Mextram Action Items

November 17, 2004

Priority 1

1.1 Consistency in Release Announcements

Problem

The Mextram model Level 504 is currently available in various commercial simulators in different and often outdated releases. A centralized and more consistent system for the announcements of the master Mextram release in the Philips SiMKIT library and corresponding implementations in the commercial simulators is required.

Realized

1. The central repository for the announcements of the current Mextram releases (including a log on modifications and bug fixes along the release history) has been established at TU Delft as Mextram User Group (MUG) web site
   `http://hitec.ewi.tudelft.nl/mug/`.

2. A table with the the detailed current status of the Mextram releases in commercial simulators is posted on the MUG web site. The contacts with the software companies has been established to regularly update the list.

Planned

1. A new mailing list of the Mextram users will be established (November 2004)
2. The latest release of the Verilog-A Mextram 504.5 (fully complaint with the SiMKIT Mextram 504.5) will be posted at the MUG web site. (November 2004).

1.2 Model Implementation Time

Problem

The standard period between two Mextram releases in the Philips SiMKIT library is about 6 months. In this period the bug reports from the users are collected and investigated. However, for the bugs that could have severe effect on the performance of the model and simulator

Mextram users would like to have more prompter bug fixing.

Planned

1. In the special situations when the reported bugs in the current SiMKIT release could seriously affect the model or simulator capabilities intermediate releases are also possible.

1.3 Introducing Thick IFO Flicker Noise

Problem

The interfacial oxide (IFO) suppresses the minority current (hole current for NPN transistors) into the polysilicon emitter and signifacantly increases the current gain. However, the IFO is at the same time the main source of the low-frequency noise for these devices [1].

Required

1. TI/UTA will provide equations and corresponding data for the model evaluation.

Planned

1. TU Delft will implement the governing noise equations into the experimental Verilog-A Mextram code and verify TI/UTA data.

1.4 Model for BE Zener breakdown

Problem

In the reverse operation of the bipolar transistors (e.g. reverse Early measurement) the Mextram equations for the transistor main current could significantly underestimate the measured emitter current. It is most likely due to the extra tunnelling current of the reverse base-emitter junction and Zener breakdown phenomena. Modeling of the emitter-base tunnelling current is already part of the Hicum and Vbic bipolar transistor models.

Comment

A stronger rationale for the implementation of these effects in the official Mextram release are still required. It seems that there is a quite limited number of cases where such a model is really necessary while everybody will pay the penalty for the computational overhead in the increased number of modeling equations.

Required

1. CMC members should provide additional data for the model justification.

Planned

1. TU Delft is going to test various implementations of the reverse BE tunnelling and Zener breakdown currents using measured data of the standard DIMES-04 silicon bipolar technology. The model will be implemented in the experimental Verilog-A code. (December 2004).

1.5 Operation Point Variables in SIMKIT Implementation

Problem

There is a request to enhance the list of the operation point variables provided by the SiMKIT library. The additional operation point variables which are currently requested and which are not in the current Mextram release 504.5 are

- terminal voltages: Vbe, Vce, Vse, Vbc, Vbs, Vsc
- terminal currents: Ie, Is

Realized

1. External currents Ib, Ic and current gain β_{DC}=Ic/Ib are already implemented in Mextram 504.5.
2. TU Delft is currently collecting the wishes on operation point variables from Mextram users.

Planned

1. As soon as the list of additional operation point variables is complete it will be considered for the implementation in the next Mextram release.

1.6 Improving Temperature Scaling of IS

Problem

The problem has been recognized in an attempt to design *bandgap voltage reference* circuits that essentially require accurate temperature scaling of the main saturation current I_S. To this end, Gummel-Poon model employs temperature scaling expression

$$I_S(T) = I_S(T_0) \left(\frac{T}{T_0}\right)^{\texttt{XTI}} \exp\left[\frac{\texttt{EG}}{V_T}\left(\frac{T}{T_0} - 1\right)\right] \tag{1.1}$$

where XTI and EG are model parameters. The expression (1.1) is identical to to the Mextram implementation if the parameters XTI and EG are identified from the corresponding Mextram parameters as

$$\mathtt{XTI} = 4 - \mathtt{AB} - \mathtt{AQBO} \tag{1.2}$$

$$\mathtt{EG} = \mathtt{VGB} \tag{1.3}$$

In Hicum, the parameter ZETACT seems to have the role of XTI. It is reported (Analog Devices) that in practice often happens that $\mathtt{XTI} > 3.5$ which constrains the values of Mextram parameters to $\mathtt{AB} + \mathtt{AQBO} < 0.5$. Since AB and AQBO are strongly correlated to the temperature scaling of other electrical parameters it seems that Mextram has limitations for the accurate band gap reference circuit design.

Proposed Solution

In principle an additional parameter e.g. DQBO, that corrects "Mextram XTI" as

$$4 - \mathtt{AB} - \mathtt{AQBO} \rightarrow 4 - \mathtt{AB} - \mathtt{AQBO} - \mathtt{DQBO} \tag{1.4}$$

could solve the problem and also provide the backward compatibility.

Planned

1. The proposed modification will be implemented in the next Mextram release (March 2005).

Priority 2

2.1 Mextram for "no buried layer" bipolar structures

Problem

Without a buried layer, lateral voltage drops in the collector causes forward biasing of the internal collector base junction and collector resistance is a strong function of both Vcb and Vcs. This makes fitting DC and AC in quasi saturation very difficult. Develop bias dependent physical model.

Realized

- Intersil has provided measured data.
- The difficulties to simultaneously model DC and Ft data at high injection has been demonstrated.

Planned

- TU Delft is looking into the problem and will report on the proposed solutions.

2.2 Complete Verilog-A Mextram Release

Problem

The current Mextram Verilog-A implementation is outdated.

Planned

1. A new Verilog-A Mextram release 504.5 will appear in November (Beta version is already available). It will contain full Mextram description including noise (November 2004).

2.3 Improving the Simulation Speed

Problem

There are considerations about the computational performance (simulation speed) of Mextram.

Planned

1. Simplify (linearize) some of the exponential terms in the existing Mextram equations and code to improve the efficiency in model evaluation.
2. A thorougfull analysis of the model smoothness and its influence on the the average number of iterations will be performed.

Priority 3

3.1 Introducing a full CS leakage model

Problem

CS leakage should be physically modeled instead of just using ISS as flag (e.g. code in an existing diode model could be used).

Required

CMC members should provide data or stronger rationale to demonstrate the need for modification still required.

3.2 Adding Substrate Network

Problem

Mextram is missing a substrate network.

Comment
The presence of the proposed simple substrate network could be important for accurate parameter extraction procedure and model verification in a wide frequency range. However, it could make difficult to attach more sophisticated substrate networks. On the other side, the same effect could be archived by the corresponding substrate sub-circuit outside of the model.

Proposed solution

Substrate network consisting of parallel resistance Rp and capacitance Cp, and series resistance Rs. (Model parameters: Rp, Cp, and Rs. Instance parameters: Rp, Cp, and Rs override).

3.3 Introducing Time Dependent Impact Ionization

Problem

In the short interaction with the electric field the carrier energy (and ionization coefficients) are not in equilibrium with the electric field. Short interaction could be non only due to the localized electric fields (nonlocal effects) but also due to the rapid variation of the field. There is a strong interest of TI to have such a model in Mextram.

Planned

1. TU Delft is working together wit TI on the SRC project proposal that will cover this subject.

3.4 Improving SiGe modeling features

Problem

The specific SiGe features of Mextram are develop for ramped Ge profile model. More generic Ge modeling equations are often needed.

Required

- CMC members should provide data that demonstrate problem and the model insufficiency.

3.5 Parameter extraction from TCAD Doping Profiles

Problem

Tool for direct evaluation of Mextram parameters from 1-D or 2-D doping (potential and carrier) profiles is required.

Planned

- TU Delft is trying to establish a new MSEE thesis on this subject. It will be based on already existing approaches to perform such an extraction of Mextram 503 parameters.

3.6 Auburn RF Noise Model

Problem

Improve the Mextram noise model by introducing Auburn RF Noise Model

Planned

- The Auburn RF Noise Model will not be ready for 1-2 years. It will be tested as soon as it is ready.

3.7 GaAs Modeling Features in Mextram

Problem

Introduce GaAs Modeling features in Mextram, e.g. decrease in fT as function of Vcb.

Planned

- Some activities already exist in the modeling of BC depletion capacitance with overshot effects.

Bibliography

[1] M.M.U. Hoque, Z.Celik-Butler, D. Lan, D. Weiser, J. Trogolo and K. Green, "Effect of Interfacial Oxide Thickness on $1/f$ Noise in Polysilicon Emitter BJTs," *IEEE Trans. Electron Device*, Vol. 51, No. 9, Sep. 2004.