Extraction of a Scalable Electrical Model for a HV (600/800 V) MOS Transistor

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Outlines

- Introduction
- HV MOS Transistor description
- Model extraction strategy description
- Results
- Conclusions

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Introduction

- 600V/800V MOS are commonly present in several applications of our daily life:
  - Low consumption bulbs
  - Devices connected to the power line which use:
    - Switching regulators
    - DC/DC converters
    - Motor drivers
  - Automotive
  - Etc…

Electric Motors & Motor Drivers

Automotive Applications

- **Car electromechanical systems**
  - Fuel pump
  - Water pump
  - Air conditioning
  - Windows

- **Engine of Electric Car**
  - European Funded Project E^3CAR

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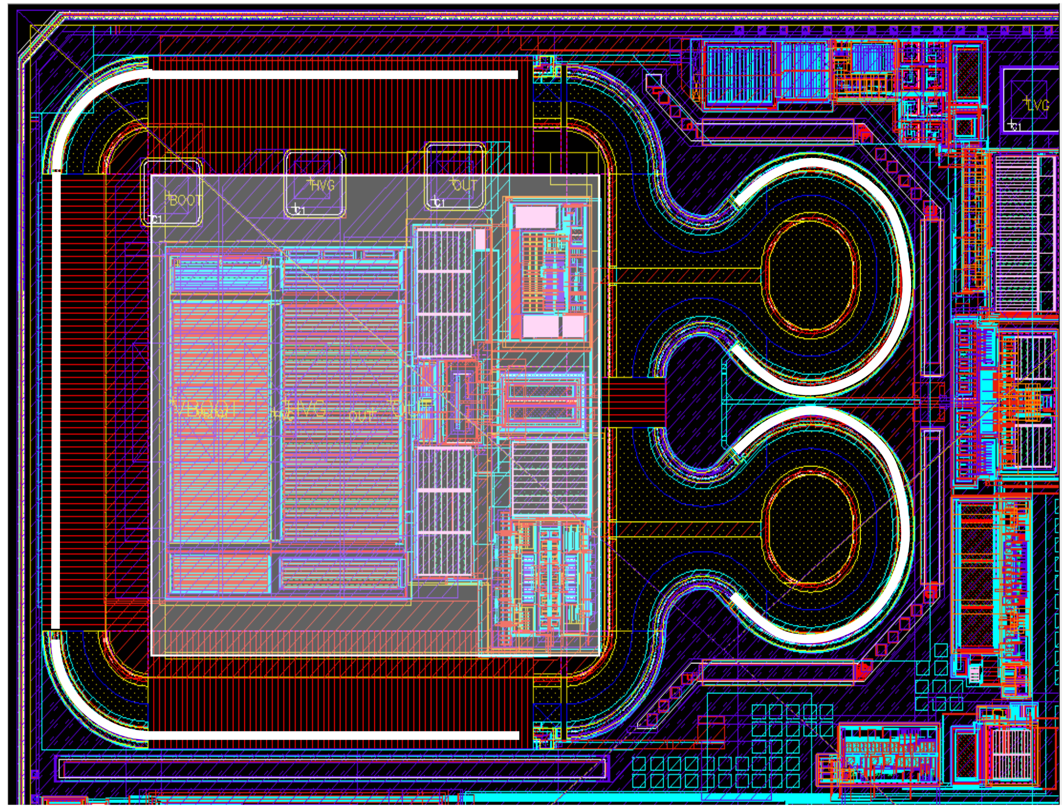
HV MOS Transistors Description

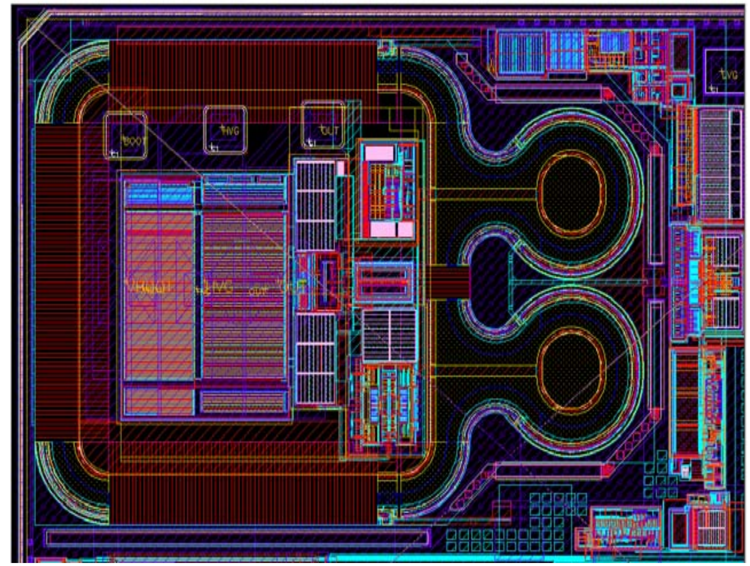
- **Level Shifter** (*Mickey Mouse*):
  - *Ears* are dedicated MOS used to bring in/out electrical signals
  - Its perimeter is also an active device
  - Isolated pocket which can contain low/medium voltage devices



- Realized in a 0.35μm smart power technology, BCD6SOFFLINE, able to integrate 3.3V/5V CMOS, BJTs, passives with MV MOS and 600/800 V MOS.

Model Purpose

- Since the perimeter transistor of the floating pocket is used to separate high voltage world from low voltage one, its shape is not defined *a priori*, but it is built up to contain low voltage devices

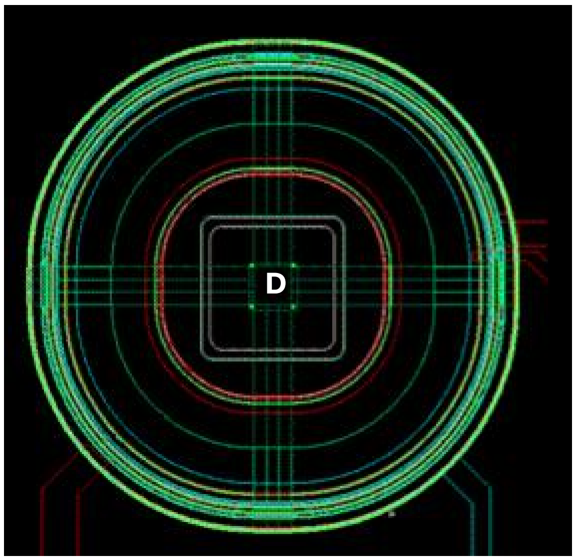


- **GOAL:**
  - Extraction of fully scalable models, able to take into account:
    - Linear width
    - Number of curves
    - Number of *Ears*

To describe perimeter devices behavior

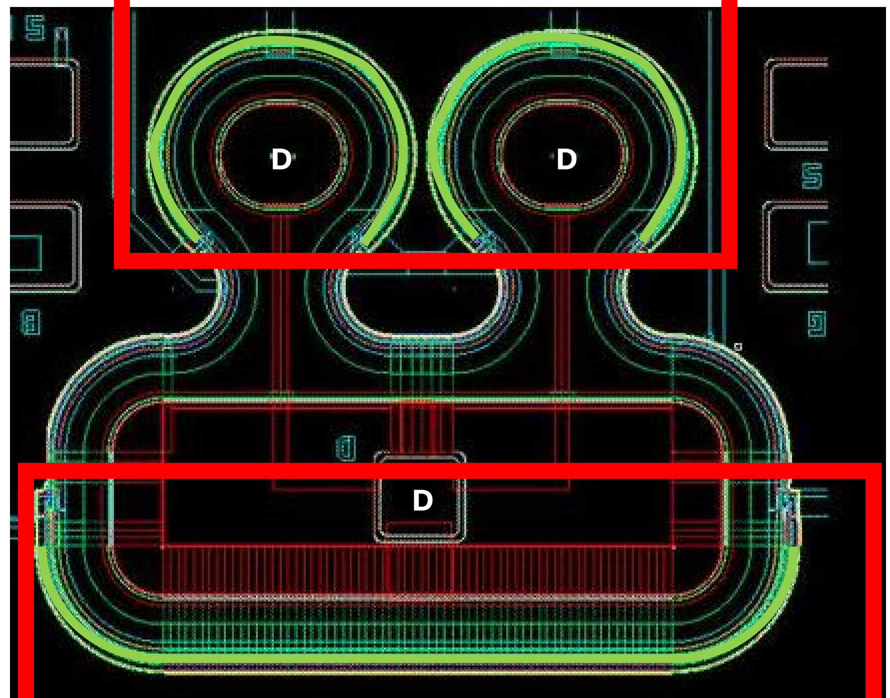
To describe the *Ear* electrical behavior

Available Devices for Model Extraction



Round MOS

Mickey Mouse Ears

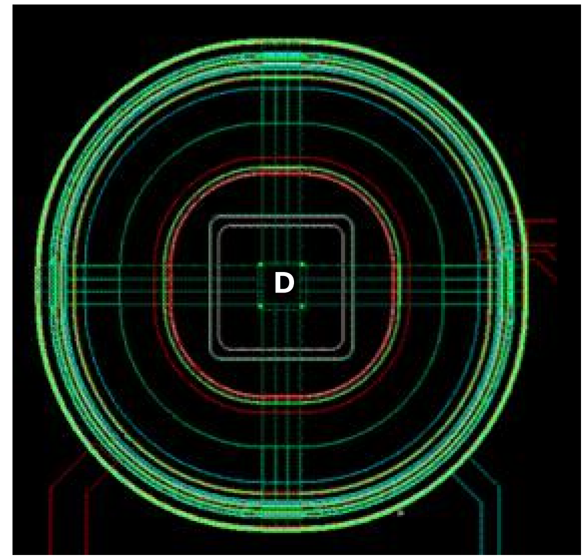


***Mickey Mouse* Perimeter**

Modeling Strategy – Starting Point

Step 1. Round MOS Modeling:

- W≈1.5mm

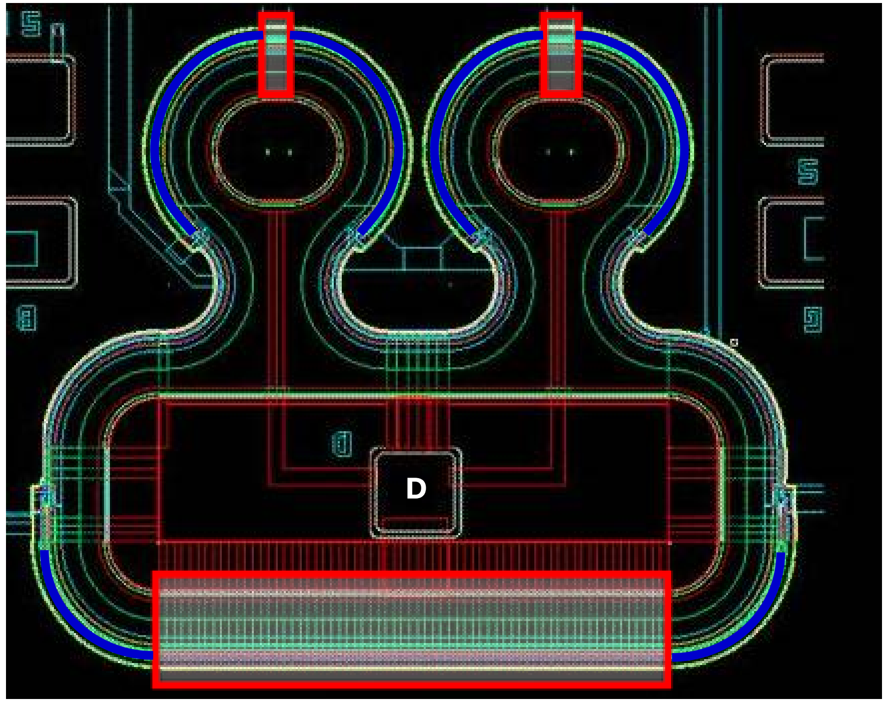


- Extraction of Round MOS model:
  - Intrinsic MOS, Rdrift, parasitic elements
- Extracted parameters have been adopted as initial values for subsequent models

Modeling Strategy – Step 2

Step 2. Doubling intrinsic MOS

- Insertion of 2 MOS into the model card:
    1. To describe straight transistors
       Parameter is linear width
    2. To describe curved MOS
       Parameter is number of curves
       (a curve has a fixed curvilinear width)

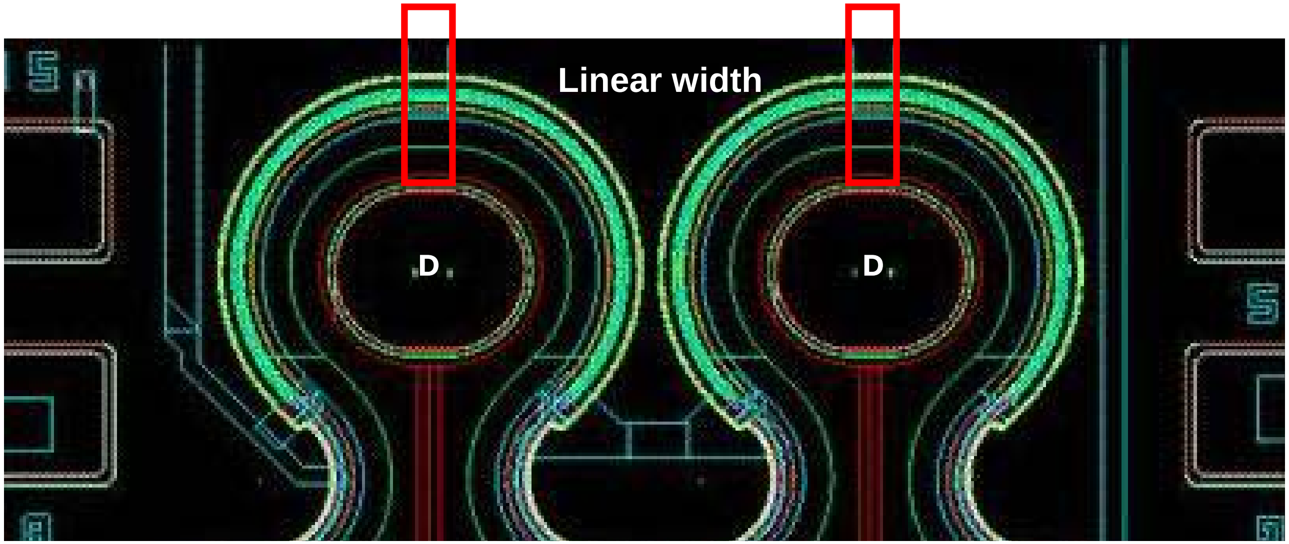


Linear width

Curvilinear width

Modeling Strategy – Step 3

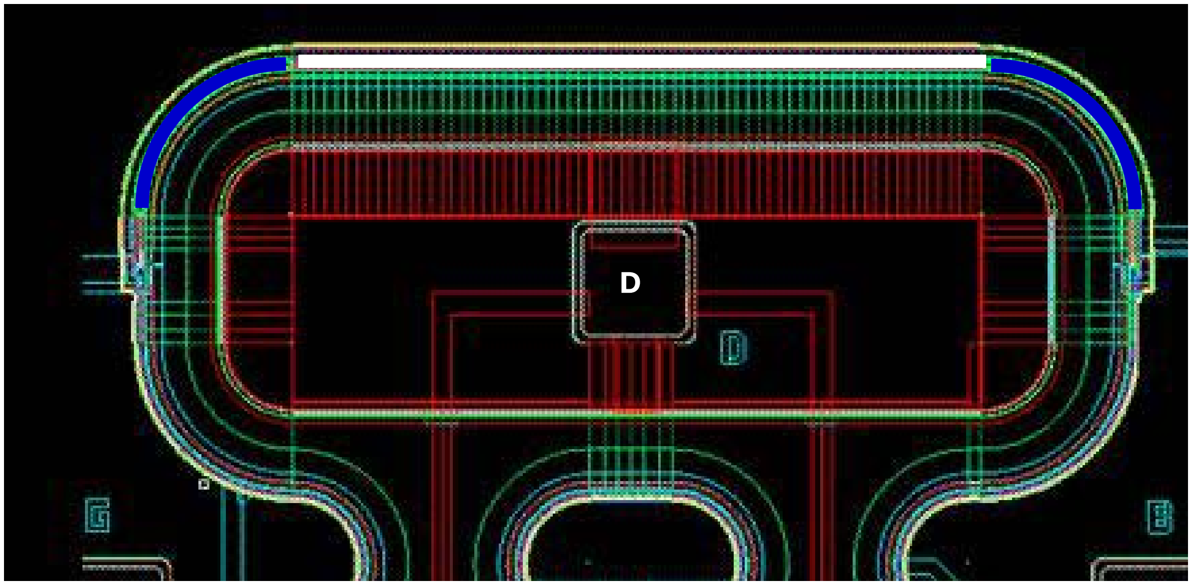
Step 3. *Ears* Modeling



- Extraction and optimization of intrinsic MOS for curvilinear width
  - Number of curve (NC) = 6
  - Linear width negligible

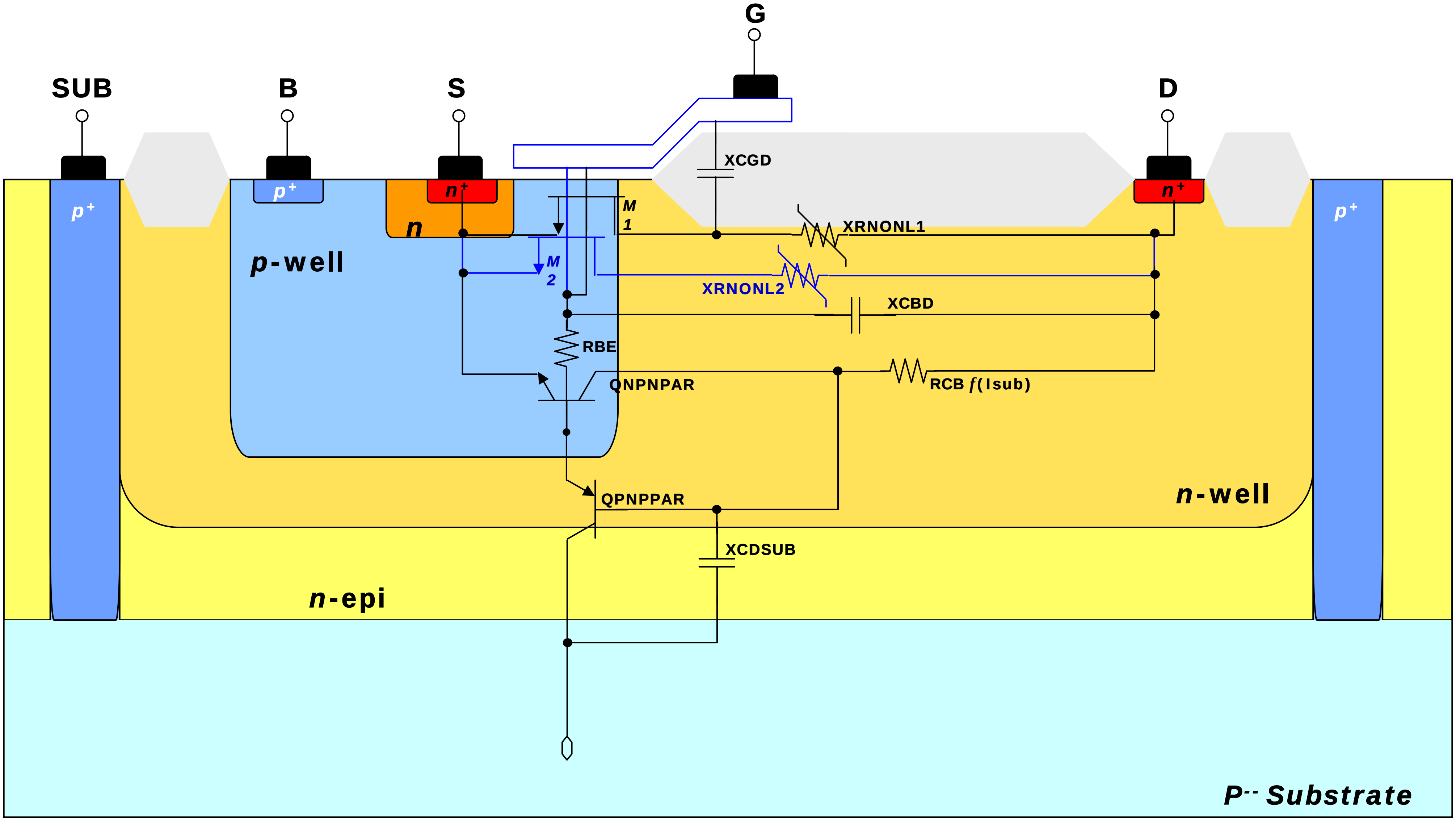
Modeling Strategy – Step 4

Step 4. *Mickey Mouse* perimeter modeling



- Extraction and optimization of intrinsic MOS for straight MOS and ΔW
  - Number of curve (NC) = 2
  - Very large linear width

Cross Section



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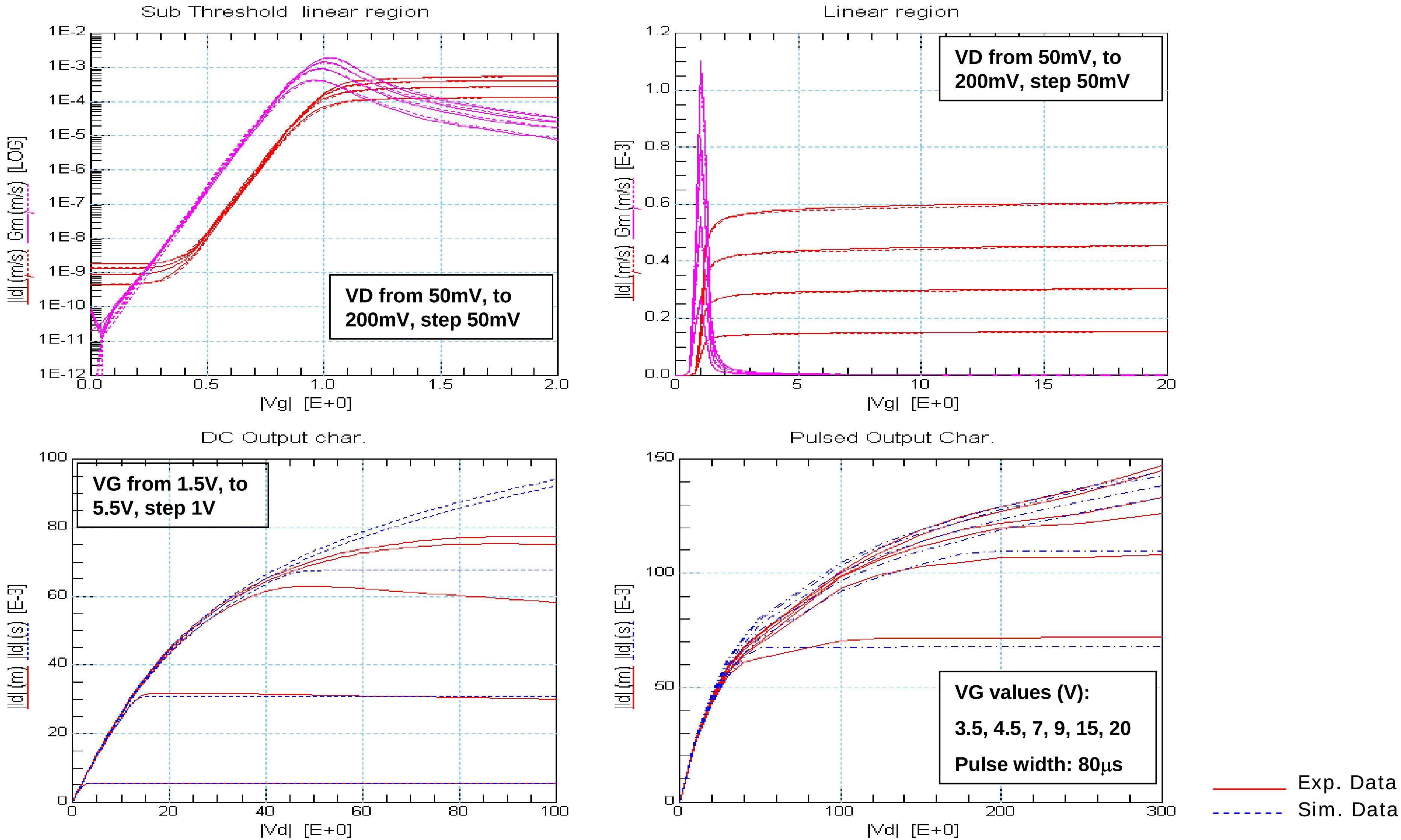
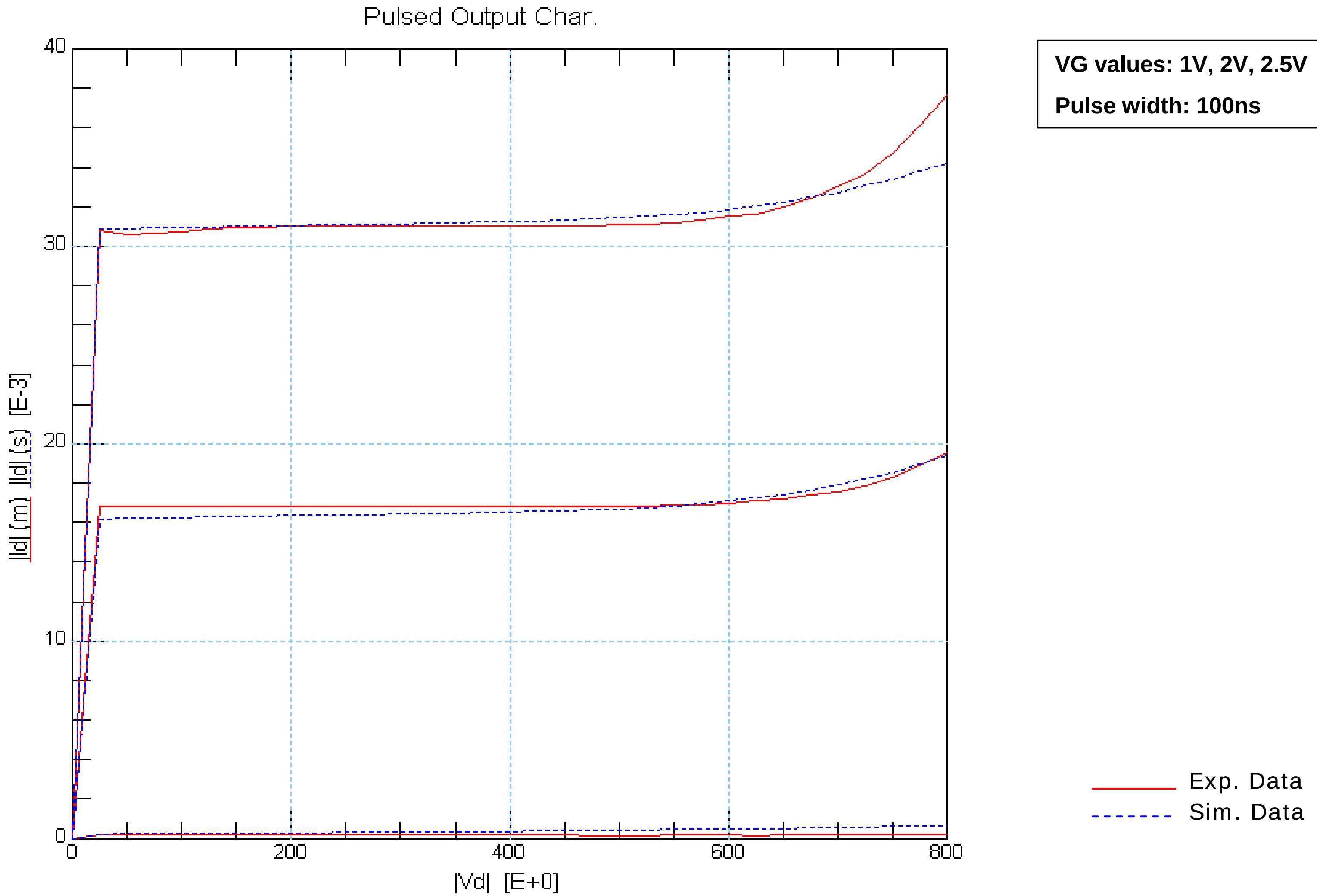
Round MOS Model Accuracy @ 25˚C



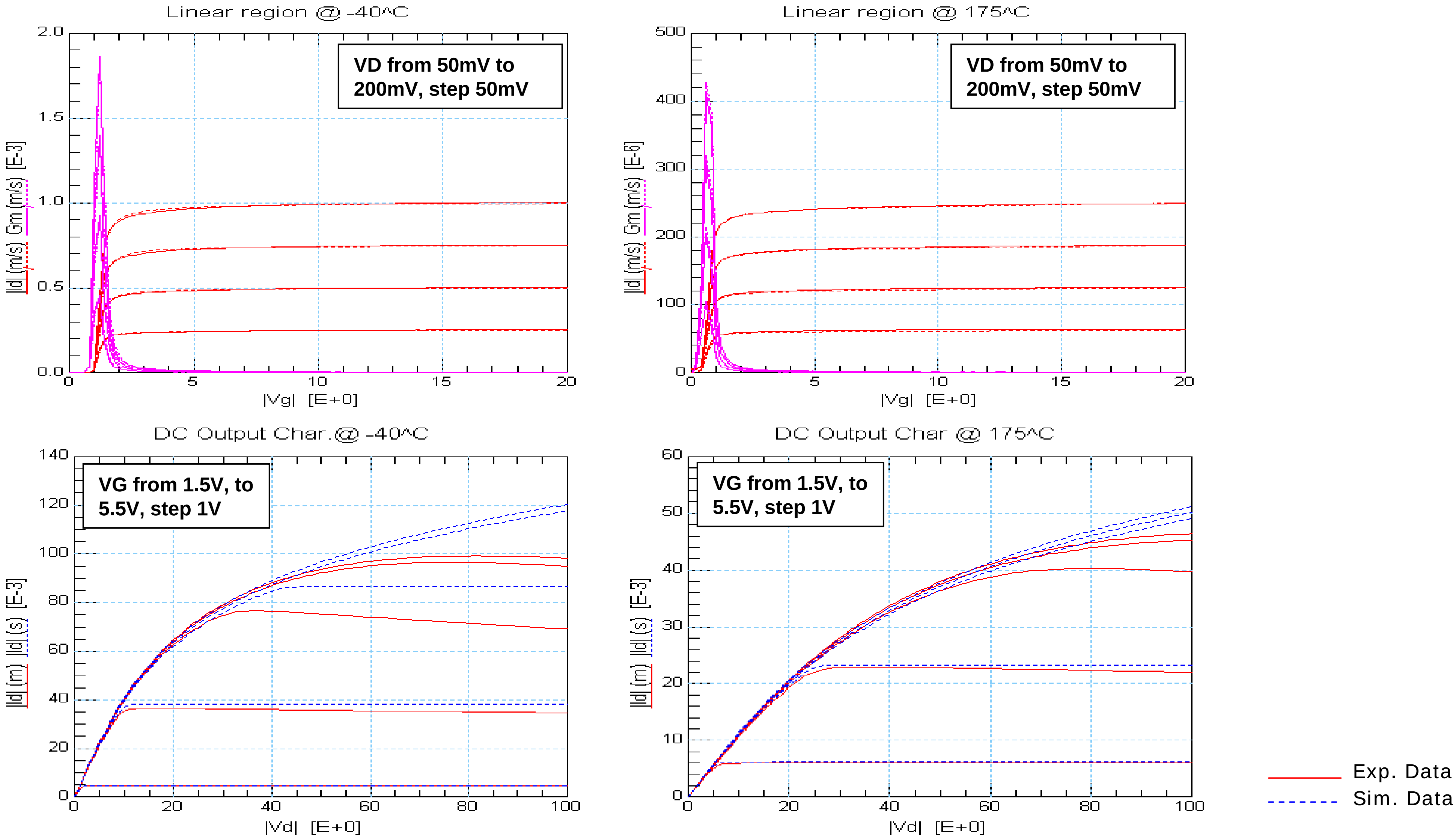
Round MOS Model Accuracy @ High Voltage



VG values: 1V, 2V, 2.5V

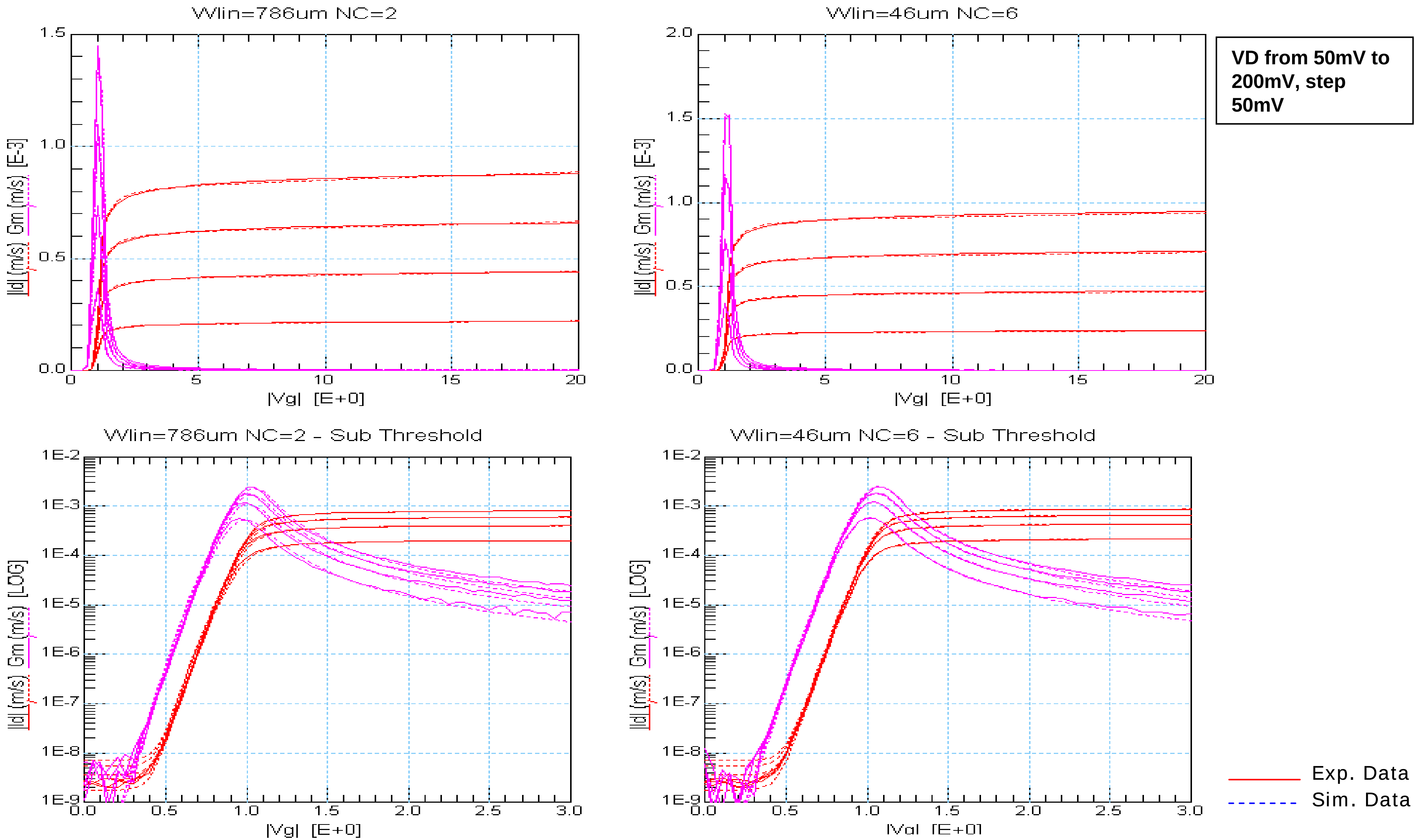
Pulse width: 100ns

Round MOS Model Accuracy *vs* Temperature

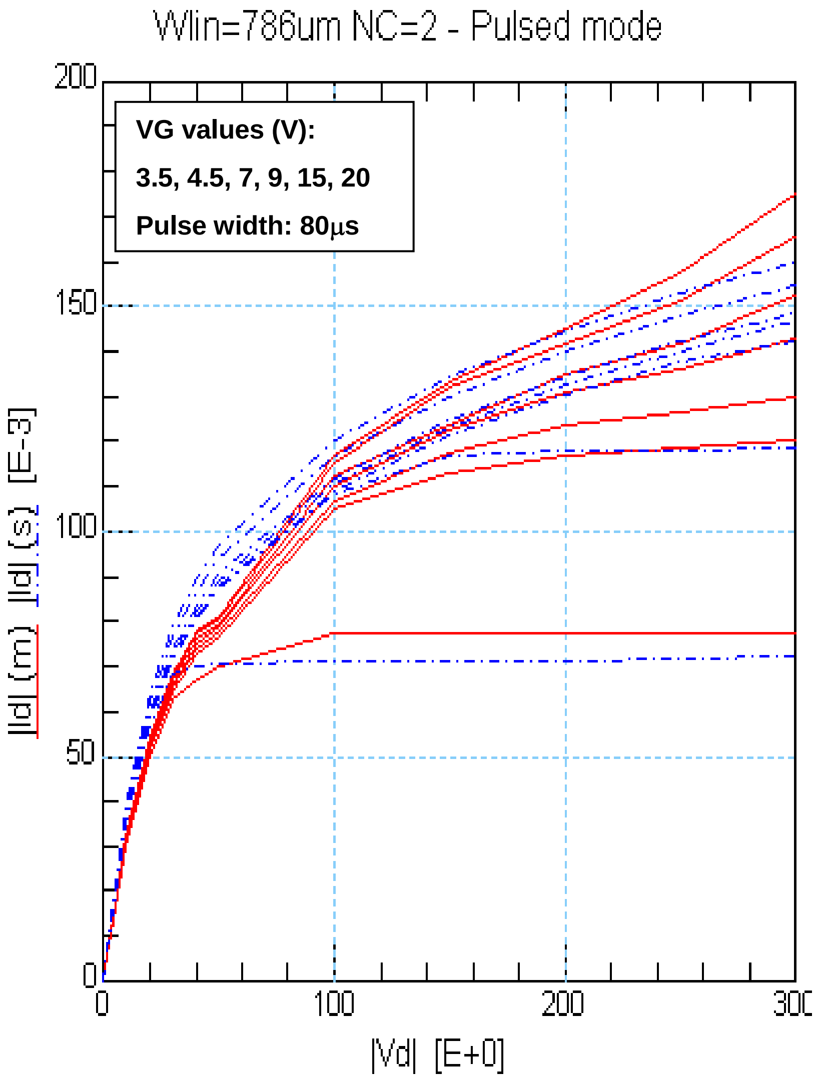


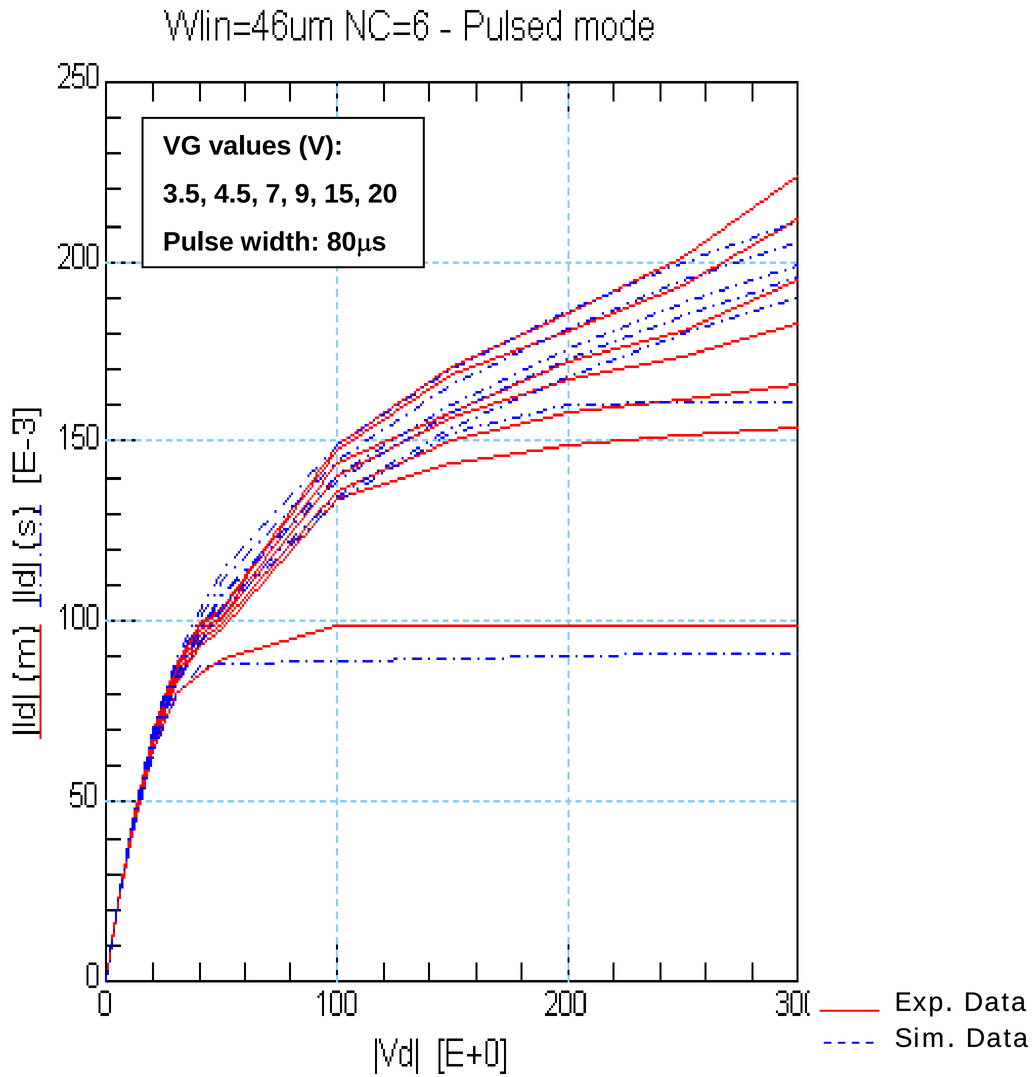
STMicroelectronics

Mickey Mouse Model Scalability – linear region

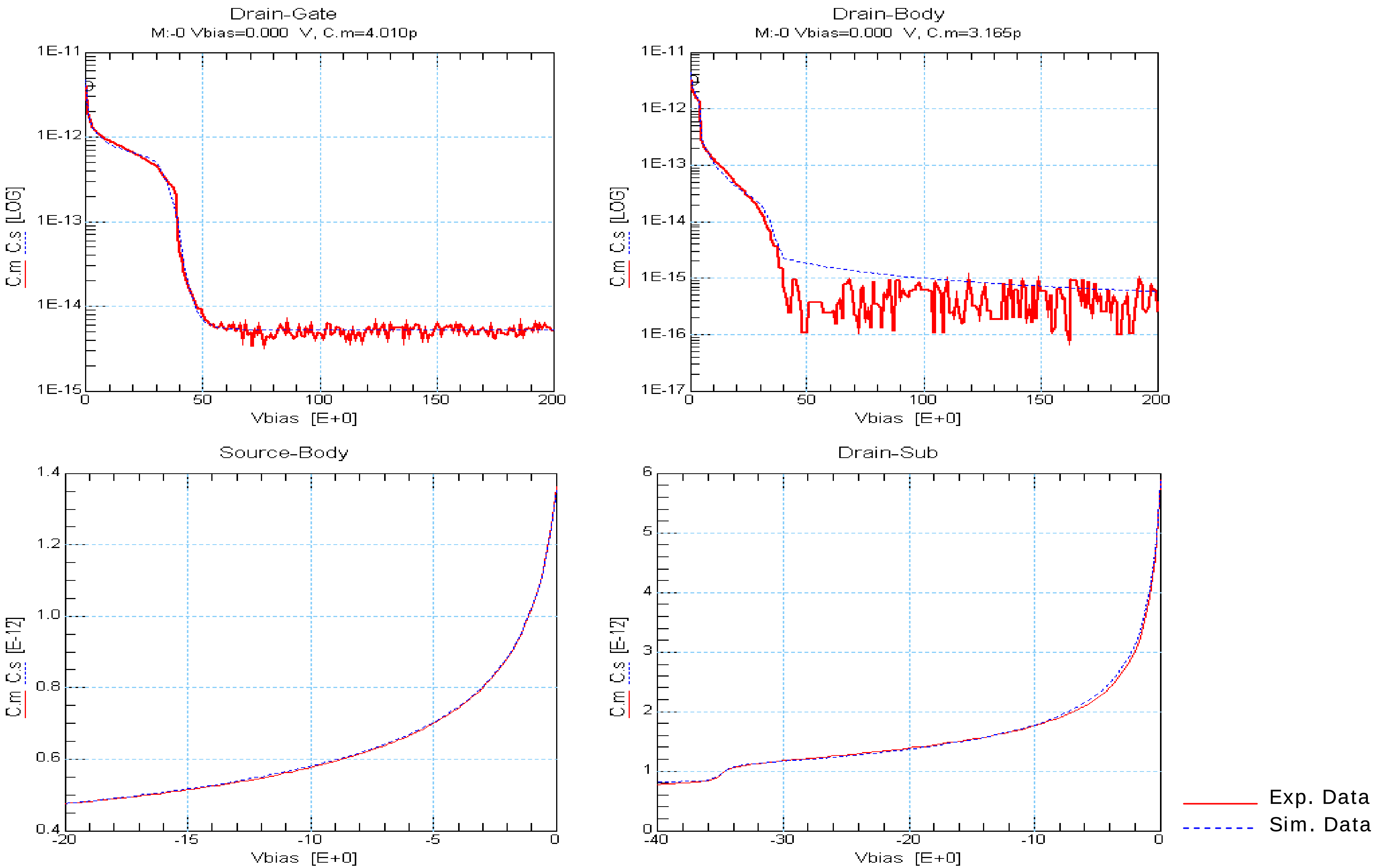


Mickey Mouse Model Scalability – output char.





Parasitic Capacitances



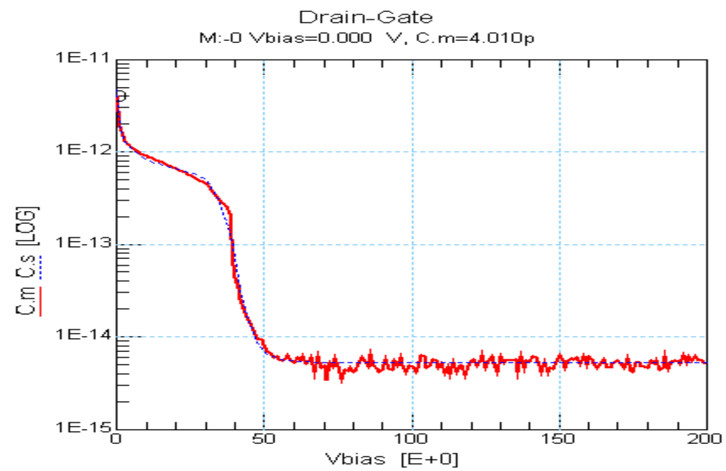
Gate-Drain Capacitance Affected by Resurf

$$C_{DG} = C_{DGL} \cdot f + C_{DGH} \cdot (1 - f) + C_{par}$$

$$C_{DGL} = \frac{C_1}{\left\{1 + K1 \cdot \left[well\_\mathrm{sgn} \cdot x + 0.5 \cdot \left(-well\_\mathrm{sgn} \cdot x - VFB1 + \sqrt{(well\_\mathrm{sgn} \cdot x + VFB1)^2 + EPS1^2} \right) \right] \right\}^{MJK1}}$$

$$C_{DGH} = \frac{C_2}{\left\{1 + K2 \cdot \left[well\_\mathrm{sgn} \cdot x + 0.5 \cdot \left(-well\_\mathrm{sgn} \cdot x - VFB2 + \sqrt{(well\_\mathrm{sgn} \cdot x + VFB2)^2 + EPS2^2} \right) \right] \right\}^{MJK2}}$$

$$f = 0.5 \cdot \left[\left(1 - \frac{well\_\mathrm{sgn} \cdot x - VSTEP}{\left(\left(abs(well\_\mathrm{sgn} \cdot x - VSTEP)^2 \right)^N + \left(eps^2 \right)^N \right)^{\frac{1}{2N}}} \right) \right]$$



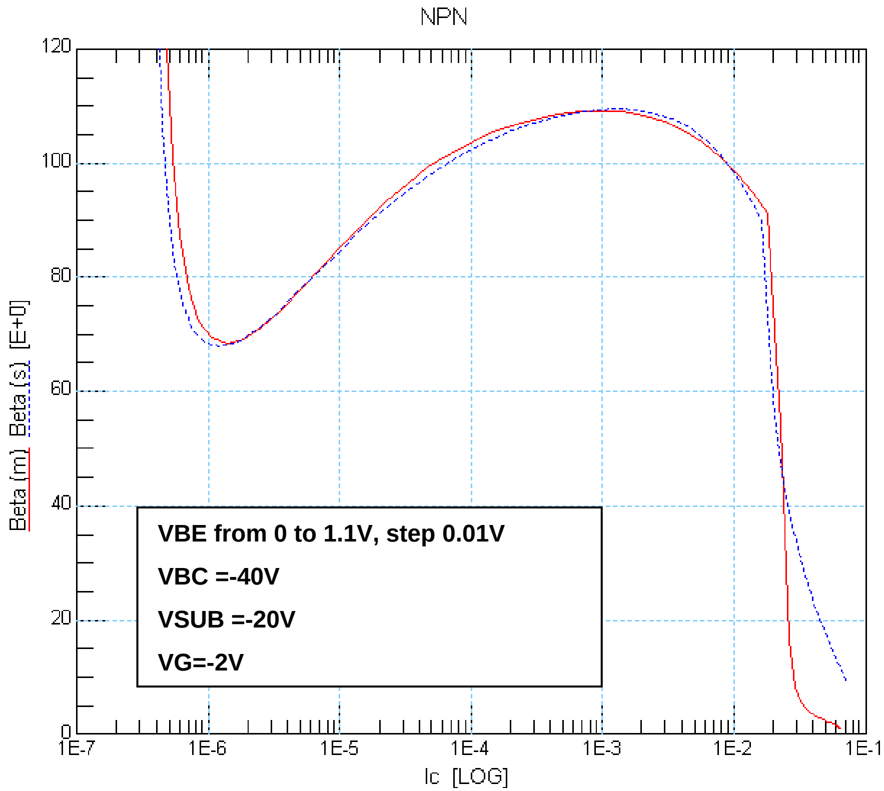
Junction Capacitance Affected by Resurf

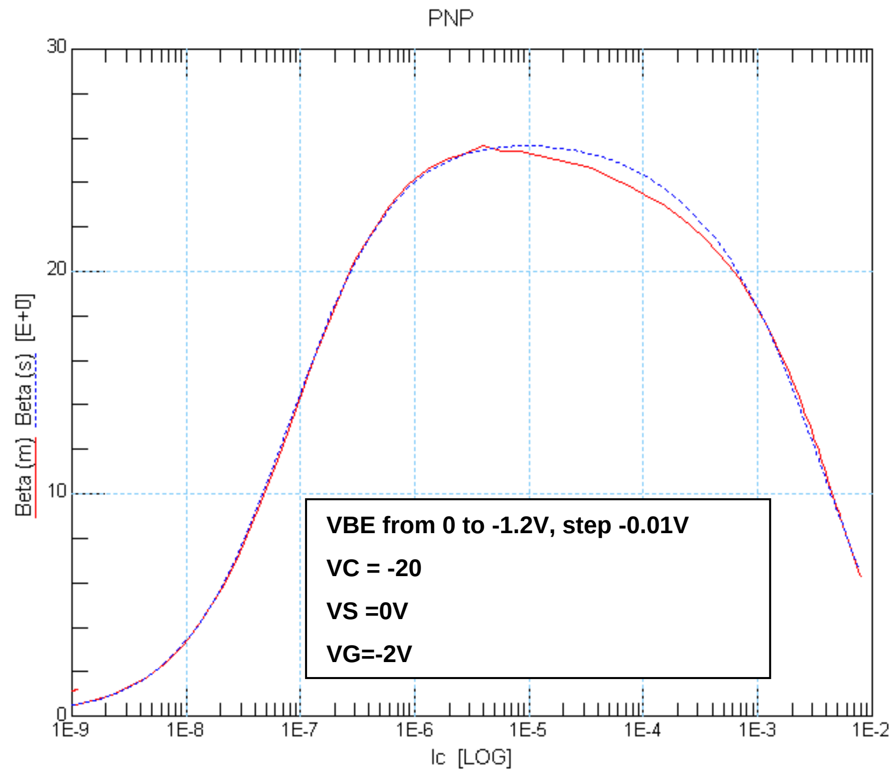
$$C_{JTOT} = C_{J1} + C_{J2}$$

$$C_{J1} = \left[\frac{C_{J01}}{\left(1 + \frac{X}{V_{J1}}\right)^{M_{J1}}} + CK_1 \right] \cdot 0.5 \cdot \left[\left(1 - \frac{X - V_P}{\left(abs(X - V_P)^{2N} + eps^{2N} \right)^{\frac{1}{2N}}} \right) \right]$$

$$C_{J2} = \left[\frac{C_{J02}}{\left(1 + \frac{X}{V_{J2}}\right)^{M_{J2}}} + CK_2 \right] \cdot 0.5 \cdot \left[\left(1 + \frac{X - V_P}{\left(abs(X - V_P)^{2N} + eps^{2N} \right)^{\frac{1}{2N}}} \right) \right]$$

Parasitic BJTs





Exp. Data

Sim. Data

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Conclusions

- Two models have been extracted in order to describe the whole level shifter:
  - *Mickey Mouse* perimeter
  - *Mickey Mouse Ears*
- Models are fully scalable with linear W, number of curves and number of *Ears*
- Models fit the whole temperature range: -40 / 175 °C.
- Models fully describe parasitic effects
- The highest flexibility for designers is guaranteed

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End of Presentation

Thank you for your attention