ECE/CS 5720/6720

Assignment for Week 4

1. Read Sections 3.1-3.8, 3.11 in Johns & Martin. Work problems 3.1, 3.2, 3.3, 3.5, 3.6, and 3.11 (5 points each). Note: In problem 3.5, assume that the circuit is begin driven by an identical common-source circuit. In other words, assume that R_{in} equals R_{out} (R_2).

   - Before continuing with problems 2 and 3 in this problem set, work through the MATLAB curve fitting exercise. (Do not turn in the results of this exercise.)

2. (10 points) **I_D vs. V_{GS}.** Load the MATLAB dataset `vgssweep.dat` from the class web page. This 81 × 2 matrix contains *I-V* data taken from a 3.6μm × 3.6μm *n*MOS transistor fabricated in a 1.2μm CMOS process. The gate-to-source voltage (column 1, units = V) was swept from zero to 1.0V while the drain current (column 2, units = A) was measured with a sensitive ammeter. The ammeter was capable of measuring currents as small as 3pA. Below this level, the current readings are not accurate. Measurements were taken with $V_{SB} = 0$. The drain-to-source voltage was held constant at 1.0V during the measurement. Turn in the following:

   a. A linear-axis plot of I_D vs. V_{GS} with a fit to the square-law behavior characteristic of above-threshold MOSFETs. *In all plots in Problems 2 and 3, plot measured data points as circles and your theoretical fit as a continuous line.* You may use any method (including trial-and-error by hand) to find parameters that result in a good fit. Label your axes and indicate the threshold voltage and a value for $\mu_n C_{ox}'/2$ (based on your fit). Given the gate oxide thickness of 305Å, what is the electron mobility μ_n in this process (in units of $cm^2/V \cdot s$)?

   b. A plot of the square root of drain current (i.e., $I_D^{1/2}$) vs. V_{GS} with a fit to the square-law behavior characteristic of above-threshold MOSFETs. You should use `polyfit` to fit the straight-line (above threshold) portion of this plot. The x-intercept point will be your threshold voltage. Label your axes and mark the threshold voltage (based on your fit). What is the drain current at $V_{GS} = V_{tn}$?

   c. The transconductance g_m is given by $\partial I_D/\partial V_{GS}$, but we can approximate it as $\Delta I_D/\Delta V_{GS}$ for small increments in gate voltage. Plot the transconductance vs. gate voltage from the data given. The `diff` command in MATLAB (type "`help diff`") is useful for this type of analysis.

d. Plot the **normalized transconductance** g_m/I_D (linear scale) vs. gate voltage (linear scale). What is the maximum value of this parameter (with units!), and in which region is it found?

Note: For all fits, fit only the appropriate regions!

3. (10 points) $\boldsymbol{I_D}$ **vs.** $\boldsymbol{V_{DS}}$**.** Load the MATLAB dataset `vdssweep.dat` from the class web page. This 81 × 2 matrix contains *I*-*V* taken from a 3.6µm × 3.6µm *n*MOS transistor fabricated in a 1.2µm CMOS process. The drain-to-source voltage (column 1, units = V) was swept from zero to 5.0V while the drain current (column 2, units = A) was measured. The gate-to-source voltage was held constant during the measurement, and was quite low so that the transistor enters active (saturation) region for very small values of V_{DS}. Measurements were taken with $V_{SB} = 0$. Turn in the following:

   a. A linear plot of I_D vs. V_{DS} with a linear fit to the saturation region (use `polyfit` over the appropriate range). Label your axes and indicate the Early voltage V_A (based on your fit). What is the value of λ? What is the output resistance r_{ds}?

   b. Using techniques outlined in Problem 2c, plot the output resistance r_{ds} ($\Delta V_{DS}/\Delta I_D$) vs. V_{DS} on a linear scale. Do the values of r_{ds} obtained here agree with the value derived from the fit in part (a)?