Analog IC Design
Lab 01
LPF Simulation and MOSFET Characteristics

Part 1: Low Pass Filter Simulation (LPF)

1. Transient Analysis

a. Design a first order low pass filter that has $R = 1k\Omega$ and 1ns time constant.
b. Apply a square wave input with $T_{high} = T_{low} = 5ns$ and $T_{rise} = T_{fall} = 100ps$.
c. Report transient analysis results for two periods (use max time step $= T_{clk}/100$).
d. Calculate rise and fall time (10% to 90%) using waveforms calculator.
e. Compare simulation with analytical results in a table.
f. Do parametric sweep for $R = 1{:}\,1{:}\,5k\Omega$. Report overlaid results. Comment on the results.

2. AC Analysis

a. Report Bode Plot (magnitude and phase) for the previous LPF.
b. Calculate DC gain and 3dB bandwidth using calculator expressions.
c. Compare simulation with analytical results in a table.
d. Do parametric sweep for $R = 1{,}10{,}100{,}1000k\Omega$. Report overlaid results. Comment on the results.

3. Pole Zero Analysis

a. Report pole zero analysis results from the AMS results browser.
b. Find the pole frequency and compare it with the bandwidth calculated from AC analysis.

Part 2: MOSFET Characteristics

1. ID vs VGS

a. Plot $I_D - V_{GS}$ characteristics for NMOS device. Set $V_{DS} = V_{DD}$, and $V_{GS} = 0{:}\,10m{:}\,V_{DD}$. Plot the results overlaid for the following:
   - Short channel device: $W = 1\mu m$ and $L = 200nm$
   - Long channel device: $W = 10\mu m$ and $L = 2\mu m$.

b. Comment on the differences between short channel and long channel results.
   - Which one has higher current? Why?
   - Is the relation linear or quadratic? Why?

c. Repeat for PMOS device. Comment on the differences between NMOS and PMOS.
   - Which one has higher current? Why?
   - What is the ratio between NMOS and PMOS currents?

2. g_m vs VGS

a. Plot g_m vs V_{GS} for NMOS device. Set $V_{DS} = V_{DD}$, and $V_{GS} = 0{:}\,10m{:}\,V_{DD}$. Plot the results overlaid for the following:
   - Short channel device: $W = 1\mu m$ and $L = 200nm$
   - Long channel device: $W = 10\mu m$ and $L = 2\mu m$.

b. Comment on the differences between short channel and long channel results.
   - Does g_m increase linearly? Why?
   - Does g_m saturate? Why?

3. ID vs VDS

a. Plot $I_D - V_{DS}$ characteristics for NMOS device. Set $V_{DS} = 0{:}\,10m{:}\,V_{DD}$, and $V_{GS} = 0{:}\,0.2{:}\,V_{DD}$ (nested sweep). Plot the results overlaid for the following:
   - Short channel device: $W = 1\mu m$ and $L = 200nm$
   - Long channel device: $W = 10\mu m$ and $L = 2\mu m$.

b. Comment on the differences between short channel and long channel results.
   - Which one has higher current? Why?
   - Which one has higher slope in the saturation region? Why?

c. Repeat for PMOS device. Comment on the differences between NMOS and PMOS.
   - Which one has higher current? Why?
   - What is the ratio between NMOS and PMOS currents?

4. g_m and r_o in Triode and Saturation

a. Plot g_m and r_o vs V_{DS} for NMOS device. Use $W = 10\mu m$ and $L = 2\mu m$, $V_{DS} = 0{:}\,10m{:}\,V_{DD}$, and $V_{GS} = V_{DD}$.

b. Comment on the variation of g_m vs V_{DS}.
   - In the first part of the curve, is the relation linear? Why?
   - Does g_m saturate? Why?
   - Where do you want to operate the transistor for analog amplifier applications?

c. Comment on the variation of r_o vs V_{DS}.
   - Does r_o saturate? Why?
   - Where do you want to operate the transistor for analog amplifier applications?