A New Self-heat Modeling Approach for LDMOS Devices

Hitoshi Aoki and Haruo Kobayashi
Gunma University, 1-5-1 Tenjin-cho, Kiryu, Gunma 376-8515, Japan.
h.aoki@gunma-u.ac.jp

Self-heating effects have been discussed for more than one decade and their models were also proposed. Self-heating effects are mainly occurred in bipolar transistors, SOI-MOSFETs, and power MOSFET devices, which significantly affect the current–voltage characteristics of the device, and cause negative differential resistance in the characteristics and complex behavior at frequencies where the internal device temperature can follow the applied signal.

There are mainly two types of SPICE compact modeling approaches. The one is to use thermal feedback calculations based on small signal admittance parameters, that have been applied for bipolar transistors\(^1\). The other is made up of separate thermal network\(^2\), which demands extra computation time and may cause convergence problem, that have been used for SOI-MOSFETs and power MOSFET devices. In order to improve the accuracy and convergence of the self-heating (SH) simulations in DC, transient, and small signal AC (S-Parameter) domains a new SH model, which does not require a separate thermal network, has been developed and implemented in BSIM3 model to simulate an LDMOS device.

With the correct isothermal \(I-V\) characteristics and thermal resistance, a large-signal model can produce the correct steady-state behavior, but for circuit modeling, the correct dynamic behavior is also required. The model is based on the DC and isothermal conductance \((g_{dc} \text{ and } g_{iso})\) formulations as:

\[
R_{th0} = \frac{g_{dc} - g_{iso}}{\frac{\partial T}{\partial T_{dev}}[g_{iso} V_{ds} + I_{ds}]} \quad (1), \quad \Delta T = I_{ds} \cdot V_{ds} \cdot \left(\frac{R_{th0} + \Delta T}{1 + j \cdot \omega \cdot R_{th0} \cdot C_{th}}\right) \quad (2),
\]

and DC drain current with SH, \(I_{ds,th}\) as:

\[
I_{ds,th} = \frac{I_{ds}}{1.0 + \frac{\Delta T}{T_{dev}}} \quad (3).\]

Where \(R_{th0}, K_{th}, C_{th}, I_{ds}, V_{ds}, \text{ and } T_{dev}\) are thermal resistance, coefficient, and capacitance, DC drain current and voltage, nominal temperature, respectively. After solving equations (1), (2), and (3), we can obtain drain current with SH effect.

Based on equation (2) transient and small signal SH model equations are formulated.

The proposed model has been extracted with DC, CV, and S-parameter measurement of LDMOS devices, then verified by DC, transient, and S-parameter simulations. As shown in Fig. 1, the results show excellent agreements between measured and simulated data.

![Fig. 1 Measurement and simulation verifications of LDMOS (\(L_{\text{mask}}=5\mu\text{m}, W_{\text{mask}}=20\mu\text{m}\)) for (a) Pulsed \(I_{ds}, V_{gs}\) and (b) \(S_{21}\)-Frequencies.](image)

References