(a) **All problems worth 10 points. Grading will be at three levels: 0, 5, or 10 on each problem**

(b) **Please submit a pdf of your completed homework on Canvas- Scanning your handwritten homework is okay**.

(c) **Snapshots of the output plots should be labelled as shown in the tutorial**.

(d) **Homework file name should be <YourName>_HW_Sim_ECE422.pdf or <YourName>_HW_Sim_ECE522.pdf**

(e) Collaboration and discussion about problems is encouraged, but please write the solutions on your own.

Device parameters for simulations and calculations:

NMOS: $W = 25\mu m, L = 0.5\mu m, AS = AD = 0.6\mu m, PS = PD = 1.2\mu m + 2 * W,$
$t_{ox} = 4.1nm, V_{t0} = 0.376V.$

PMOS: $W = 60\mu m, L = 0.5\mu m, AS = AD = 0.6\mu m, PS = PD = 1.2\mu m + 2 * W,$
$t_{ox} = 4.1nm, V_{t0} = -0.404V.$

Calculating κ_n and κ_p:
$\kappa = \mu_0 Cox.$
$\mu_0 = U0$ from the model file.
Cox $= \frac{4.1*8.854e-12}{tox} F/m^2$
$tox = TOX$ from the model file.

Problem 1. Example Circuit : Common-source amplifier with resistive load

For the circuit shown in in Fig. 1: $V_{DD} = 1.8V, R_L = 1K\Omega$

(a) Plot the I_{DS} vs V_{in} characteristics for V_{in} from 0V to 1.8V.

(b) Plot the g_m vs V_{in} characteristics for V_{in} from 0V to 1.8V.

(c) Plot the I_{DS} vs V_{in} characteristics for V_{in} from 0V to 1.8V.

(d) Plot the small-signal gain of the circuit.

Fig. 2 shows the example circuit in LTspice. For more detailed usage of LTSpice options please refer to the tutorial posted on blackboard.

- To plot (a), (b) and (c) parts of the problem, use DC sweep analysis. Sweep Vin from 0 to 1.8 in steps of 0.01 V.
- To plot (d) use AC analysis. Sweep from 1Hz to 1GHz with 10 points per decade.
- The plots are shown in Fig. 3. Use the color preferences mentioned in the tutorial. For submission, label your snapshots as shown in the example plots.

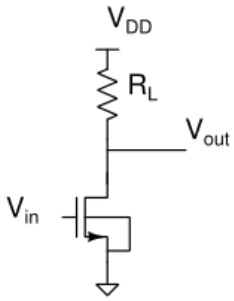


Figure 1: Example Circuit: CS amplifier with resistive load

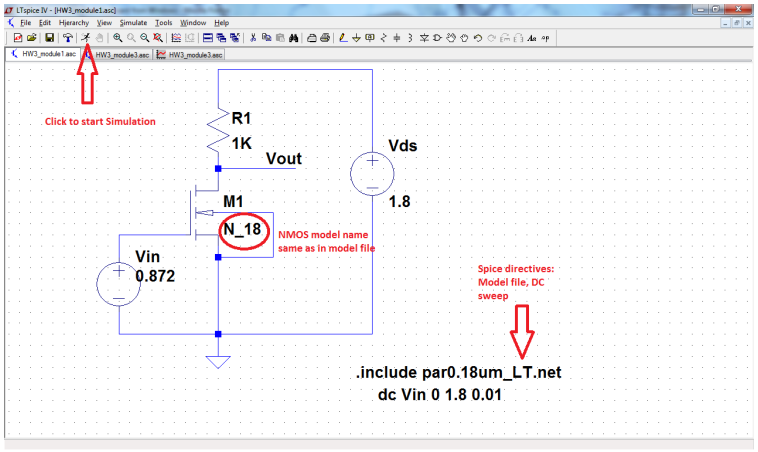


Figure 2: Example Circuit: LTspice

Problem 2. Common-source amplifier with PMOS transistor and resistive load

For the circuit in Fig. 4: $V_{DD} = 1.8V, R_L = 1K\Omega$

(a) Plot the I_{DS} vs V_{in} characteristics for V_{in} from 0V to 1.8V.

(b) Plot the g_m vs V_{in} characteristics for V_{in} from 0V to 1.8V.

(c) Plot the I_{DS} vs V_{in} characteristics for V_{in} from 0V to 1.8V.

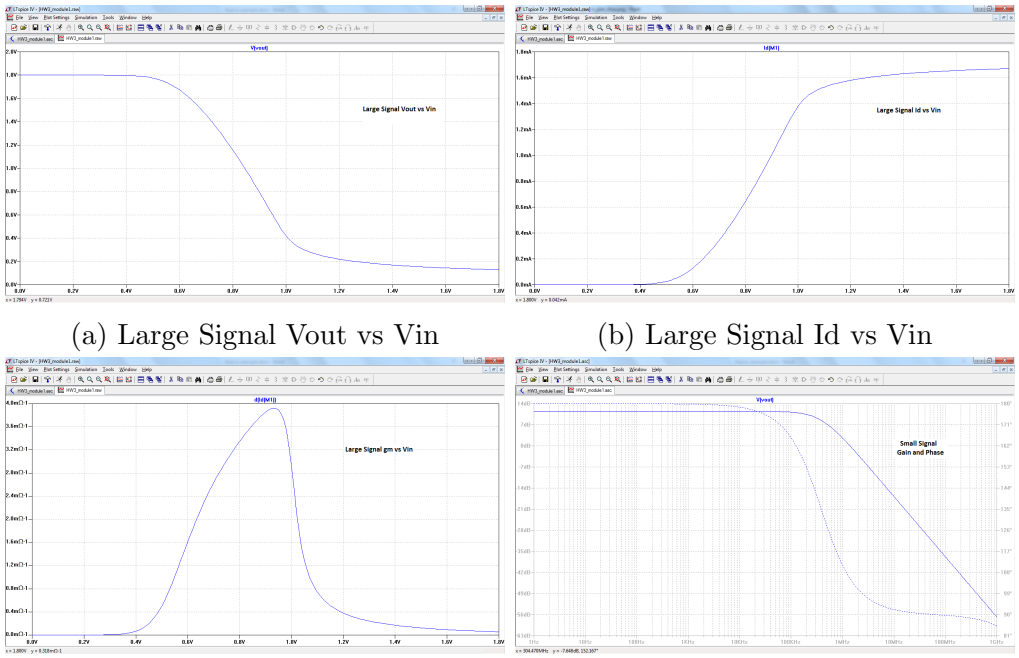
(d) Plot the small signal gain of the circuit.

Problem 3. MOS output resistance

(a) For the circuit shown in Fig. 5a With $Vin = 0.872V$ Plot r_{DS} vs V_{DS}

(b) For the circuit shown in Fig.5b With $Vin = 0.832V$ Plot r_{DS} vs V_D

Hint: $Rds = dI_D/dV_{DS}$



(a) Large Signal Vout vs Vin (b) Large Signal Id vs Vin

(c) Large Signal gm vs Vin (d) Small Signal gain and phase plot

Figure 3: Plots for the Example circuit

Problem 4. Common-source amplifier with current-source load

For the circuit shown in Fig. 5, $V_{DD} = 1.8V$

(a) For $V_{in} = 0.872V$ Find V_{BIAS} such that Vout = VDD/2 (Can do this by plotting Vout vs V_{BIAS})

(b) Estimate small signal gain $A_v = g_m * (rds_n || rds_p)$

- Use Example circuit to calculate g_m
- Use Problem 3a and 3b to calculate rds_n and rds_p

(c) Simulate AC gain, Compare Av_{calc} and Av_{gain}

(d) Change V_{BIAS} to $V_{BIAS} + \delta$ and $V_{BIAS} - \delta$ for $\delta = 0.1V$ and $0.2V$. What happens to the AC gain in each case?

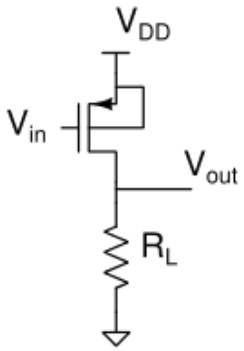
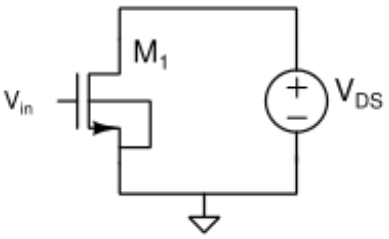
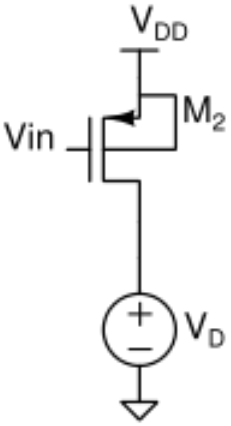


Figure 4: Problem 2: CS amplifier with PMOS transistor and resistive load



(a) NMOS



(b) PMOS

Figure 5: Problem 3: Output resistance

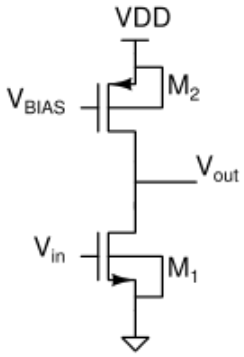


Figure 6: Problem 4: CS amplifier with current source load