Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Circuits & Electronics
Spring 2007

Homework #7
Handout S07-036

Issued 03/22/2007 – Due 04/06/2007

Helpful readings for this homework: Chapter 8

Exercise 7.1: Exercise 8.2 from Chapter 8 of A&L (page 448).

Exercise 7.2: Exercise 8.6 from Chapter 8 of A&L (page 449).

Problem 7.1:

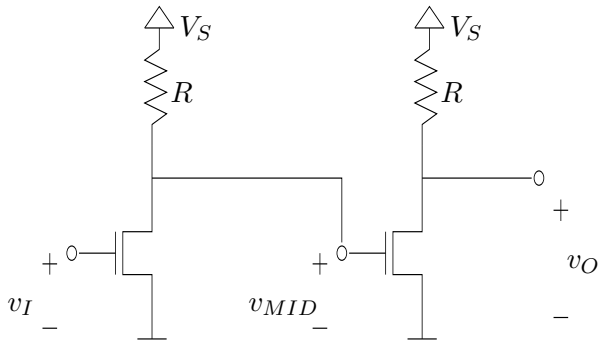


Figure 1: A two-stage non-inverting MOSFET amplifier is shown above. In this problem, V_I is chosen such that $V_I = V_{MID} = V_O$

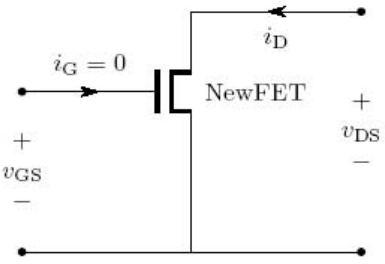
(a). Show that the input bias V_I for which $V_I = V_{MID} = V_O$ is given by:

$$V_I = V_T + \frac{-1 + \sqrt{1 + 2KR(V_S - V_T)}}{KR}$$

(b). Draw the small-signal circuit for the amplifier and use it to determine the small-signal gain $G = v_o/v_i$. Express G as a function of K, V_T, V_I and R.

Problem 7.2: Parts (a), (b) and (c) of Problem 8.2 from Chapter 8 of A&L (page 450). In part (c), determine the small-signal gain in terms of $g_m = K(V_{IN} - V_{OUT} - V_T)$.

Problem 7.3: This problem examines the behavior and application of a new field effect transistor (NewFET) with large-signal electrical characteristics as described in Figure 2. Here, it is assumed that $v_{DS} \geq 0$. Note that the coefficient K and the threshold voltage V_T are both positive and constant.



$$i_D = \begin{cases} 0 & \text{for} \quad v_{GS} < V_T \quad \text{(Cutoff Region)} \\ K(v_{GS} - V_T)v_{DS}^2 & \text{for} \quad v_{GS} \geq V_T \quad \text{(Active Region)} \end{cases}$$

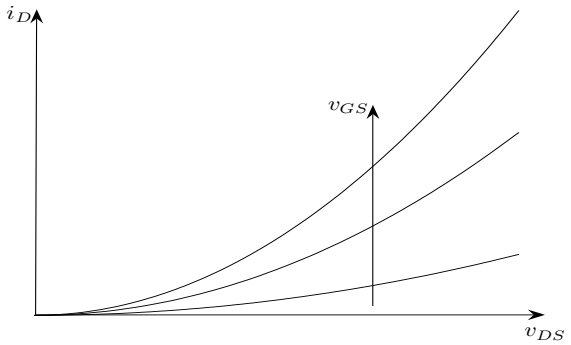


Figure 2: Large-signal characteristics of the NewFet.

(a). An amplifier is constructed with the NewFET as shown in Figure 3. Note that this amplifier does not have a load at its output. Derive an expression for v_{OUT} as a function of v_{IN}, in terms of the power supply voltage V_S, the resistance R, and the NewFET parameters K and V_T. Do so for $0 \leq v_{IN} \leq V_S$ assuming that $0 < V_T < V_S$.

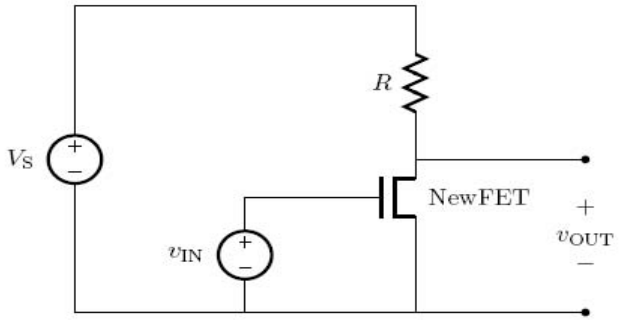


Figure 3: The NewFet used as an amplifier.

(b). For the amplifier shown in Figure 3 and analyzed in part (a), sketch and clearly label a graph of v_{OUT} versus v_{IN} for $0 \leq v_{IN} \leq V_S$.

(c). When the NewFET is biased into its active region, its small-signal model is as shown in Figure 4. Using the model shown in Figure 4, find i_d in terms of g_m, r_o, v_{gs}, and v_{ds}.

(d). Assuming that the NewFET is biased into its active region, derive expressions for the small-signal-model parameters g_m and r_o in terms of the large-signal-model parameters K and V_T, and the bias voltages V_{GS} and V_{DS}.

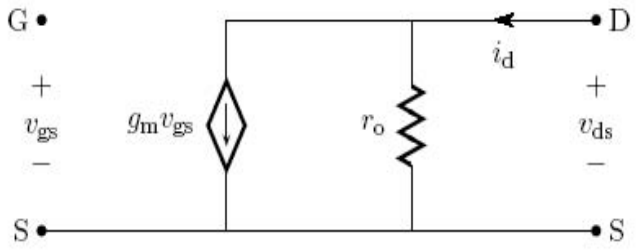


Figure 4: Small-signal model of the NewFET when biased in its active region.