LAB 5.2

PMOS I-V Characteristics

(See Sections 5.1–5.2, p. 232 of Sedra/Smith)

OBJECTIVES:

To study PMOS 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_{SG} and I_D vs. V_{SD} curves.
- Extracting values of k_p, V_{tp}, and λ_p.

MATERIALS:

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

PART 1: SIMULATION

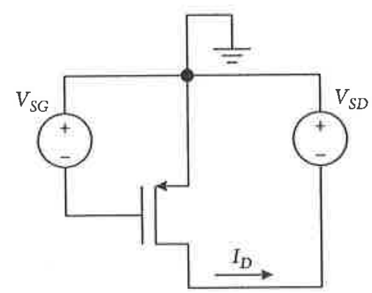

FIGURE L5.2: Transistor measurement circuit.

Consider the circuit in Figure L5.2. Enter the circuit into your simulator's schematic editor, applying DC voltage supplies to the gate and drain of the transistor. In the diagram, the source is indicated as the reference node (ground). What voltages would you need to apply if another node, e.g., the drain, were labeled as the reference?

I_D vs. V_{SG}

While setting V_{SD} 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_{SG}. At what value of V_{SG} does the PMOS turn on?

I_D vs. V_{SD}

For three values of V_{SG} (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_{SD} onto a single graph, clearly indicating the value of V_{SG} next to each curve.

PART 2: MEASUREMENTS

Assemble the circuit from Figure L5.2, using a power supply to generate the DC voltages. Note the polarities of the voltage sources. You may need to be creative to get the correct polarities! Remember that for a PMOS transistor that is on, V_{SG}, V_{SD}, and I_D will be positive quantities.

I_D vs. V_{SG}

While setting V_{SD} 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_{SG}. At what value of V_{SG} does the current turn on?

I_D vs. V_{SD}

For three values of V_{GS} (2.5 V, 3.0 V, and 3.5 V), sweep the drain voltage from 0.0 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_{SD} onto a single graph, clearly indicating the value of V_{SG} 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_{tp}

From the measured I_D vs. V_{SG} curve, at what value of V_{SG} does the PMOS turn on? Set this as the threshold voltage V_{tp} of your transistor, but express it as a negative number to be consistent with practice.

(2) MOSFET transconductance parameter, k_p

Based on the value of drain current I_D at $V_{SG} = -V_{tp} + 1$ V, and using the saturation model for the transistor, i.e., $I_D = (1/2)k_p(V_{SG} - |V_{tp}|)^2$, extract the value of $k_p = \mu_p C_{ox}(W/L)$ Using your extracted values of V_{tp} and k_p, plot a curve of I_D vs. V_{SG}, 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_{SD} curves for a saturated transistor, extract the Early voltage V_A. Does V_A change significantly for each value of V_{SG}? What is the average value of V_A? Based on your average value of V_A, calculate $\lambda_p = 1/V_A$.

Repeat Steps 1 to 3 for your measured results.

Summarize your results in the following table.

	MEASURED
V_{tp} [V]	
k_p [mA/V^2]	
λ_p [V^{-1}]	

PART 4 [OPTIONAL]: EXTRA EXPLORATION

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