NEED for accurate parameter extraction in MOSFET modeling

PRINCIPLE of Linear Cofactor Difference Extreme for analytical extraction

LCDE application and verification

CONCLUSIONS
INTRODUCTION

- Important parameters: Vth and mobility
- Previous methods: simplicity and accuracy
- LCDE method: non-linear conduction principle of FET and a mathematical test
- Principle introduction and applications
PRINCIPLE OF LCDE

- Non-linear conduction principle of FET: If FET current is non-linear, the difference of FET current and any linear function always shows the extreme peak in this non-linear region.

\[ G(x) = \Delta f(x) = b + Kx - f(x) \]

\[ G'(x_p) = \frac{\partial G}{\partial x} \bigg|_{x=x_p} = 0 \]

- LCDE makes use of this principle to extract FET parameters.
- FET drain current always shows the extreme peak either in gate voltage axis or drain voltage axis.
FORMULATION OF LCDE

MOSFET drain current equation including series resistance and mobility degradation effect

\[ \frac{V_{ds}}{I_{ds}} = R_s + R_d + \frac{1}{\beta \mu_{eff} (V_{gs} - V_{th})} \]

\[ R_t = R_s + R_d \quad \theta = \theta_0 + R_t \beta \]

\[ I_{ds} = \frac{\beta (V_{gs} - V_{th}) V_{ds}}{1 + \theta (V_{gs} - V_{th})} \]
EXTRACTION EQUATIONS

- Extraction function
  \[ \Delta I_{ds}(V_{gs}) = \frac{\beta(V_{gs} - V_{th})V_{ds}}{1 + \theta(V_{gs} - V_{th})} - (KV_{gs} + b) \]

- LCDE Principle
  \[ \frac{\partial \Delta I_{ds}(V_{gs})}{\partial V_{gs}} \bigg|_{V_{gs} = V_{GP}} = 0 \]

- Extraction equation (1)
  \[ I_{ds}(V_{GP}) = \sqrt{KV_{ds}} \beta(V_{GP} - V_{th}) \]

- Extraction equation (2)
  \[ \beta = \frac{1}{V_{ds}} \left[ \frac{I_{ds}(V_{GP_1}) - I_{ds}(V_{GP_2})}{\sqrt{K_1} - \sqrt{K_2}} \right]^2 \]

- Extraction equation (3)
  \[ \theta = \frac{\sqrt{\beta V_{ds}} - \sqrt{K}}{\sqrt{K}[V_{GP} - V_{th}]} \]
The drain current linear cofactor difference versus gate voltage for different value of $K$. The LCDO method is applied to the linear region I-V characteristics of a fabricated n-channel MOSFET.
Dependence of the extracted parameters on $K_i$ and $K_j$: (a) Threshold voltage and transistor gain factor extracted (b) Low field mobility and its degradation factor for the different $K$. 
The drain current linear cofactor difference versus gate voltage for different values of $K$ in the sub- and linear region of a simulated n-FETs.
Vth EXTRACTION COMPARISON

Comparison of threshold voltage variation obtained by LCDO the standard second-derivative methods.
Mobility degradation characteristics of the simulated MOSFETs with the different channel length obtained by the linear cofactor difference operator method.
SUMMARY

- New method LCDE for FET parameter extraction developed
- LCDE spectrums of MOSFET drain current demonstrated
- Parameter extraction of MOSFET realized and verification
- LCDE can be used in more MOSFET modeling characterization.