Stony Brook University

EEO311

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Transfer and output characteristics of NMOS and PMOS Field Effect Transistors

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Copy of Original Assignment

EEO311 Simulation 1.

Transfer and output characteristics of NMOS and PMOS Field Effect Transistors

Objective: Familiarization with realistic current-voltage characteristics of MOSFETs. Observation of exponential dependence of drain current on VGS in the subthreshold range, estimation and comparison of Early voltages for NMOS and PMOS devices with similar gate lengths and drain currents.

Assignment:

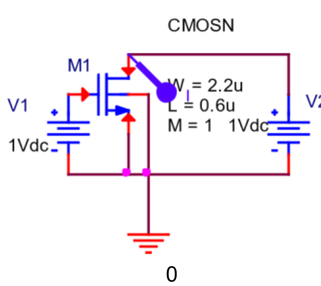
1. Obtain the family of transfer characteristics of the NMOS and PMOS devices with the provided models for the gate length L =0.6 um and the default width W =2.2 um. Use the primary DC sweep for VGS in the range from 0.4 to 1.2 V with a 10 mV increment and the secondary sweep for VDS in the range from 1 to 3 V with a 1 V increment.

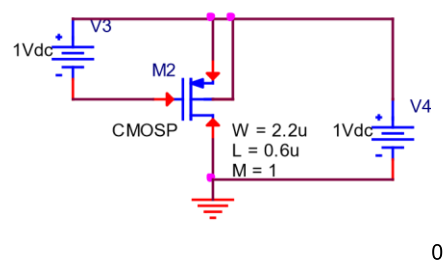
Obtain two plots for each type of MOSFETs: one with the drain current in linear scale and one with the drain current in log scale. The plots in semilog scale illustrate presence of subthreshold currents which decay exponentially with decrease of VGS below the threshold. In the subthreshold range (VGS < 0.7 V for NMOS, |VGS| < 0.8 for PMOS) estimate the increment of the gate-to-source voltage ΔVGS= VGS1 – VGS2 required for change of the drain current by an order of magnitude: Id1/Id2= 10.

2. Obtain the family of output characteristics of the NMOS and PMOS devices with the same dimensions. Use the primary sweep for |VDS| in the range from 0 to 3 V with a 10 mV increment and the secondary sweep for |VGS | from 0.7 to 0.9 V for NMOS and 0.8 to 1 V for PMOS with a 20 mV increment.

3. Estimate and compare Early voltages for the NMOS and PMOS devices for similar drain currents and VDS >> Vov (select some drain current and estimate ro = ΔVDS /ΔId within the linear part of the output characteristic for VDS in the range between, say, 1 and 2 V, find the current increment for this change of VDS, extrapolate the linear part of the output characteristic to VDS = 0, multiply ro by estimated drain current value at VDS = 0).

Instructions: the MOSFET characteristics can be simulated with the following schematics.





The MOSFET symbols should be placed from ESE311models.olb file: add the symbol library with Alt+A. Create and name a new simulation profile. Edit the profile: set the parameters for the primary and secondary DC sweeps. In Configuration Files under Library category show the path to the library with MOSFET data ESE311model.lib (Browse.., Add to Design). Place the current probe to the MOSFET terminal connected to Vdd (V2 or V4 in the schematic above). Run the simulation (F11). Click the vertical axis in the plot, change the current scale to log and adjust the current range.

Copy of Original Assignment

Report: Include the cover page with name, ID, semester, a brief description of the work, requested plots and parameters and a brief summary. Export (print to a file) plots in *.tiff format for white background. Upload the report to BSpace for grading.

Overview

In simulation 1 our primary objective is to explore the transfer and output characteristics of MOSFETs. Through simulation, we gain a deep understanding of how these transistors operate in real-world applications. Our focus lies in graphing the relationship between drain current I_D and gate-source voltage V_{GS}, particularly emphasizing the exponential behavior observed in the subthreshold range. We plot transfer and output characteristics for both NMOS and PMOS devices, and compare their responses. Furthermore, we estimate Early voltages for both types of transistors under similar conditions, to learn about their operational dynamics.

1 Transfer Characteristics

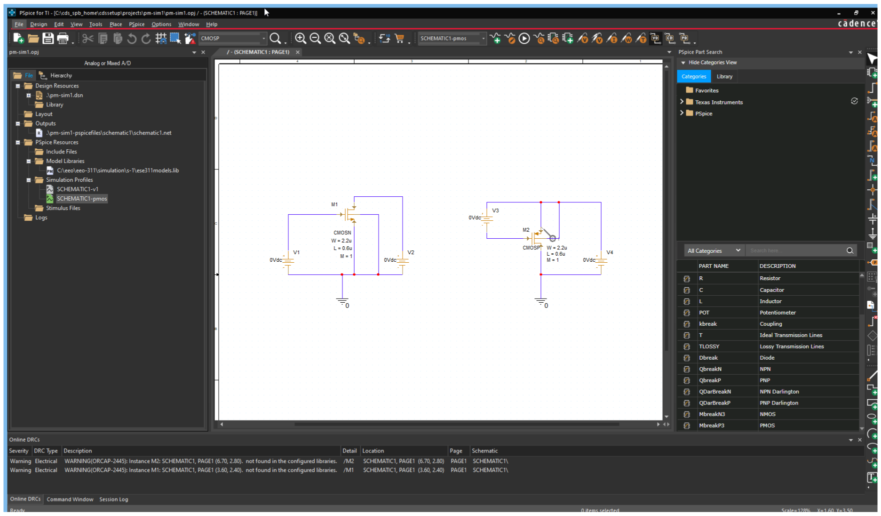


Figure 1: NMOS and PMOS schematic for simulation.

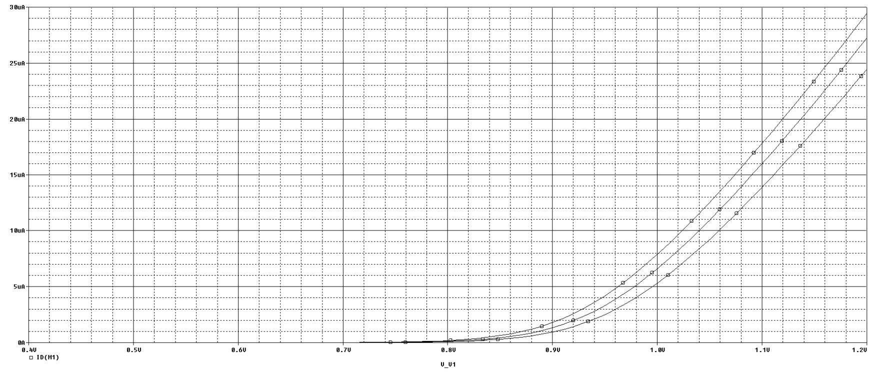


Figure 2: NMOS - linear y-axis.

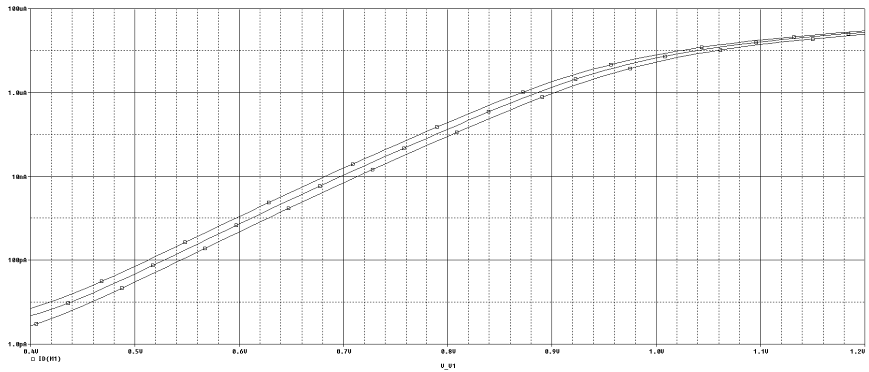


Figure 3: NMOS - logarithmic y-axis. In the subthreshold range, drain current changes by an order of magnitude when $\Delta V_{GS} \approx 800\,\mathrm{mV}$.

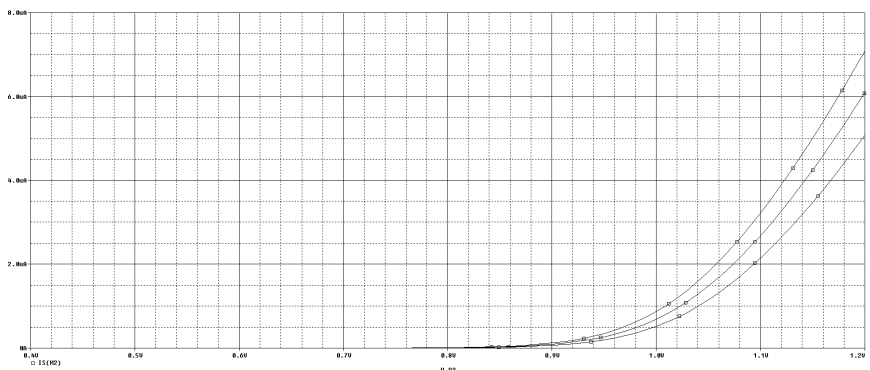


Figure 4: PMOS - linear y-axis.

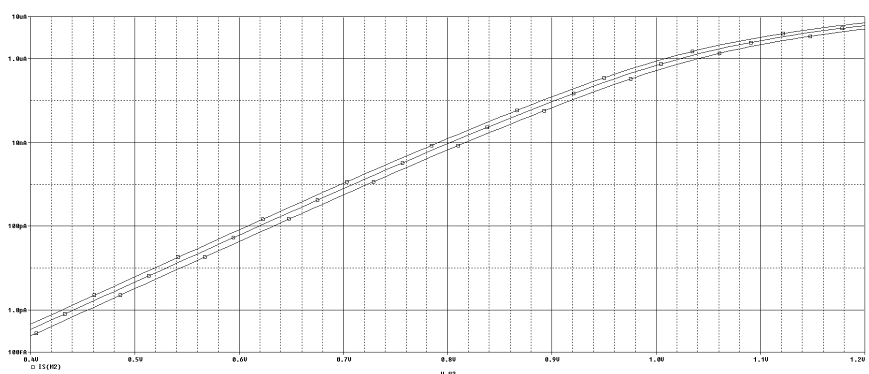


Figure 5: PMOS - logarithmic y-axis. In the subthreshold range, drain current changes by an order of magnitude when $\Delta V_{GS} \approx 900\,\mathrm{mV}$.

2 Output Characteristics

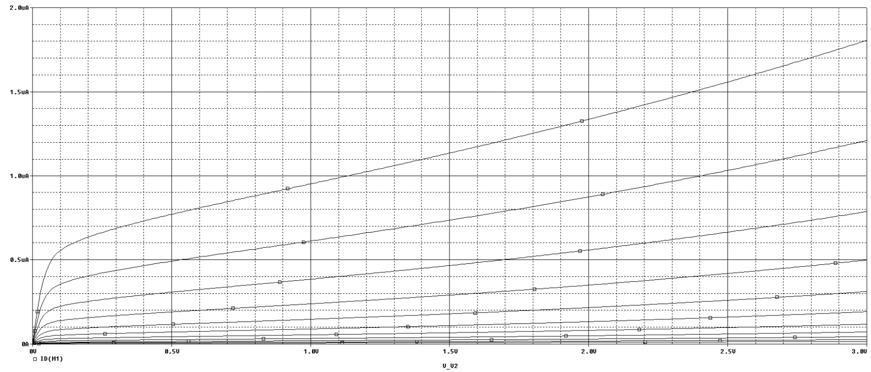


Figure 6: NMOS output characteristics.

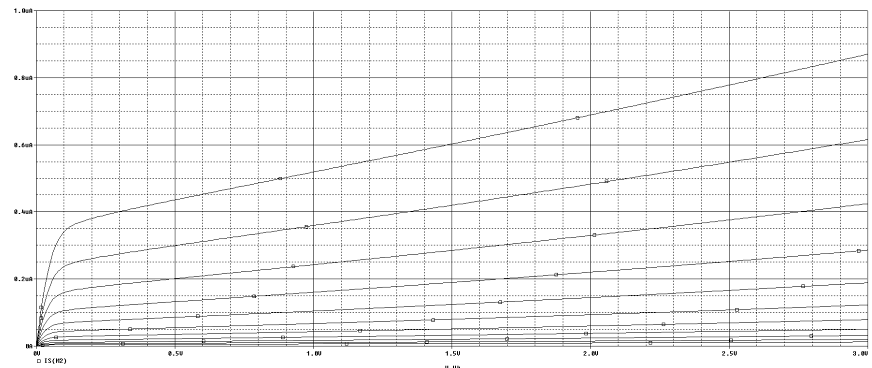


Figure 7: PMOS output characteristics.

3 Early Voltage

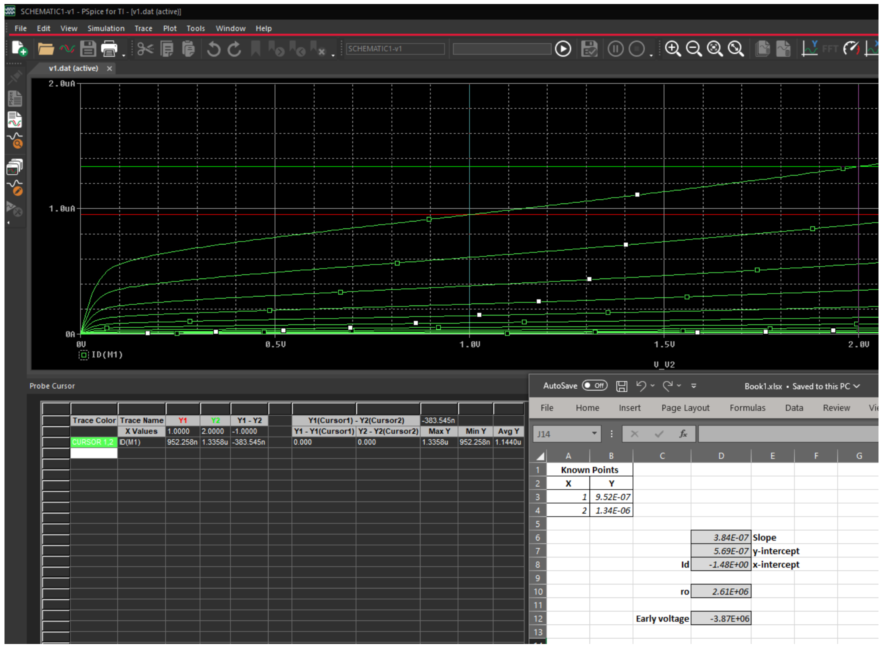


Figure 8: Adding two cursors to the plot and extracting the X-Y coordinates reveal an early voltage of -3.87×10^6 V.

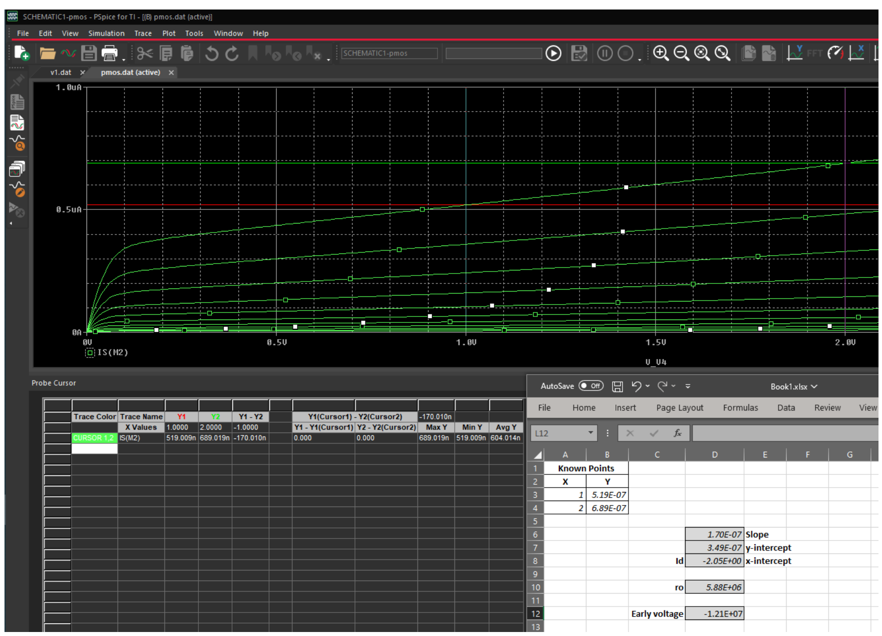


Figure 9: Adding two cursors to the plot and extracting the X-Y coordinates reveal an early voltage of -1.21×10^7 V