Theory for an Algorithm to Extract Device Model Parameters with High Confidence from Nonlinear Models

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BRIEF ABSTRACT

We have developed an efficient algorithm for automatically extracting model parameters from complex nonlinear device models. Furthermore, this algorithm determines the confidence interval of each of the extracted model parameters and identifies regions where more experimental data is needed to increase the confidence level.

DETAILED DESCRIPTION

With the constant quest for reliable, high performance integrated circuits, the device geometries have been scaled down and the level of integration has been increased. These two factors have necessitated the development of a numerically efficient but complex analytical model to represent the electrical behavior devices. Also other developments such as automated circuit optimizers and silicon compilers have put requirements of scalability on the analytical device model. The experimental determination of the parameters of a nonlinear device model is a nontrivial task. Here we report the theory and an efficient algorithm for the experimental determination of model parameters. *The algorithm establishes a level of confidence for each parameter and automatically eliminates ill-determined parameters resulting in a more reliable and accurate set. Also it identifies regions where more experimental data is needed in order to more accurately extract all model parameters.*

The algorithm uses the modified gauss method to extract the model parameters and a procedure based on information theory to check the validity of the parameters. The variance and covariance matrices are used to do an in depth analysis of the parameters. Confidence intervals and unceratinties are calculated for each parameter and any ill-determined parameters, those with a large confidence interval, are eliminated and the remaining parameters are used to reextract a more reliable and accurate set of parameter from the experimental data. Figure 1 compares the predictive power of two parameter sets: the initial fitted set, where no ill-determined parameters have been defaulted, and a minimal parameter set in which all parameters have been accurately extracted and verified. These two parameter sets were used to predict the DC behavior of a $25/1.2\mu m$ MOSFET whose IV characteristics were not used to extract the parameters. As can be seen, the parameter set with no ill-determined parameters gives much better agreement to the experimental data. The confidence interval is also used to create a model window which accounts for the numerical deviations in the parameters. A normalized covariance matrix is used to get a qualitative understanding of the degree of coupling or correlation between parameters. This information is used to evaluate the model and locate problems.

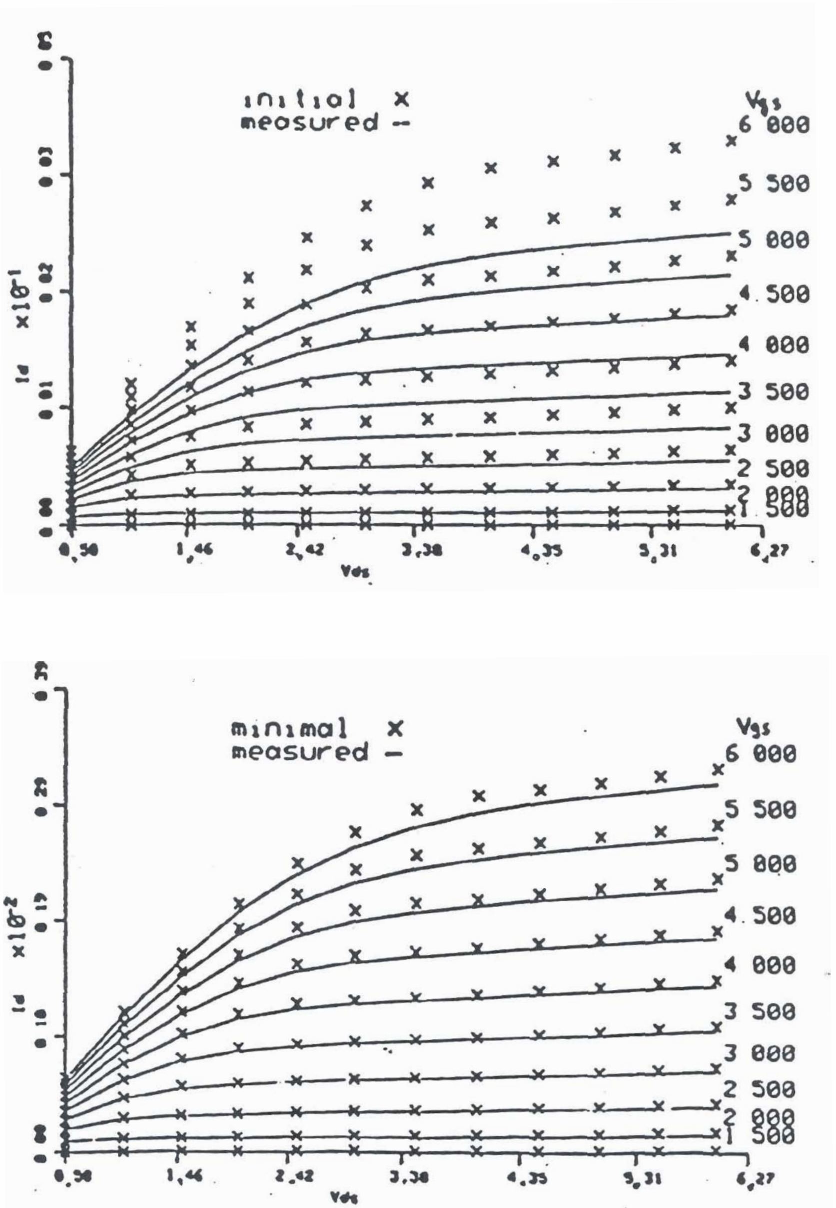

Fig. 1. Comparison of measured and predicted I-V characteristics of a 25/1.2-μm n-channel transistor using the full parameter set including ill-determined parameters and the minimal set.

TABLE I

COMPARISON OF THE PREDICTIVE POWER OF AN INITIAL FITTED PARAMETER SET (INCLUDING ILL-DETERMINED PARAMETERS) AND A MINIMAL SET, AFTER ALL ILL-DETERMINED PARAMETERS HAVE BEEN DEFAULTED

The parameter sets were extracted from three n-channel devices, widths and lengths (in micrometers) of 25/4, 2/1, and 4/5. Data were taken at 0 to 6 V on gate and drain and 0 to −3 V on the substrate. The two parameter sets were then used to predict the I-V characteristics of the MOSFET's listed. There were 25 parameters in the initial set and 14 in the minimal set.

Width/Length in microns	Average Error Before Elimination	Average Error After Elimination
50/1	18%	7%
25/3	5%	4%
25/2	12%	6%
25/1.5	19%	7%
25/1.2	24%	7%
3/1	76%	16%
2/5	24%	11%
3/5	5%	4%