

HiSIM_HV Temperature Modeling for Multi-Geometry LDMOS Comparison of the Temperature Flag Options

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Abstract – This paper will report HiSIM_HV [1] model parameter extraction for the multi-geometry LDMOS devices at several temperatures and the result comparison of the temperature flag options. The extraction procedure was implemented on SILVACO parameter extraction tool UTMOST IV [2] which ran it sequentially to get the model parameters with no user intervention. The sequence was applied to three LDMOS technology devices. One data set was based on SILVACO TCAD [3] simulation results. The other two were from the silicon data.

I. Introduction

HiSIM_HV 1.2.0 model release (Oct. 2009) was accepted initially among the Compact Modeling Council [4] community. Then, both the independent device manufactures and the process design kit (PDK) users recognized the performance. Now, an issue for HiSIM_HV series of models becomes the productivity of the model parameter extractions as the increasing number of the circuit designers demands the best performance models on time.

The multi-geometry LDMOS device modeling at several temperatures had challenged HiSIM_HV 1.2.2 about the temperature scaling. A good nominal temperature model had sometimes failed to preserve the behavior when the temperature model was generated. The past extraction procedure was reviewed and reorganized to overcome the challenge.

II. Traditional Extraction Flow

The approach was that the multi-geometry model was generated at the nominal temperature and the temperature model parameters were optimized for other temperature data sets. It worked sometimes and failed in other occasions to obtain the proper temperature behavior. The incidents at the last moment of the parameter extraction activities obstructed the scheduled releases of the SPICE model libraries.

There are four temperature flag options in HiSIM_HV 1.2.2 [5]. The option used for the traditional approach was $\text{cotemp} = 2$ which included a temperature induced by the device self-heating effect into such HiSIM_HV model components as rd0 , rdvd , vmax and ninvd . The selection among four options was based on a preconception that the self-heating device temperature could influence the model

parameters. Also, the inconsistent results made the comparison impractical.

III. Approach of the Temperature Modeling for the Multi-Geometry LDMOS

The reorganized flow is to extract the initial temperature model parameters at the intermediate step for a reference geometry device. The model parameters used include both the reference model parameters and the temperature model parameters. The succeeding steps are as usual: the multi-geometry optimization at the nominal temperature, then the temperature modeling for all geometry devices and temperatures. The procedure was generated with the temperature flag of $\text{cotemp} = 2$.

IV. Results and Observation

The procedure was applied to three LDMOS technology devices for this report. And all four HiSIM_HV temperature flag options were tried. Also, two optimization flows were executed. The step of the temperature model parameter optimization was the same, but in one flow, the temperature parameters and the reference model parameters were optimized at the same time. In another one, the temperature model parameters only were optimized, then, both the temperature model and the reference model parameters were included for the optimization. The former and the latter flows are denoted respectively as the flow A and B in the following tables. The rms error numbers for the idvd and idvg simulations done with HiSIM_HV 1.2.2 are summarized.

1. TCAD data set: V_{ds} : 45 v, V_{gs} : 0 – 10 v, -40C, 27C, 150C
 $L_{draw} = 5 \text{ um}$, $W_{draw} = 30\text{um}, 50\text{um}, 100\text{um}$

Flow A:

| cotemp | idvd | idvg |
|--------|-------|-------|
| 0 | 1.57% | 2.14% |
| 1 | 1.49% | 1.38% |
| 2 | 1.33% | 1.46% |
| 3 | 1.74% | 1.96% |

Flow B:

| cotemp | idvd | idvg | |
|--------|-------|-------|--------------------------------|
| 0 | 1.14% | 1.62% | |
| 1 | 1.52% | 1.55% | |
| 2 | 2.51% | 2.27% | idvd_idvg_init0_tp is no good. |
| 3 | 1.31% | 1.58% | |

Note on TCAD data set:

The single geometry HiSIM_HV model parameters were extracted using the 2D TCAD data sets which included the temperature conditions. The model library was edited for the geometry scaling parameters. Then, the multi-geometry device data sets were simulated using the modified model library.

2. Silicon data set I: Undisclosed voltage and geometry.
4 devices at -55C, 27C, 85C and 150C.

Flow A:

| cotemp | idvd | idvg | |
|--------|-------|--------|------------------|
| 0 | 7.99% | 8.62% | |
| 1 | 8.77% | 7.99% | |
| 2 | 8.63% | 8.78% | |
| 3 | 6.66% | 10.16% | -55C isn't good. |

Flow B:

| cotemp | idvd | idvg | |
|--------|--------|-------|-------------------|
| 0 | 9.57% | 6.31% | |
| 1 | 15.69% | 4.01% | : confirmed twice |
| 2 | 10.85% | 5.80% | |
| 3 | 10.54% | 7.09% | |

Note on the silicon data set I:

The device shows the prominent impact ionization current. Also, the sub-threshold idvg at the linear region exhibits the hump type characteristics.

3. Silicon data set II: Undisclosed voltage and geometry.
5 devices at -50C, 25C and 125C.

Flow A:

| cotemp | idvd | idvg | |
|--------|-------|-------|------------------------|
| 0 | 2.43% | 5.87% | |
| 1 | 2.52% | 6.98% | |
| 2 | 2.91% | 8.95% | : idvglin_tp conv. pbm |
| 3 | 2.50% | 6.41% | |

Flow B:

| cotemp | idvd | idvg | |
|--------|-------|-------|------------------------|
| 0 | 2.77% | 8.43% | : idvglin_tp cov. pbm. |
| 1 | 2.61% | 6.76% | |
| 2 | 2.70% | 7.98% | : conv. pbm |
| 3 | 2.84% | 8.13% | |

Note on the silicon data set II:

The device shows the typical quasi-saturation high voltage characteristics which resemble to the TCAD data set.

The execution times of the flow A cotemp = 0 on a 2.13GHz dual core machine were 62 min., 139 min., and 99 min., respectively for TCAD data set, silicon data set I and II.

The flow A and B comparison for each data set at the same cotemp flag option is interpreted that the flow A is better in most cases, especially for the silicon data set I which drain current exhibited the impact ionization effect. The initial optimization of the temperature model parameters combined with the reference model parameters could give the balance among them.

The difference of the cotemp flag option in the flow A isn't apparent in the TCAD data and the silicon data set II. Although the cotemp = 3 in the silicon data set I showed the smallest rms error for the idvd, the characteristic plots were a bit degraded in most cases, some were in the saturation and the others were in the quasi-saturation regions.

The observation of the rms error numbers and the characteristic plots suggest that the temperature flag option of cotemp = 0 which is the default is the most appropriate for extracting HiSIM_HV 1.2.2 model parameters.

V. Conclusion

HiSIM_HV 1.2.2 model parameter extraction procedure for the multi-geometry LDMOS devices at several temperatures was reported. Three example results comparing the HiSIM_HV temperature flag options were explained.

References

- [1] HiSIM Research Center: HiSIM_HV
http://home.hiroshima-u.ac.jp/usdl/HiSIM_HV/
- [2] SILVACO, Inc. UTMOST IV User's Manual
<http://www.silvaco.com>
- [3] SILVACO, Inc. "ATHENA User's Manual" and "ATLAS User's Manual"
<http://www.silvaco.com>
- [4] Compact Modeling Council
<http://www.geia.org/CMC-Introduction>
- [5] SILVACO, Inc. SPICE Models Manual
<http://www.silvaco.com>

The excerpt of the cotemp flag follows.

| | Rd0,temp | Rdvd,temp | Vmax | Ninvd | |
|-----------|----------|-----------|------|-------|-----------|
| COTEMP=0: | T | T0 | T0 | T0 | (default) |
| COTEMP=1: | T0 | T0 | T0 | T0 | |
| COTEMP=2: | T | T | T | T | |
| COTEMP=3: | T | T | T0 | T0 | |

T includes the temperature induced by self-heating effect. T0 is the temperature defined in Section 11.1.19 Temperature Dependence.

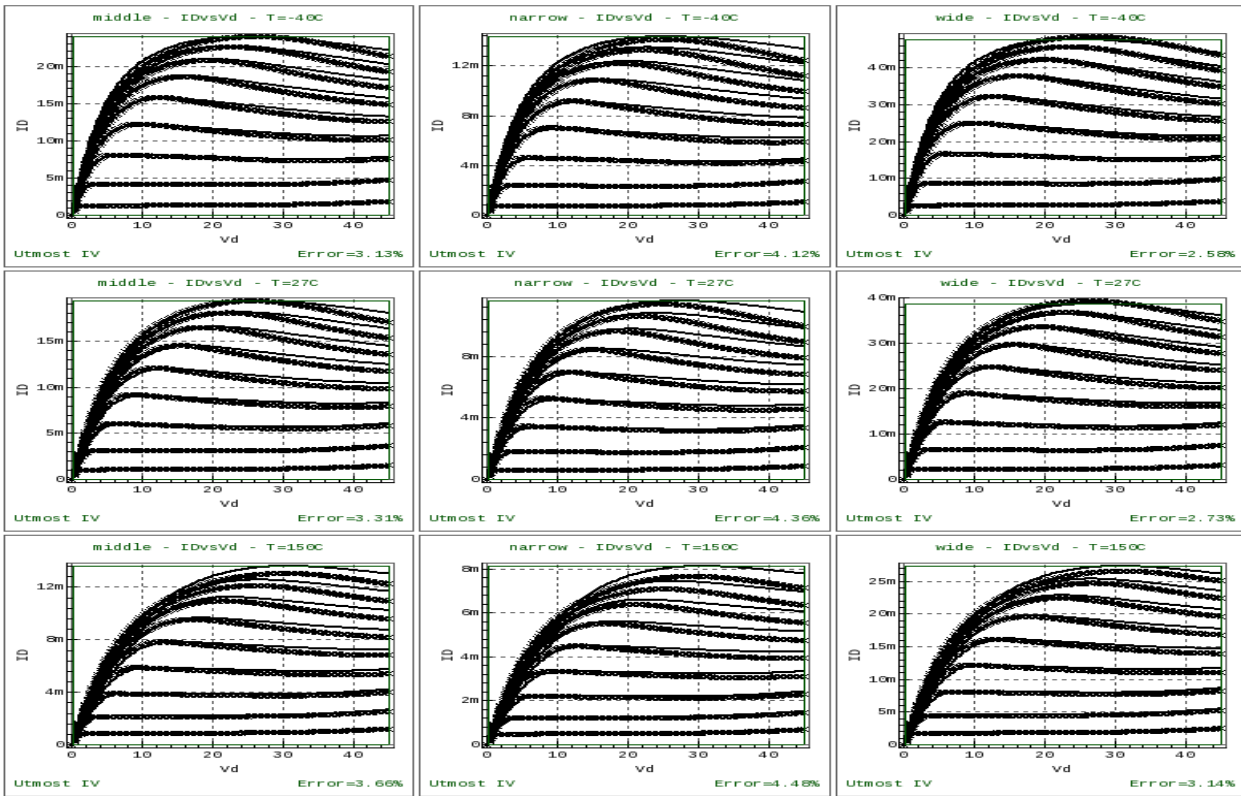


Figure 1: HiSIM_HV 1.2.2 model parameter extraction example: Id-Vd curves
 solid lines: TCAD data marked lines: HiSIM_HV 1.2.2, cotemp = 0, traditional flow

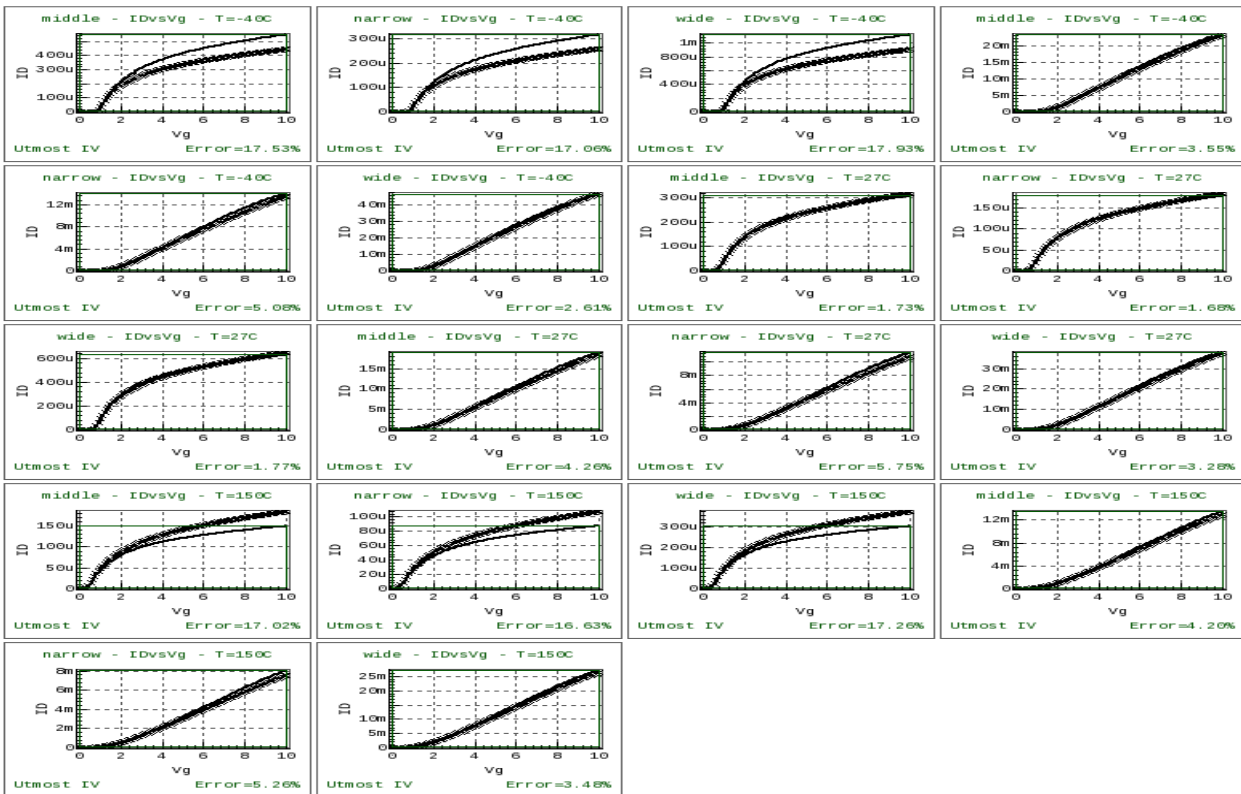


Figure 2: HiSIM_HV 1.2.2 model parameter extraction example: Id-Vg curves
 solid lines: TCAD data marked lines: HiSIM_HV 1.2.2, cotemp = 0, traditional flow

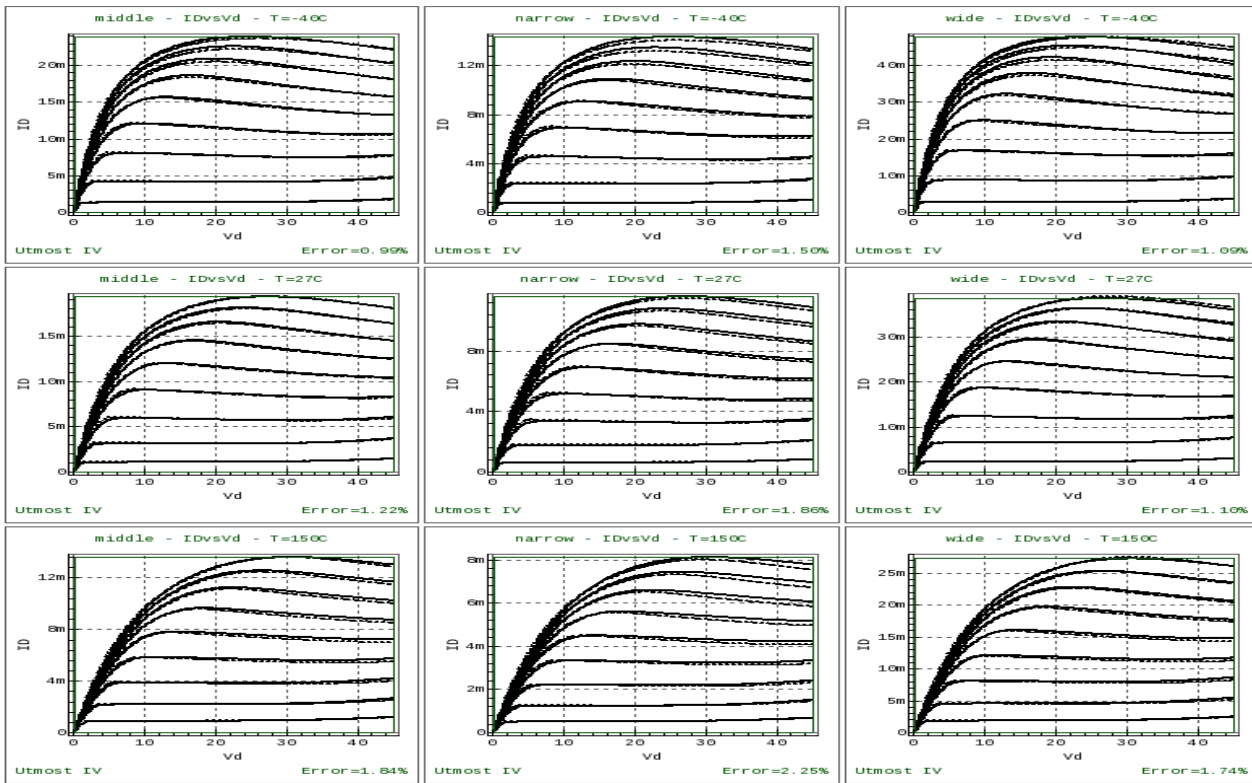


Figure 3: HiSIM_HV 1.2.2 model parameter extraction example: Id-Vd curves
 solid lines: TCAD data dashed lines: HiSIM_HV 1.2.2, cotemp = 0, flow A

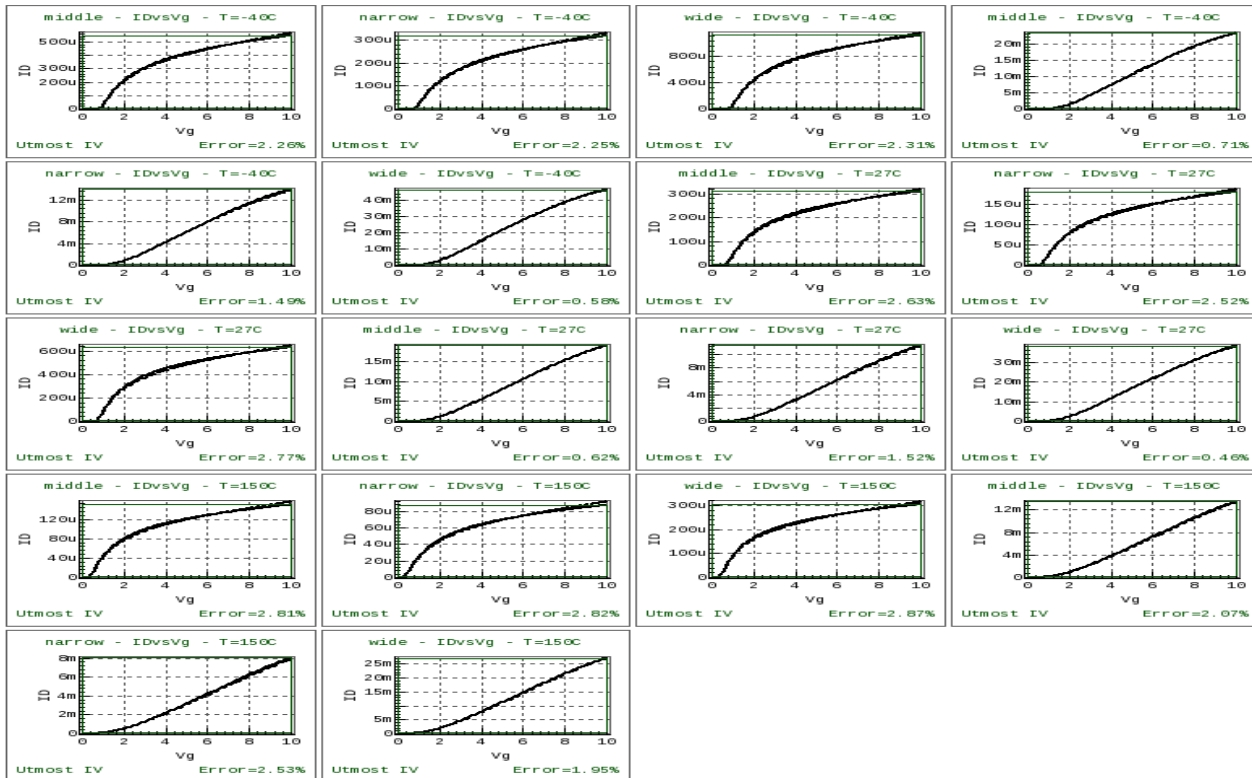


Figure 4: HiSIM_HV 1.2.2 model parameter extraction example: Id-Vg curves
 solid lines: TCAD data dashed lines: HiSIM_HV 1.2.2, cotemp = 0, flow A