

# HiSIM\_HV Single Geometry Parameter Extraction with Automated Utmost IV Optimization

## Introduction

HiSIM\_HV model parameter extraction using Utmost III is explained in another Silvaco application note [1]. This application note will detail Utmost IV optimization setup for HiSIM\_HV single geometry parameter extraction which could be automated as the sequential flow.

The Utmost IV optimization module is powerful, and yet the sequence itself has to follow the HiSIM\_HV model concept. The drift resistance model flag is `CORSRD = 3` in this note. HiSIM\_HV v.1.1.1 which requires SmartSpice 3.11.30.C and the later versions is used.

## Measurement Data Requirements

A part of Utmost III application note [1] for the data requirements is excerpted in the following, as this has a significant impact on the optimization efficiency and the quality. Utmost IV version 1.4.13.R and later versions support data import from the Utmost III `AL_IDVGB` routine logfile. Utmost IV native data format is universal and the data conversion scripts are available for the third party tool users.

In addition to the usual measurement data of `Ids/Vds` and `Ids/Vgs` at the linear and saturation regions, additional `Ids/Vgs` curves under several drain voltages are preferable to ensure HiSIM\_HV model parameter extraction. High voltage application devices, such as LDMOS and extended drain MOS (XDMOS) for which HiSIM\_HV model was developed, would exhibit such characteristics as a strong quasi-saturation effect, trans-conductance reduction in the high gate voltage region, and a self-heating effect. The drain voltage conditions for `Ids/Vgs` should be selected to cover these regions.

For this purpose Utmost III 25.1.1.C and the later versions are implemented with a new extraction routine named `AL_IDVGB`. `AL_IDVGB` data are used mainly for HiSIM\_HV parameter optimization. `ALL_DC` `Ids/Vds` curves are used for the final optimization step.

The LDMOS data set is less flexible as the channel length is fixed and the body contact is shorted to the source terminal. The test structure with the isolated source and body contacts is desirable for HiSIM\_HV parameter extraction which needs accurate substrate concentration parameters.

The XDMOS data set would be suitable as the large Larray and Warray geometry structures could be available with isolated source and body terminals.

## Utmost IV Optimization Sequence: The Single Geometry

Utmost IV optimizer selection for this note is a hybrid of the genetic and Levenberg-Marquardt algorithms.

### 1. HiSIM\_HV parameter extraction using the linear region `Ids/Vgs-Vbs`

#### Data subset

The linear region `Ids/Vgs-Vbs` for a reference device is used for the first step of parameter optimization.

**Optimization Setup Property: `idvg_large_1` (Figure-1)** HiSIM\_HV basic device parameters such as **`NSUBC`** (substrate impurity concentration) and **`VFBC`** (flat band voltage), and the low field mobility parameters of **`MUECB0`** and **`MUECB1`** (Coulomb scattering) are optimized first. Also, the **`XLDLD`** (gate overlap length at drain side) parameter needs to be optimized for the effective channel length determination. **`NDEP`** (depletion charge contribution on effective-electric field) is optional for the high voltage devices. Maximum and minimum values of **`NSUBC`** could be defined according to the process specification, as the wide range could lead to the unnecessary search of the genetic algorithm optimization.

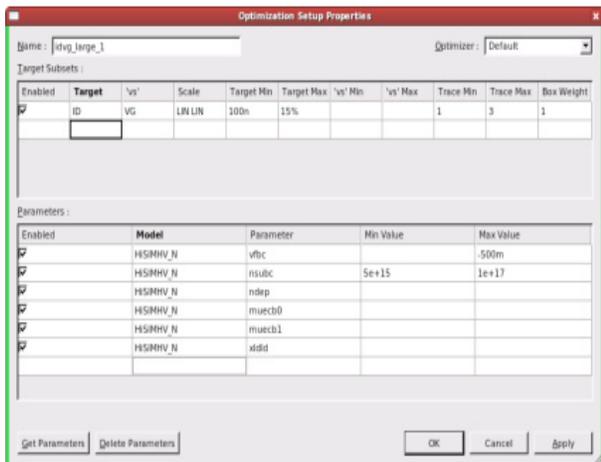


Figure-1 Utmost IV Optimization Setup Property for idvg\_large\_1.

The target drain current region is around the on-set of the threshold voltage, and the number of target traces is at least 3. **NSUBC** in HiSIM\_HV model is a true substrate concentration which determines both the threshold voltage and the voltage shift due to the Vbs (body bias effect). This step is quite significant as these parameters from the HiSIM\_HV model foundation.

**Optimization Setup Property: idvg\_large\_2 (Figure-2)**

The next step is to determine HiSIM\_HV low field mobility parameters. The target drain current region is difficult to be define clearly as the drain current of a high voltage device is influenced by the drift region resistance. What is clear is that the entire current region shouldn't be used for low field mobility parameter optimization for the high voltage device. The mobility effect would be overestimated for the current decrease which is caused by the drift region resistance. The target trace is Vbs = 0 for the mobility parameters.

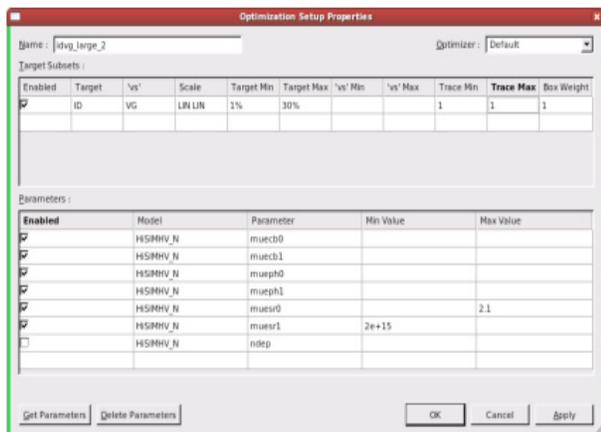


Figure-2 Utmost IV Optimization Setup Property for idvg\_large\_2 .

**Optimization Setup Property: idvg\_large\_hisimhv (Figure-3)**

Several HiSIM\_HV drift resistance parameters such as **RDVG11** and **RDVG12** (Vgs dependence of RD) are optimized for the linear region Ids/Vgs-Vbs to get the initial values even if the resistance effect might be small for the region. Also, the **RDVB** (Vbs dependence of RD for CORSRD =1,3) and **RD22** (Vbs dependence of RD for CORSRD=2,3) parameters are optimized for the Vbs influence on the drain current.

The target drain current is the large current region with multiple traces.

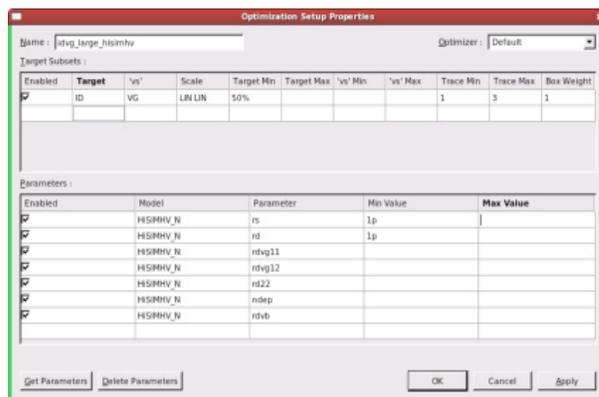


Figure-3 Utmost IV Optimization Setup Property for idvg\_large\_hisimhv.

**Optimization Setup Property: idvg\_large\_hisimhv2 (Figure-4)**

This setup is a combination of the low field mobility and the drift resistance model parameters. The target drain current is for the entire above threshold region including the Vbs variation. This is to balance both sets of model parameters for which initial values are optimized independently for the separate regions.

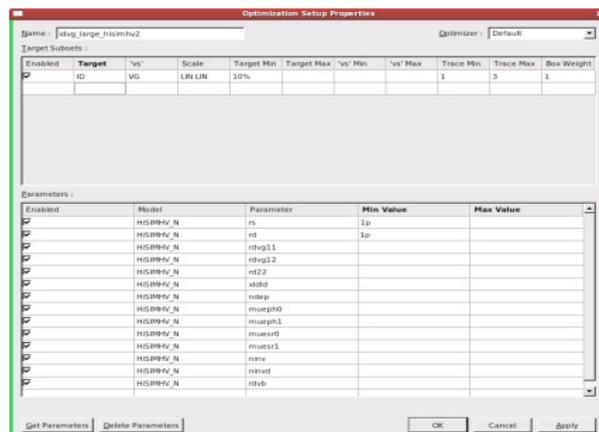


Figure-4 Utmost IV Optimization Setup Property for idvg\_large\_hisimhv2.

## 2. HiSIM\_HV Parameter Extraction Using Ids/Vgs at Several Vds Conditions

### Data subset

The next step, which is the major part of HiSIM\_HV parameter extraction is to use Ids/Vgs at several Vds bias conditions for the drift resistance parameters. This is the key step in obtaining a good model for the quasi saturation expression, the trans-conductance reduction at the large Vgs and the self-heating effect of the high voltage device. The number of Vds bias steps for the Ids/Vgs should be increased with the additional measurement when the Ids/Vds-Vgs expression lacks the characteristics with this step completed. Otherwise, the subsequent Ids/Vds-Vgs optimization would be lengthy and the fit would be low quality.

### Optimization Setup Property: idvg\_hvds\_hisimhv1 (Figure-5)

Velocity parameters such as VMAX, VOVER and VOVERP need ids/vgs at the large drain voltage for the relatively small Vgs. At the same time, almost all HiSIM\_HV drift resistance model parameters should be selected, as the resistance effect would become prominent with the increase of drain bias. The parameter decomposition is unrealistic as HiSIM\_HV drift resistance equations interact.

The target drain current region is used for extracting proper initial parameter values (excluding the velocity parameters) and it is smaller compared to the middle current region. There could be a large number of target traces when the Vbs effect on the drift resistance is observed.

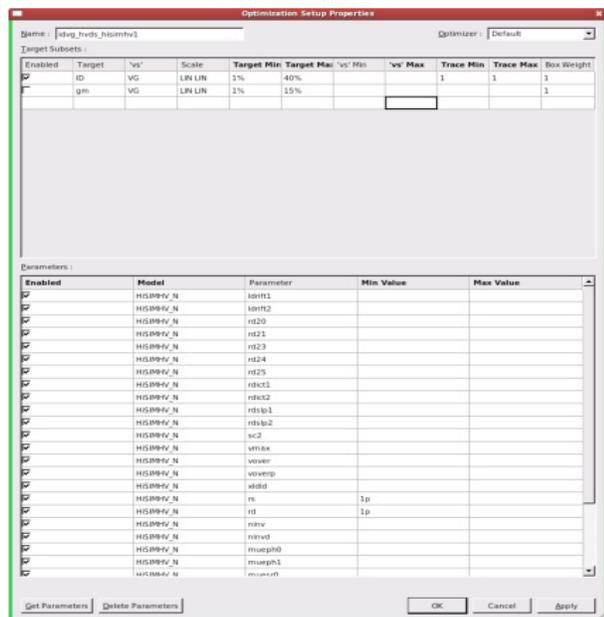


Figure-5 Utmost IV Optimization Setup Property for idvg\_hvds\_hisimhv1.

### Optimization Setup Property: idvg\_hvds\_hisimhv2 (Figure-6)

The model parameters are almost the same as used in the previous step. The difference is the target drain current region which is at the large Vgs voltage. The drain current includes such effects as quasi-saturation, self-heating and impact ionization with the increasing drain bias. The RTH0 (thermal resistance) parameter should be optimized if the self-heating effect appears in Ids/Vds-Vgs.

Using near maximum and the middle to the maximum drain current regions help improve modeling of the trans-conductance (gm) degradation at the large Vgs.

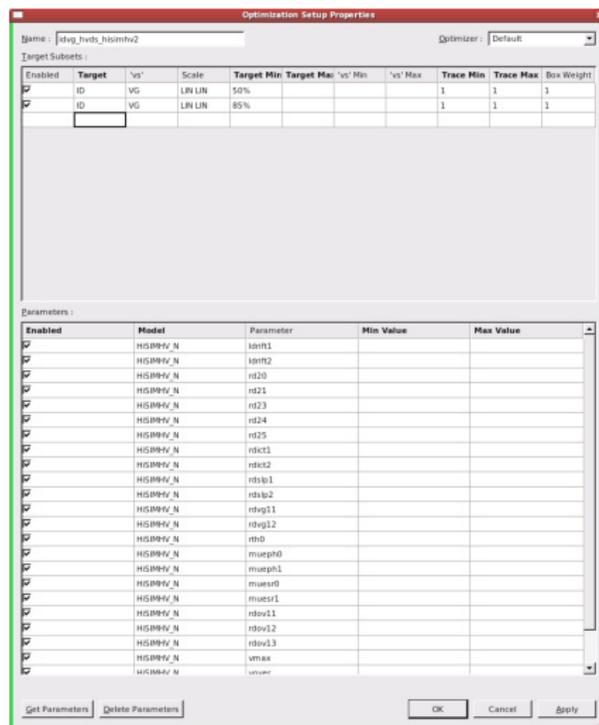


Figure-6 Utmost IV Optimization Setup Property for idvg\_hvds\_hisimhv2.

## 3. HiSIM\_HV Parameter Extraction Using Ids/Vds-Vgs

### Data subset

The final step for single geometry HiSIM\_HV parameter extraction is to use Ids/Vds-Vgs. The previous step of using Ids/Vgs-Vbs under several Vds conditions should produce a reasonable fit for Ids/Vds-Vgs when the conditions cover the phenomena specific to the high voltage devices mentioned previously. The previous steps have to be checked when the result fails to depict the distinctive points.

**Optimization Setup Property: idvd (Figure-7)**

Almost all HiSIM\_HV model parameters are used. The exceptions are NSUBC, VFBC and the body bias effect parameters of drift resistance. This is to tune the model parameters slightly for Ids/Vds-Vgs characteristics based on the previously optimized parameters using Ids/Vgs-Vbs. The optimizer selection could be Levenberg-Marquardt as the parameter values optimized so far would be reasonable as the initial set. The target drain current could be separated for such concerned regions as quasi-saturation, trans-conductance (gm) reduction at the large Vgs, negative drain current slope due to the self-heating and impact ionization current increase at the large Vds.

**Summary**

Utmost IV optimization setups were explained for HiSIM\_HV single geometry parameter extraction. HiSIM\_HV parameter extraction could become complicated, however, the Utmost IV genetic algorithm combined with efficient Levenberg-Marquardt optimizers enable automated extraction. Although the initial stage of Utmost IV HiSIM\_HV parameter optimization requires careful parameter selections with the appropriate target regions, no intensive setup is necessary for the rest of the process. The Utmost IV optimization module is equipped with fast simulation capability to enable the global parameter search required by the genetic algorithm optimizer.

**Reference**

- [1] Silvaco application note 2009-038 HiSIM\_HV Local Optimization Templates Prepared for Utmost III

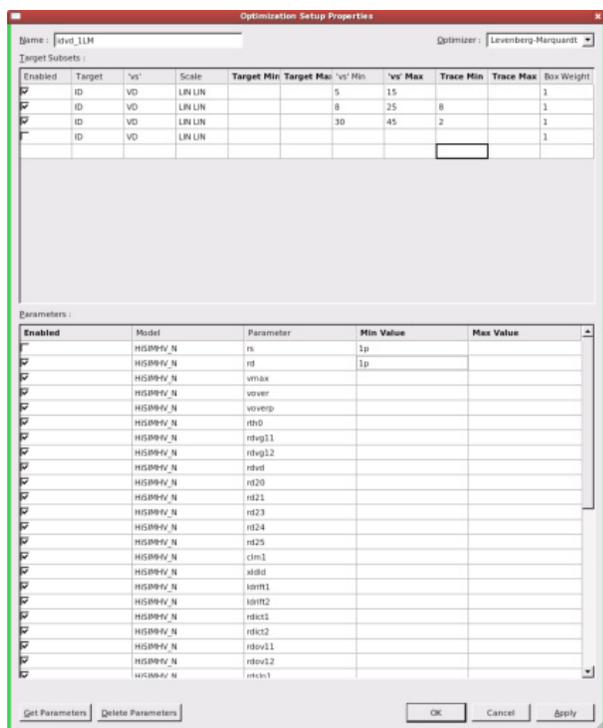


Figure-7 Utmost IV Optimization Setup Property for ids/vds.