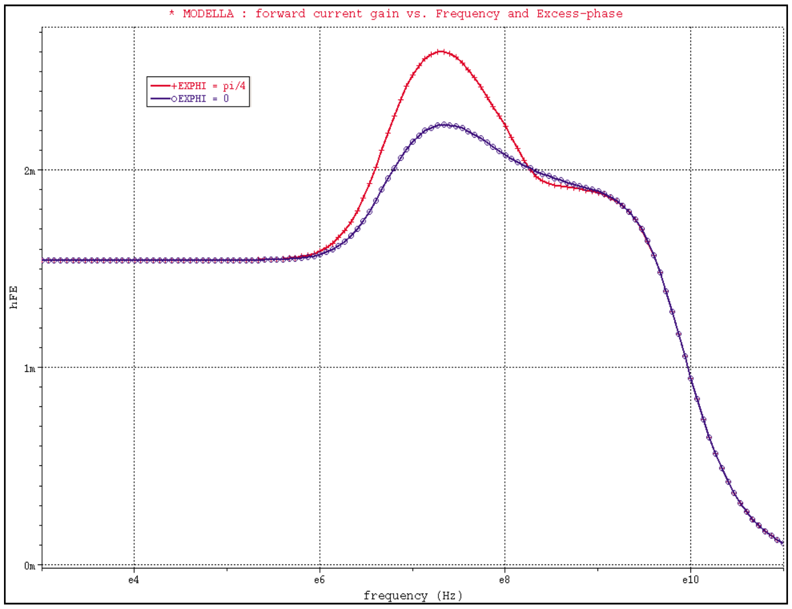


Figure 3. Forward current gain vs. frequency and excess-phase

New Berkeley BSIM4v2.1 MOSFET Model Available Within *SmartSpice/UTMOST III*

1. Introduction

So far the BSIM3v3.2 MOSFET model, developed by UC-Berkeley, has been considered as the industry standard model for deep-submicron CMOS design. It was rapidly adopted by IC companies and foundries for modeling devices down to 0.25 . However, for device scale down to 0.10 , some physical mechanisms need to be better characterized.

BSIM4 model is developed to explicitly address the following issues, for which BSIM3v3 was found lacking and inaccurate:

- Modeling of sub-0.13 microns MOSFET devices
- High-frequency analog and high-speed digital CMOS circuit simulation
- Layout-dependent parasitics model

UC-Berkeley officially released BSIM4v0.0 for the first time on March 24, 2000. Later versions BSIM4v1.0, BSIM4v2.0 and BSIM4v2.1 were released on October 11, 2000, on April, 06 2001 and on October 05, 2001, respectively. They account for user's feedback and provide bug fixes over earlier versions.

This article is intended to give an overview of the implementation of BSIM4 within Silvaco products. Further details and up-to-date information may be found in ***SmartSpice/UTMOST*** *Modeling Manuals* and ***SmartSpice*** *Release Notes*.

Readers interested in obtaining more detail about BSIM4 may refer to the Berkeley documentation and source code, available for download at:

http://www-device.eecs.berkeley.edu/~bsim3/bsim4.html

2. Fundamental Improvements Over BSIM3v3.2

Like BSIM3v3.2, BSIM4 accounts for major physical effects:

- Short/Narrow channel effects on threshold voltage
- Non-uniform doping effects
- Mobility reduction due to vertical field
- Bulk charge effect
- Carrier velocity saturation
- Drain induced barrier lowering (DIBL)
- Channel length modulation (CLM)
- Source/Drain parasitic resistances
- Substrate current induced body effect (SCBE)
- Quantum mechanic charge thickness model
- Unified flicker noise model

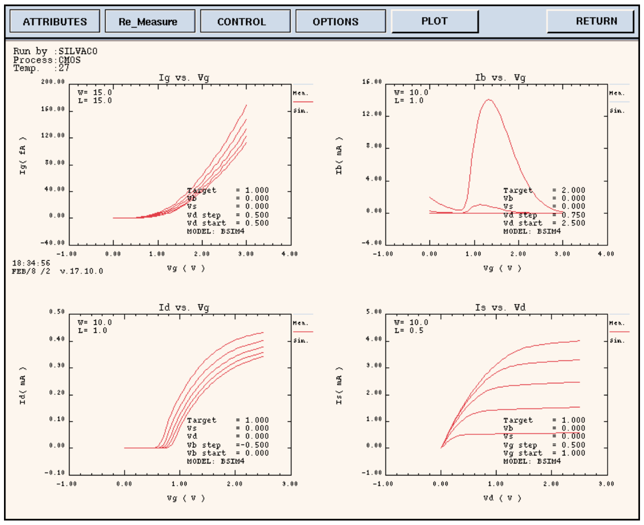


Figure 1. BSIM4 DC characteristics.

BSIM4 has the following major improvements and additions over BSIM3v3.2:

- an accurate new model of the intrinsic input resistance for both RF, high-frequency analog and high-speed digital applications
- flexible substrate resistance network for RF modeling
- a new accurate channel thermal noise model and a noise partition model for the induced gate noise
- a non-quasi-static (NQS) model that is consistent with the Rg-based RF model and a consistent AC model that accounts for the NQS effect in both transconductances and capacitances
- an accurate gate direct tunneling model
- a comprehensive and versatile geometry-dependent parasitics model for various source/drain connections and multi-finger devices
- improved model for steep vertical retrograde doping profiles
- better model for pocket-implanted devices in Vth, bulk charge effect model, and Rout
- asymmetrical and bias-dependent source/drain resistance, either internal or external to the intrinsic MOSFET at the user's discretion
- acceptance of either the electrical or physical gate oxide thickness as the model input at the user's choice in a physically accurate manner
- the quantum mechanical charge-layer-thickness model for both IV and CV
- a more accurate mobility model for predictive modeling

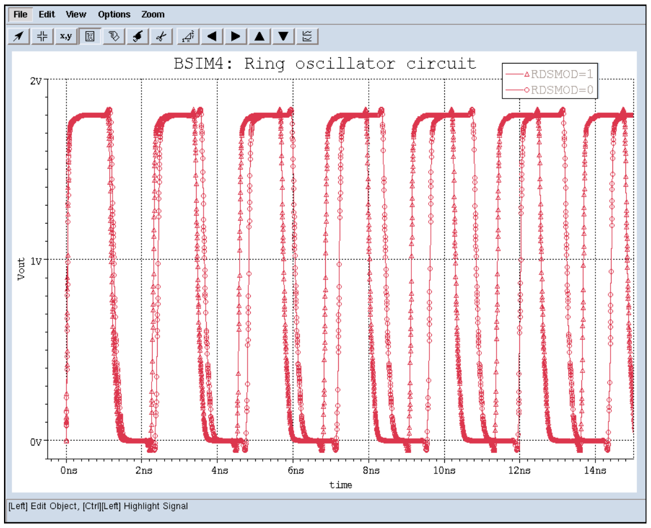


Figure 2. BSIM4 RF/High-Speed model: digital ring oscillator.

- a gate-induced drain leakage (GIDL) current model, available in BSIM for the first time
- an improved unified flicker (1/f) noise model, which is smooth over all bias regions and considers the bulk charge effect
- different diode IV and CV characteristics for source and drain junctions
- junction diode breakdown with or without current limiting
- dielectric constant of the gate dielectric as a model parameter

3. Silvaco Implementation

The Silvaco implementation of BSIM4 is based on the official Berkeley releases. BSIM4 is currently accessible within ***SmartSpice/UTMOST*** by specifying the model selector LEVEL=14. The alias LEVEL=54 is also supported for HSpice compatibility.

The most recent version (BSIM4v2.1) is selected by default but older versions may be invoked by specifying the model parameter VERSION=0.0, 1.0 or 2.0. In the Silvaco implementation, VERSION is a real value and not a string, as in the Berkeley code. Consequently, the Berkeley syntax VERSION=4.2.1 corresponds to VERSION=2.1 in ***SmartSpice/UTMOST III***. A warning message is issued when an invalid VERSION number is given. It is recommended to systematically use the most recent version to benefit from the last Berkeley bug fixes and improvements.

The structure of the original Berkeley code has been modified. These changes do not directly involve equations, except minor bug fixes in derivatives. So they do not affect the accuracy of results but may significantly improve convergence. The Silvaco implementation offers the best performances regarding speed and convergence without any loss of accuracy.

3.1 Differences Between BSIM4v2.1 and BSIM4v2.0

BSIM4v2.1 provides bug fixes over its previous version, BSIM4v2.0. Most of them were already included in the Silvaco implementation of BSIM4v2.0 when UC-Berkeley released the new version. Consequently, only the changes listed below have been incorporated. They are active only if VERSION=2.1 is selected:

- Gate Induced Source Leakage (GISL) is added to give an enormous improvement in simulation convergence. Together with GIDL, it makes the gate induced leakage component of the substrate current symmetric
- The warning limits for effective channel length, channel width and gate oxide thickness (Leff, LeffCV, Weff, WeffCV, Toxe, Toxp and Toxm) are substantially decreased to avoid a large number of warnings when BSIM4 is used beyond its design region. For meaningful results, it is still recommended to keep these variables/ parameters within the BSIM4 design region. This change is intended only to allow users to extend the model beyond this region with fewer warnings.
- The model parameter ACDE is now checked only when CAPMOD=3 to avoid useless warning messages
- The 1/f noise bug fix avoids negative DelClm when calculating noise density by turning off the second part of the noise density equation
- In addition, this version adds many variables as output such as some of the current components (igs, igd, igb, igcs, igcd, isub, igidl, igisl) to ease the model verifications

3.2 Differences Between BSIM4v2.0 and BSIM4v1.0

The improvements incorporated into BSIM4v2.0 are bug fixes and two new model parameters XL and XW.

XL and XW are geometry offset parameters due to mask/etch effect with default values of 0.0. With these changes, the BSIM3 parasitic resistance model file becomes a compatible subset of the BSIM4 parasitic resistance model.

In versions 0.0 and 1.0, the value of the intrinsic capacitance cbdb of the CAPMOD=0 capacitance model was wrong. This has been corrected in version 2.0.

Also, the computation efficiency is enhanced due to a better extraneous node allocation strategy. In version 2.0, internal drain and source nodes are created only if access resistances have non-zero values or if a noise analysis is performed with the holistic thermal noise model selected (TNOIMOD=1). When extraneous nodes collapse, the size of the matrix is reduced, leading to a significant gain of speed, especially with large circuits.

3.3 Differences between BSIM4v1.0 and BSIM4v0.0

The improvements of BSIM4.1.0 over BSIM4.0.0 are bug fixes and an analytical equation for the model parameter PIGCD when it is not specified. The relevant changes are:

- Gate Tunneling Currents: in BSIM4.0.0, PIGCD is set to a constant value (1.0) if unspecified. In BSIM4.1.0, its default value is given by an analytical equation:

$$PIGCD = \frac{B \cdot TOXE}{V_{gsteff}^2} \cdot \left(1 - \frac{V_{dseff}}{2 \cdot V_{gsteff}}\right)$$

  where B is a constant, set to 7.45669e11 for NMOS or to 1.16645e12 for PMOS, and TOXE is a model parameter (Electrical gate equivalent oxide thickness).

- Thermal Noise Charge Based Model (TNOIMOD=0): in BSIM4.0.0, the inversion charge Qinv used in the thermal noise current formulation depends on the effective saturation voltage calculated for the drain current equation, which causes a current spike. In BSIM4.1.0, this bug has been fixed by replacing the original value of Vdsat by a simple expression, corresponding to a long-channel saturation voltage:

$$V_{dsat} = \frac{V_{gsteff}}{A_{bulk}}$$

- Parameter checking: in BSIM4.0.0, the maximum number of device fingers (NF) is limited to 500. In BSIM4.1.0, this limit is removed and if NF is too large and makes the effective width (Weff) to be lower than or equal to zero, a fatal error will be issued.

3.4 Silvaco Specific Features

The following ***SmartSpice***-specific features have been added to the original Berkeley implementation, for all BSIM4 versions:

- The BSIM4 code has been optimized to benefit from ***SmartSpice*** multi-threading capabilities. A gain of speed of 30% or more may be observed on 2-processors machines, especially when running large circuits
- The VZERO and BYPASS options are fully supported. Specifying VZERO=2 and/or BYPASS=1 on .OPTION lines may significantly speed-up computation for transient analysis. The original Berkeley BYPASS criterion has been modified to ensure accuracy and for HSpice compatibility
- The ***SmartSpice*** standard multiplier, useful to put several identical transistors in parallel, is supported as a BSIM4 instance parameter M. This parameter is not equivalent to the instance parameter NF (number of fingers) introduced in BSIM4 by Berkeley to account for devices in parallel. Please refer to Berkeley documentation for further details on this new parameter
- In ***SmartSpice***, it is possible to specify the temperature of each device using the standard instance parameters TEMP and DTEMP. They are also supported for BSIM4 instances. TEMP has the highest priority and correspond to the temperature of the device in. If TEMP is unspecified and DTEMP is specified, the instance temperature is evaluated by adding DTEMP to the circuit temperature. If none of these parameters are specified the circuit temperature is used, which defaults to 27 if unspecified with .OPTION or .TEMP statements
- The original Berkeley BSIM4 parameter checking scheme has been modified to avoid the same warning message be issued several times when a parameter is out of range. In the Silvaco implementation, instance and model parameters are separately tested. As the main consequence, each warning message is now issued only once
- The implementation of NQS models has been optimized so that related matrix elements are created only when TRNQSMOD or ACNQSMOD selector are set to 1. That fixes a singular matrix error when TRNQSMOD=1 and ACNQSMOD=0
- The ***SmartSpice*** standard conductances GMIN / DCGMIN have been added. They are connected in parallel with bulk junction diodes and between internal drain and source nodes. They account for the instance multiplier (M) and the number of device fingers (NF)
- The CAPTAB and DCCAP options are supported.
- The terminal currents and charges can be printed, plotted or saved for DC, TRAN and AC analysis using the ***SmartSpice*** syntax @instance_name[variable_name]. The related variable names are listed in Table 1

Variable name (alias)	Definition
id (cd)	Drain terminal current
cs	Source terminal current
cg	Gate terminal current
cb	Bulk terminal current
*qdrain	Intrinsic drain charge
*qbulk	Intrinsic bulk charge
*qgate	Intrinsic gate charge
*qd	Total drain charge
*qb	Total bulk charge
*qg	Total gate charge
*cqd	Total drain capacitance current
*cqb	Total bulk capacitance current
*cqg	Total gate capacitance current

Table 1. BSIM4 extra output variables added in ***SmartSpice.***

The variables marked with an asterisk are systematically computed after transient and small-signal analysis. For DC analysis, they are computed only if DCCAP option is turned on.

How to Achieve Good Parameter Optimization Using The New Methodology in *UTMOST III* Optimizer

1.Introduction

What is the goal of optimization?

The optimization is the task of finding the absolute best set of admissible conditions to achieve your objective, formulated in mathematical terms. The goal of optimization is, given a system, to find the setting of it's parameters so that to obtain the optimal performance. The performance of the system is given by an evaluation function. Optimization problems are commonly found in a wide range of fields, and it is also of central concern to many problems.

The basic approach in all cases is usually the same: User selects or designs a "merit-function" that measures the agreement between the data and the model with a particular choice of parameters. The merit function is generally designed so that small values represent close agreement. The parameters and the model are then adjusted to achieve a minimum in the merit function, yielding best-parameters set. The adjustment process is thus a problem in minimization in many dimensions. The computational wish is always the same: do it quickly and cheaply. Often the computational effort is dominated by the cost of evaluating the merit function (and perhaps its partial derivatives). In such cases, the wishes are sometimes replaced by a simple goal: Evaluate the merit-function as few times as possible.

Finding a global extremum is, in general, a very difficult problem.

Two standard methods are widely used:

- find local extrema starting from widely varying starting values of the independent variables and then pick the most extreme of these
- perturb a local extremum by taking a finite amplitude step away from it, and then see if your method returns you a better point, or always to the same one (Simulated Annealing)[1]

Unfortunately, there is no perfect optimization algorithm. and the choice of the optimization method is based on the following consideration: A selection must be made between methods that need only evaluations of the "merit-function "to minimize and those that also require evaluations of the derivatives of that functions. Algorithms using the derivative are somewhat more powerful than those using only the function, but not always enough so as to compensate for the additional calculations of derivatives.

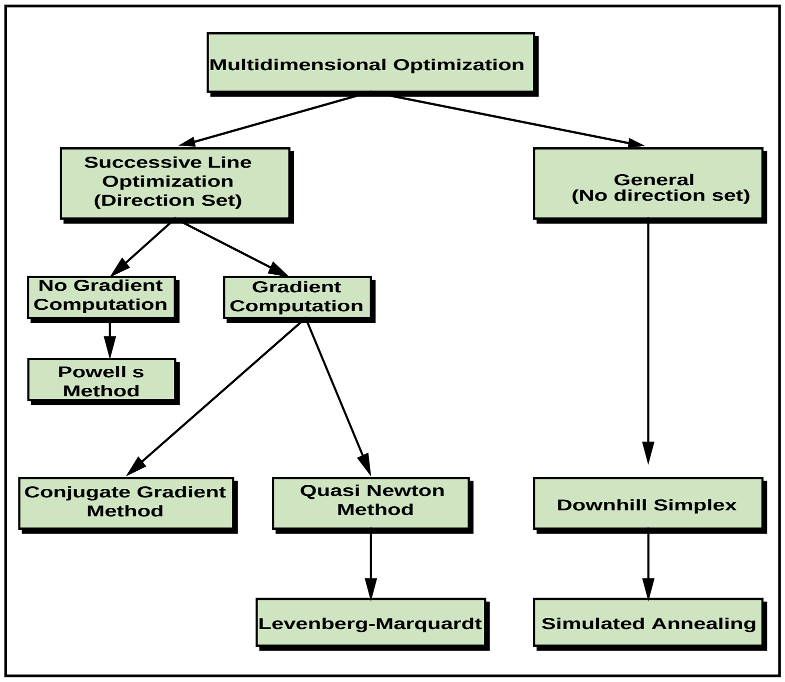


Figure 1. The basic optimization methods.

Figure 1 describes the two different basic optimization methods. One is based on direction-set, the other not. The well known Levenberg-Marquardt[2] method is associated to the direction-set, the Downhill Simplex method and the Simulated annealing are issued from the no-direction set way.

It should take into account that optimization is always a question of compromise. The main problem of the optimization with spice model is that the cost of an evaluation of the merit-function is very high (i.e. it's very long). The Levenberg-Marquardt method implemented for many years in ***UTMOST*** optimizer limit the number of evaluation of the merit-function but also computes the derivatives. Now available, the Downhill Simplex method does not not compute the derivatives. In fact, our goal is to make available the Simulated Annealing method in which have demonstrated important successes on a variety of global optimization problems[3].

Reading the following pages you will find an explanation of the two optimization methods now available in ***UTMOST***. The goal of explanations is to give a reader the bases of optimization theory in order to perform better optimizations using the two methods.

2. The Levenberg-Marquardt Method

2.1 Basic Theory

The Levenberg-Marquardt method is a standard of non-linear least-squares optimization routines[4]

It defines a merit function and determines the best fit parameters by it's minimization. Given a trial values for the parameters the procedure improves the trial solution and is repeated until stop decreasing. Basically the model to be fitted is $y = y(x;a)$ (2.1)

where a is the set of parameters and the χ^2 merit function is:

$$\chi 2(a) = \sum_{i=1}^{N} \left[\frac{yi - y(xi;a)}{\sigma_i} \right] \quad (2.2)$$

The basic idea is to take a step down the gradient (steepest descent method), that we can write as:

$$a_{next} = a_{cur} - \lambda \nabla \chi 2 \quad (2.3)$$

Where λ is defined as a constant (the step).

It is conventional to define

$$\beta_k = \frac{1}{2} \frac{\partial \chi 2}{\partial p_k} \quad (2.4)$$

and

$$\alpha_{kl} = \frac{1}{2} \frac{\partial^2}{\partial a_k \partial a_l} \chi 2 \quad (2.5)$$

Supposing that the merit function $\chi^2(a)$ is well approached by is quadratic form (sufficiently close to the minimum) and regarding the equation 2.3 we can write

$$\sum_{l=1}^{N} \alpha_{kl} \delta a_l = \beta_k \quad (2.6)$$

This set is solved for the increment δal that, added to the current approximation, gives the next approximation.

Given an initial guess for the set of parameters a, the Levenberg-Marquardt method is as follows:

(1): compute $\chi^2(a)$

(2): Pick a modest value of λ

(3): Solve the system (2.6) for δa and evaluate $\chi^2(a + \delta a)$

(4): If $\chi^2(a + \delta a) \geq \chi^2(a)$ increase λ by a factor f and go back to (3)

(5): If $\chi^2((a + \delta a) \leq \chi^2(a))$, decrease λ, by a factor f, update the trial solution $a \leftarrow a + \delta a$ and go back to (3)

Also necessary is a condition for stopping and this is the goal of the following paragraph that will explain the start and stop criteria available in ***UTMOST***.

2.2. Application

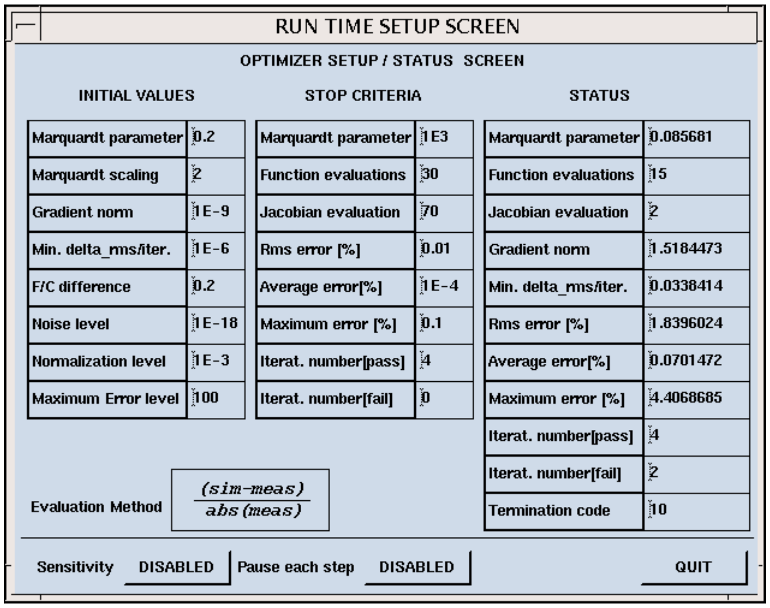
As you can see in Figure 2 there are many parameters that you can change in the ***UTMOST Optimizer*** Setup.

All the optimizer parameters are interrelated. The stop criteria that can be specified is present to prevent the optimizer from performing unnecessary calculations when the convergence is not possible, or that the number of calculations needed to reach convergence is excessive. The termination code indicates the reason why the optimizer stops. If you are not satisfied with a optimization result, it will indicate which optimization parameters you may change.

Now, we can explain some of them.

Marquardt parameter, Marquardt scaling: These parameters are the λ (Marquardt parameter) and the factor f (Marquardt scaling) that are used in the previous chapter. They are the most important parameter the methods used. In fact, when an optimization is performed the Marquardt parameters decrease or increase depending of the result of $\chi^2(a + \delta a)$.

If the Marquardt parameters decrease, the optimizer is going to converge, this is an iter-pass. On the otherhand, if it increases, the optimizer is not on the right track and this is an iter-fail.To prevent it from performing unnecessary calculations, you can limit the number of maximum iter-fail (last row of the stop criteria column) or the Marquardt parameter (first row of the stop-criteria column). The number of iterations depends on the number of Spice parameters the user wants to optimize. If n is this number of parameters, a number of n^2 iterations is a minimum.



RUN TIME SETUP SCREEN

OPTIMIZER SETUP / STATUS SCREEN

INITIAL VALUES		STOP CRITERIA		STATUS	
Marquardt parameter	0.2	Marquardt parameter	1E3	Marquardt parameter	0.085681
Marquardt scaling	2	Function evaluations	30	Function evaluations	15
Gradient norm	1E-9	Jacobian evaluation	70	Jacobian evaluation	2
Min. delta_rms/iter.	1E-6	Rms error [%]	0.01	Gradient norm	1.5184473
F/C difference	0.2	Average error[%]	1E-4	Min. delta_rms/iter.	0.0338414
Noise level	1E-18	Maximum error [%]	0.1	Rms error [%]	1.8396024
Normalization level	1E-3	Iterat. number[pass]	4	Average error[%]	0.0701472
Maximum Error level	100	Iterat. number[fail]	0	Maximum error [%]	4.4068685
				Iterat. number[pass]	4
				Iterat. number[fail]	2
				Termination code	10

Evaluation Method $\frac{(sim-meas)}{abs(meas)}$

Sensitivity DISABLED Pause each step DISABLED

Figure 2. Optimizer Setup / Status screen (Levenberg-Marquardt)

In most general cases, when the results of the optimization are not convenient, one solution is to increase the Marquardt parameter value (this value can not be higher than 1) and at the same time to decrease the Marquardt scaling (that can never be lower than 1.2) before starting a new optimization.

3. The Downhill Simplex Method

3.1 Theory

The simplex optimization method is easy to understand (easier than Levenberg-Marquardt) and use. Trials are successively performed of a direction of improvement until the optimum solution is reached.

The simplex methods can handle many variables with only a few trials, and does not require any calculation of derivatives.

The simplex method is based on an initial design of k+1 trials, where k is the number of variables. A k+1 geometric figure in a k-dimensional space is called a simplex. The corners of this figure are called the vertices. With two variables the first simplex design is based on three trials, for three variables it is four trials, etc. This number of trials is also the minimum for defining a direction of improvement. Therefore, it is a timesaving and economical way to start an optimization project. After the initial trials the simplex process is sequential, with the addition and evaluation of one new trial at a time. The simplex searches systematically for the best levels of the control variables. The optimization process ends when the optimization objective is reached or when the responses cannot be improved further[5].

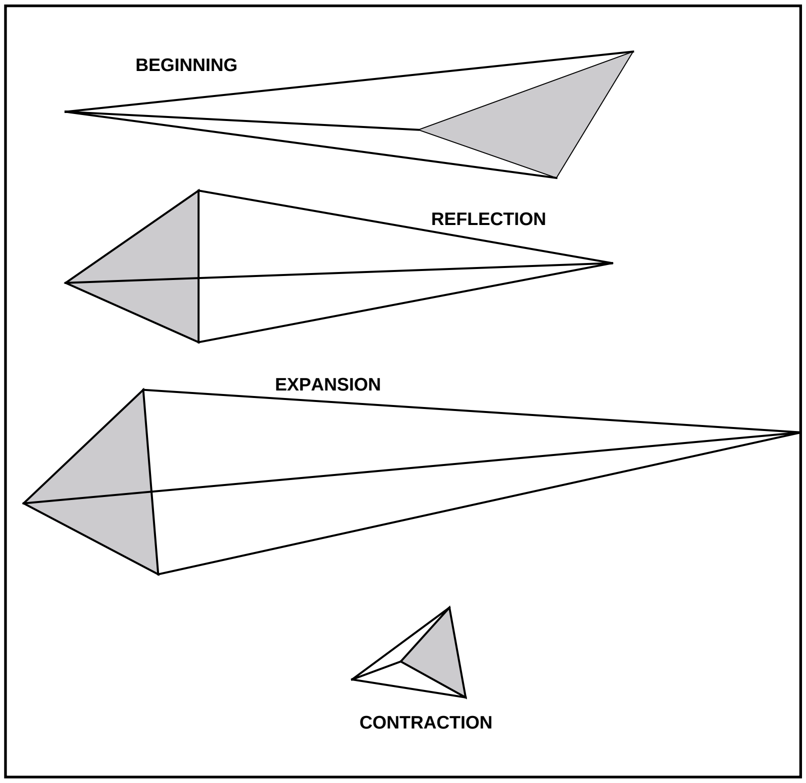


Figure 3. The basic moves of the simplex.

The algorithm is intended to make is own way downhill through the complexity of an N-dimensional topography until it encounters a (local, at least) minimum.

The downhill simplex method must be started not just with a single point, but with N+1 points, defining the initial simplex. Consider P0 as your starting point, you can take the other N points to be

$P_i = P_0 + \lambda e_i$.

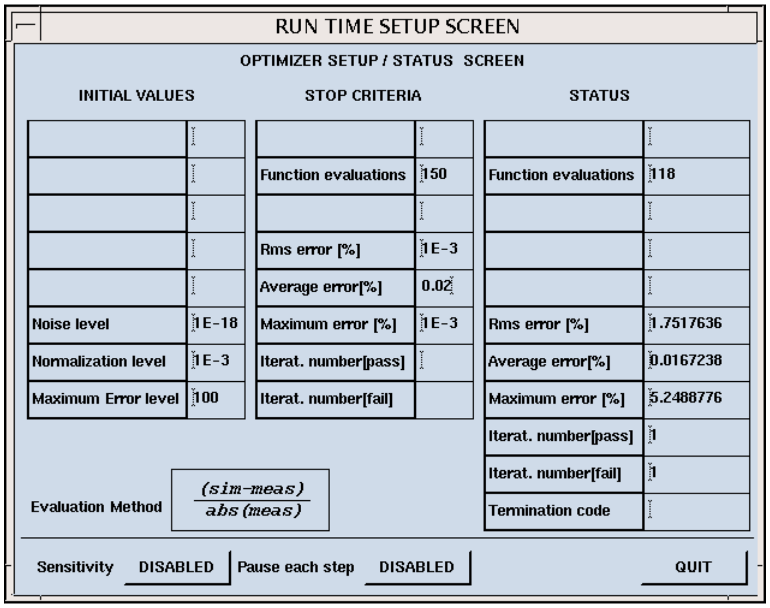
The e_i's are N unit vectors and λ is a constant which is the problem's characteristic length scale. In the ***UTMOST*** optimization method, this value is not a constant but dependent on the initial, the maximum and the minimum values of each parameter. Thus, this purely mathematical method keeps the physical meaning of the spice model.

The method takes a series of steps, moving the points of the simplex where the function is largest, through the opposite face of the simplex to a lower point. These steps are called reflections, and they are constructed to conserve the volume of the simplex (maintain in non degeneracy). Next the method takes the simplex in another direction to make a larger step, and find a minimum, it contracts itself in all directions, pulling itself in around its lowest (best) point.

The basic moves are shown in Figure 3. In this figure, it shows the possible moves for a step in the downhill Simplex method. The simplex, at the beginning of the step is a tetrahedron. The simplex, at each step, can be a reflection, and expansion or a contraction away from the high point. The sequence of such steps will always converge to the minimum of the function.

The basic simplex algorithm consists of a few rules. The first rule is to reject the trial with the least favorable response value in the current simplex. A new set of control variable levels is calculated, by reflection into the control variable space opposite the undesirable result. This new trial replaces the least favorable trial in the simplex. This leads to a new least favorable response in the simplex that, in turn, leads to another new trial, and so on. At each step you move away from the least favorable conditions.

By that the simplex will move steadily towards more favorable conditions. The second rule is never to return to control variable levels that have just been rejected.



RUN TIME SETUP SCREEN

OPTIMIZER SETUP / STATUS SCREEN

INITIAL VALUES		STOP CRITERIA		STATUS	
		Function evaluations	150	Function evaluations	118
		Rms error [%]	1E-3		
		Average error[%]	0.02		
Noise level	1E-18	Maximum error [%]	1E-3	Rms error [%]	1.7517636
Normalization level	1E-3	Iterat. number[pass]		Average error[%]	0.0167238
Maximum Error level	100	Iterat. number[fail]		Maximum error [%]	5.2488776
				Iterat. number[pass]	1
				Iterat. number[fail]	1
				Termination code	

Evaluation Method $\frac{(sim-meas)}{abs(meas)}$

Figure 4. Optimizer Setup / Status screen (downhill Simplex).

The calculated reflection in the control variables can also produce a least favorable result. Without this second rule the simplex would just oscillate between the two control variable levels.

3.2 Application

Contrary to the Levenberg-Marquardt method, you can see on the Figure 4 that there are only a few parameters to control with the downhill simplex method.

You find the classical error stop criteria (rms, average and max error) and the maximum number of function evaluation. This stop criteria allows you to limit the optimization time. Then the algorithm make is own way through the complexity of an N dimensional topography.

The “merit-function” used in our algorithm is the rms (root mean square) error, which is the most commonly used.

With this method, there is no necessity to define iteration fail or iteration pass, the control parameter is the number of function evaluations shown in the status column. To reduce the optimization time, the best way is to decrease the maximum function evaluation in the stop criteria column. To perform better optimization, the best way is to increase the maximum allowed function evaluation, what will also increase the optimization time.

4. Conclusion

This article, which will allow users to perform better optimization, also presents the new optimization method now available in ***UTMOST***. It makes the comparison between these two optmization methods, which have more advantages than drawbacks.

The Levenberg-Marquardt method is very powerful but is not very useful to use when the optimizer is not converged. This article, which give the basics of the theory also explains what parameters to change in the optimizer in order to help it to converge.

On the otherhand, the Downhill Simplex method is very easy to use and preserves the physical meaning of the spice parameters. As it is based on a very simple theory, it is very easy to understand and does not have any parameters to tune so complicated as in the Levenberg-Marquardt method.

One efficient solution is to use the both methods when the first selection does not give acceptable results.This is a new feature that will allow to perform better and faster optimizations.

The Simulated Annealing method, which has demonstrated important successes on a variety of global optimization problems will be the next step of the ***UTMOST*** optimizer. This method is based on a modified Downhill Simplex method. Simulated annealing is a global optimization method that distinguishes between different local optima. Starting from an initial point, the algorithm takes a step and the function is evaluated. When minimizing a function, any downhill step is accepted and the process repeats from this new point.

References

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[3] R. Desai, “Combining Simulated Annealing and local optimization for efficient global optimization.”, proceeding of the 9th Florida AI research symposium, pp. 233-237, June 1996.

[4] Numerical recipes, the art of scientific computing, 1992.

[5] www.multisimplex.com

Calendar of Events

January

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30	ASP DAC - Yokohama,Japan
31	ASP DAC - Yokohama,Japan

February

1	TCAD W/S - Scottsdale, AZ EDS Techno Fair-Yokohama ASP DAC - Yokohama,Japan
2	EDS Techno Fair-Yokohama ASP DAC - Yokohama,Japan
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13	Int'l Conf. on Microelectronics and Interface - Santa Clara, CA
14	Int'l Conf. on Microelectronics and Interface - Santa Clara, CA
15	Expert W/S - Scottsdale, AZ
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21	TCAD W/S- Chelmsford, MA Int'l Forum On Semicon Tech - Yokohama - Japan
22	Int'l Forum On Semicon Tech - Yokohama - Japan
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27	Compound Semiconductor Outlook - San Mateo, CA
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Bulletin Board

We Have a New Website

We invite you to check out the new Silvaco website fully reconstructed for easier navigation and use. We have developed a new products page that is much easier to navigate and check up on all the latest product releases and updates. You can check out news articles and recent events pertaining to Silvaco and all of its partners and corporate ventures. Silvaco's web site is still the place to come for your generic questions and answers to common problems. We hope you will visit the new site and feel free to offer any suggestions you may have.

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Default Prove-Up Hearing Set for Feb 6, 2002

Default hearing in Silvaco/Avant case is set for Feb. 6, 2002 for two counts, defamation and interference. Silvaco is seeking damage of $20M plus $6M in interest. The case is a retrial of the old Meta case, after the Appeals court remanded the case to the Superior Court to fix several mistakes from the first trail held in 1997.

For more information on any of our workshops, please check our web site at ***http://www.silvaco.com***

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Hints, Tips and Solutions

Mustafa Taner, Applications and Support Engineer

Q. How can I extract BSIM4 parameters using *UTMOST III* ?

A. The BSIM4_FI routine in ***UTMOST III*** MOS module should be used for data collection and BSIM4 SPICE model parameter extraction. The BSIM4_FI routine features are similar to the BSIM3_MG routine. The BSIM4_FI routine will collect four types of measured data curves from each device:

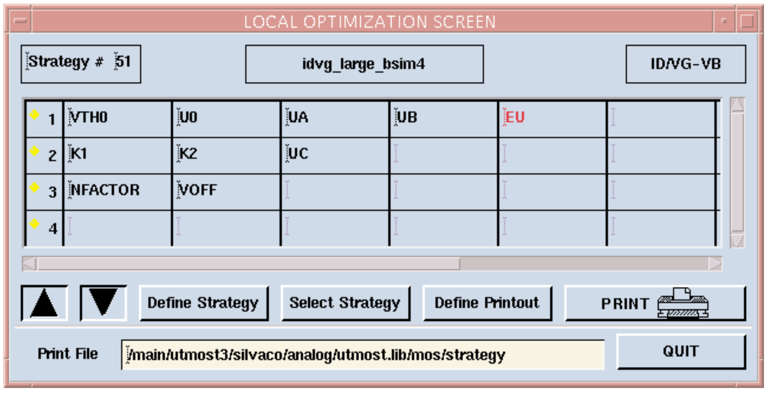
1) IDS/VGS @ low VDS bias.
2) IDS/VDS @ VBS=0V.
3) IDS/VGS @ High VDS bias.
4) IDS/VDS @ High VBS bias.

After the data collection is completed the menu item "Measure&extract" in the Fit Variables screen should be set to "1". This will enable the automatic parameter extraction and refinement process. (Figure 1.)

If the "Measure&extract" flag is set to "1" the extraction will start after the measurement is completed or after loading the log file and pressing the "Measure" button will start the extraction. The BSIM4_FI routine is very easy to use and the routine will extract and refine BSIM4 parameters with user inputting only few process related parameters (TOX, XJ, NCH) in to the fit and opt columns of the parameters screen. The extracted parameters will be copied into the parameters screen.

The BSIM4_FI routine is an automatic parameter extraction and refinement routine. The simulation and local/Global optimization should be performed using the ALL_DC routines. The measured data collected with BSIM4_FI routine can be shared by any ALL_DC routine.

After the parameter extraction is completed the quality of the fits should be examined by running the SPICE simulation against the measured data in ALL_DC routine. The further fine tuning of the parameters can be achieved by using the Local optimization strategies. The local optimization strategies between Satrtegy#51 and Strategy#60 are developed by Silvaco specifically for the BSIM4 model parameter optimization. (Figure 2.)

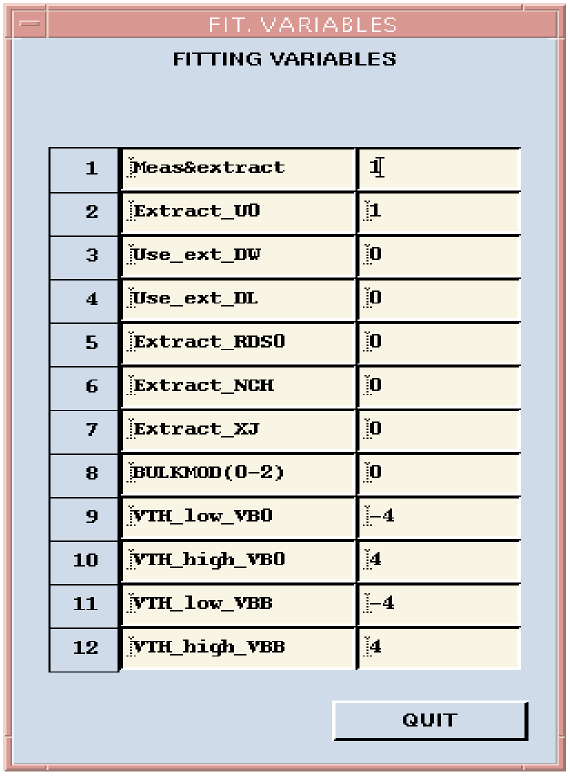


Strategy # 51 | idvg_large_bsim4 | ID/VG-VB

1	VTH0	U0	UA	UB	EU	
2	K1	K2	UC			
3	NFACTOR	VOFF				
4						

Print File /main/utmost3/silvaco/analog/utmost.lib/mos/strategy

Figure 2. Local Optimization Strategy#51 : idvg_large_bsim4



FITTING VARIABLES

1	Meas&extract	1
2	Extract_U0	1
3	Use_ext_DW	0
4	Use_ext_DL	0
5	Extract_RDS0	0
6	Extract_NCH	0
7	Extract_XJ	0
8	BULKMOD(0-2)	0
9	VTH_low_VB0	-4
10	VTH_high_VB0	4
11	VTH_low_VBB	-4
12	VTH_high_VBB	4

Figure 1. BSIM4_FI routine "Fitting Variables" screen.

Call for Questions

If you have hints, tips, solutions or questions to contribute, please contact our Applications and Support Department
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e-mail: *support@silvaco.com*

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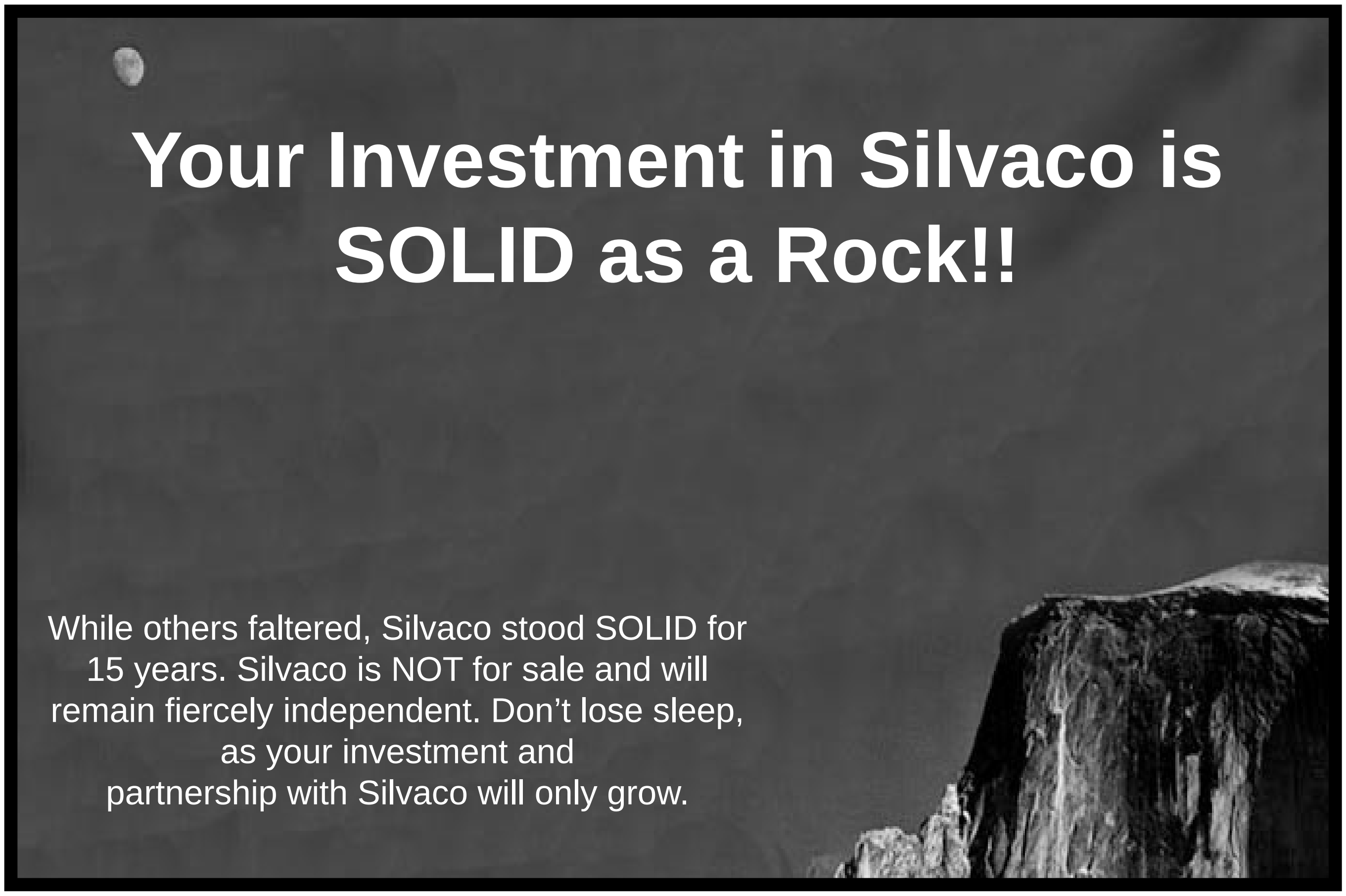
www.silvaco.com



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