Unified One-Iteration Parameter Extraction for Length/Width-Dependent Threshold Voltage and Unified Drain Current Model

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Outlines

- Modeling methodology
- Model parameter extraction methodology
- Model calibration procedure
- Model verification
- Conclusion
Modeling Methodology

- MOSFET DC operation is governed by (input) “voltage equation” and (output) “current equation”.
- Formulated based on “pinned”-\( \phi_s (V_t\)-based). Single-piece \( I_{ds} \) is the sum of unified regional \( I_{d,str} \) and \( I_{d,sub} \).
- Single-piece extremely compact form. Incorporates all major SC/NW/HF effects into the effective quantities.
- Ensure model accuracy, symmetry and continuity.

\[
I_{ds} = \beta_n V_{ge} = \beta_n \left( V_{gg} + V_{gd} \right) = I_{drift} + I_{diff}
\]

\[
V_{ge} = f[V_g, V_d, V_s, V_b], \quad \beta_n = \mu_{eff} C_{ox} W_{eff} / L_{eff}
\]
Model Parameter extraction Methodology

- Model calibration has 2 stages:
  Technology characterization
  (Technology data, $V_t - L / W$)
  Device Characterization
  ($I-V$ data @ corner geometry/bias)

- Model parameters are characterized into 2 categories:
  Process-variable physical parameter (known)
  Process-dependent fitting parameter (“unknown”)

- One iteration, 10-step $V_t$ and $I_{ds}$ extraction procedure in a step-by-step sequence.
  Only 6 $I-V$ + technology data. One parameter set is used for predicting entire geometry/bias of the given technology.
Model Calibration Procedure (Technology characterization)

Step-by-step model parameters extraction

- 3 long-channel parameters
- 4 RSCE and SCEs parameters
- Point $V_t$ data requirement:
  - $2 \ V_t - V_{bs} @ L_\infty$
  - $6 \ V_t - L_g @$ corners bias

Symbols: Measurement
Lines: Model (Xsim)

Solid Lines: Fitted
Dotted Lines: Predicted

(W = 10µm)
Model Calibration Procedure (Technology characterization)

- 1 NWE parameter
- Point $V_t$ data requirement: $1 ~ V_t - W @ L_{\infty}$

- 3 NWEs and INWE parameters
- Point $V_t$ data requirement: $1 ~ V_t - W @ L_{min}$
Model Calibration Procedure (Device Characterization)

1) Long-channel parameters
   (3 I–V @ corners bias)
   - 4 mobility parameters, $\mu_0$
   - 1 lateral field effect parameter, $\mu_{eff0}$
   - 1 tranverse field effect parameters, $\chi_b$

2) Short-channel parameters
   (2 I–V @ corners bias)
   Point data $g_{ds} - L_g @ V_{ds} = 0; V_{gg}$
   - 2 series source/drain resistance
   - 1 CLM parameter
   - 1 $\delta_s[L_g]$ for $V_{deff}$ function

3) Narrow-width channel parameters
   Point data $I_{dsat} - W @ L_\infty$
   - 1 coulombic factor, $\mu_f$

4) Narrow-width channel parameters
   (1 I–V @ $L_{mid}$)
   - 2 layout-dependent parameters

5) Narrow-width channel parameters
   Point data $I_{dsat} @ L_{min}$
   - 1 coulombic factor, $\mu_{f5}$
$I_{ds}$-Model Validation with Measurement Data ($L_\infty$)
$I_{ds}$-Model Validation with Measurement Data ($L_{min}$)

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$I_{ds}$-Model Validation with Measurement Data ($L_g = 0.3\mu m$)
$I_{ds}$-Model Validation with Measurement Data ($L_g = 0.3\mu m$)

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$I_{ds}$-Model Validation with Measurement Data ($L_g = 0.3\mu m$)
Conclusions

- **Modeling Methodology**
  - Single-piece explicit current model — include all major SC/NW/HF effects.
  - Extremely compact form — ensure symmetry, accuracy and continuity.

- **Model Parameter Extraction Methodology**
  - Technology/device characterization — “Non-binnable” model.
  - One iteration, 10-step $V_t/I_{ds}$ extraction procedure in a *step-by-step* sequence
  - *Only 6 I–V + technology data.*

- **Predictability**
  - One parameter set is used for predicting entire geometry/bias of the given technology.