Modeling – the big picture
Quiz 12  
An n-channel MOS transistor has a nominal threshold voltage of 1V with no bulk bias. What will that threshold voltage change to if the bulk bias is - 4V?  State typical values for any process parameters that you need to solve this problem and use them.

![Diagram](image.png)

$V_T = 1V$

$V_T = ?$
And the number is ....

1 8 7 5 3
6 9 4 2
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Solution

\[
V_T = V_{T0} + \gamma \left( \sqrt{\varphi - V_{BS}} - \sqrt{\varphi} \right)
\]

\[
\gamma = 0.5V^2 \quad \varphi = 0.6V
\]

\[
V_T = 1V + 0.5 \left( \sqrt{0.6 - 4} - \sqrt{0.6} \right) = 1.69V
\]

Note: Threshold shift with bulk bias can be significant!!
• Reasonably good MOSFET model characterized by 6 process parameters and 2 design parameters 
  \( \{V_{T0}, C_{OX}, \mu, \gamma, \varphi, \lambda\} \quad \{W, L\} \)
• Only a single degree of freedom (W/L)
• Small signal model can be very easily developed from large signal model
• Small signal model developed in saturation region
• Small signal model can be readily derived from the dc model
• Small signal model parameters strongly operating point dependent
Modeling Summary

Simple dc Model

- Small Signal Model
  - Frequency-Dependent Small Signal Model
- Better Analytical dc Models
- Sophisticated Model for Computer Simulations

- Better Models for Predicting Device Operation
How complete or mature are the models for the MOS Transistor?

How good are the existing MOS device models?
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- Pretty Good (sometimes)
- Good Enough (sometimes)
- Lousy (sometimes)
How complete or mature are the models for the MOS Transistor?

Many researchers continuing to work on modeling of MOS transistors

Efforts seem to be increasing in recent years

Driven, in part, by changes in performance experienced by deep sub-micron devices