LAB 5.1

NMOS I-V Characteristics

(See Sections 5.1–5.2, p. 238 of Sedra/Smith)

OBJECTIVES:

To study NMOS transistor I-V curves by:

- Simulating a transistor to investigate the drain current vs. gate-to-source voltage and drain-to-source voltage.
- Implementing a circuit and taking measurements of the I_D vs. V_{GS} and I_D vs. V_{DS} curves.
- Extracting values of k_n, V_{tn}, and λ_n.

MATERIALS:

- Laboratory setup, including breadboard
- 1 enhancement-type NMOS transistor (e.g., MC14007)
- Several wires

PART 1: SIMULATION

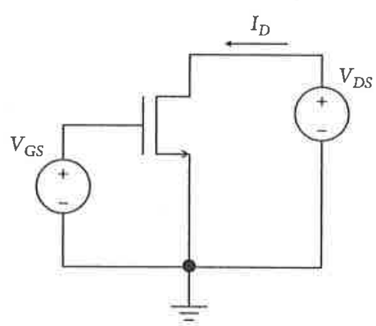

FIGURE L5.1: Transistor measurement circuit.

Consider the circuit in Figure L5.1. Enter the circuit into your simulator's schematic editor, applying DC voltage supplies to the gate and drain of the transistor.

I_D vs. V_{GS}

While setting V_{DS} to a constant value of 5 V, sweep the gate voltage from 0 V to 5 V in increments of 0.1 V. Plot a curve of I_D vs. V_{GS}. At what value of V_{GS} does the current turn on?

I_D vs. V_{DS}

For three values of V_{GS} (2.5 V, 3.0 V, and 3.5 V), sweep the drain voltage from 0 V to 5 V in increments of 0.1 V. Plot the curves for I_D vs. V_{DS} onto a single graph, clearly indicating the value of V_{GS} next to each curve.

PART 2: MEASUREMENTS

Assemble the circuit from Figure L5.1, using a power supply to generate the DC voltages.

I_D vs. V_{GS}

While setting V_{DS} to a constant value of 5 V, sweep the gate voltage from 1.0 V to 3.5 V in increments of 0.25 V (note, we have reduced the number of data points with respect to the simulations), and measure the drain current using the power supply. (*Note*: Not all power supplies allow you to measure current accurately; if this is the case for your lab setup, you may place a small resistor in series with the drain and measure the voltage drop across the resistor.) Plot a curve of I_D vs. V_{GS}. At what value of V_{GS} does the NMOS turn on?

I_D vs. V_{DS}

For three values of V_{GS} (2.5 V, 3.0 V, and 3.5 V), sweep the drain voltage from 0 V to 3.5 V in increments of 0.5 V, and measure the drain current using the power supply. Plot the curves for I_D vs. V_{DS} onto a single graph, clearly indicating the value of V_{GS} next to each curve.

PART 3: POST-MEASUREMENT EXERCISE

Simulation vs. measurement

What are the main differences between your simulated and measured curves? Can you explain the differences?

Parameter extraction

(1) Threshold voltage, V_{tn}

From the measured I_D vs. V_{GS} curve, at what value of V_{GS} does the NMOS turn on? Set this as the threshold voltage V_{tn}, of your transistor.

(2) MOSFET transconductance parameter, k_n

Based on the value of drain current I_D at V_{GS} = 3.0 V, and using the saturation model for the transistor, i.e., $I_D = (1/2)k_n(V_{GS} - V_{tn})^2$, extract the value of $k_n = \mu_n C_{ox}(W/L)$. Using your extracted values of V_{tn} and k_n, plot a curve of I_D vs. V_{GS}, using the saturation model, and compare with your simulated and measured curves. Are there any differences? Can you explain the differences?

(3) Early voltage, V_A

Based on your measured I_D vs. V_{DS} curves for a saturated transistor, extract the Early voltage V_A. Does V_A change significantly for each value of V_{GS}? What is the average value of V_A? Based on your average value of V_A, calculate $\lambda_n = 1/V_A$.

Repeat Steps 1 to 3 for your measured results.

Summarize your results in the following table.

	MEASURED
V_{tn} [V]	
k_n [mA/V^2]	
λ_n [V^{-1}]	

PART 4 [OPTIONAL]: EXTRA EXPLORATION

If you have access to a semiconductor parameter analyzer, generate the I_D vs. V_{DS} curves using the analyzer. How do they compare to the curves you generated in Part 3? Re-extract values of V_{tn}, k_n, and λ_n.