PROBLEM SET 4

Issued: Tuesday, March 20, 2007

Due (at the beginning of class): Tuesday, March 27, 2007

1. Show that the output resistance of a MOSFET in saturation, when \((V_{DS}-V_{DSat})/l >> E_{sat}\), is approximately given by:

\[ r_o = \frac{\partial V_o}{\partial I_D} = \left( L_{off} + \frac{V_{GSD}}{E_{sat}} \right) \frac{E_{sat}}{I_{Dsat}} \]

2. A simple single-stage CMOS analog amplifier is shown below. For the devices, \(V_{tn}=700\text{mV}\) and \(V_{tp}=-700\text{mV}\). Assume that the \((W/L)\) ratios are effective values, post-fabrication, and that this is an n+ gate technology.

a. Estimate the DC input bias voltage \(V_{IN}\) necessary to establish a DC output voltage, \(V_{OUT}\), of 2.5V. [Hint: The \(V_D\) dependence is in \(\Delta L\).]

b. Calculate the small-signal gain of the amplifier at the bias point of part (a). Use the expression in problem 1 above for the device output resistance.

3. The ratio \((I_{sub}/I_D)\) at hot-carrier induced breakdown usually falls within the range of 0.05 to 0.2. For this problem, assume that it is equal to 0.05 and is device independent. A 1\(\mu\)m CMOS technology has the following device and process parameters: \(L_{ox}=20\text{nm}\), \(x_j=0.3\mu\text{m}\), \(\alpha=0\), \(V_{th}=700\text{mV}\).

a. Derive an expression for the hot-carrier induced breakdown voltage, \(V_{BD}\), of the nMOS devices as a function of \(L_{off}\) and \(V_G\).

b. Plot (or sketch) \(\log(V_{BD})\) as a function of \(\log(L_{off})\) for \(L_{off}=0.1\mu\text{m}\) to 100\(\mu\text{m}\) for \(V_G=2\text{V}\).

4. Use the following parameters for an nMOSFET: \(L_{ox}=20\text{nm}\), \(x_j=0.3\mu\text{m}\), \(\alpha=0\), \(V_{th}=700\text{mV}\), \(L_{off}=1\mu\text{m}\). Based on device degradation results, it is recommended that this nMOS device should not be operated with \(E_m>2\times10^5\text{V/cm}\).

a. What is the ratio of \(I_{sub}/I_D\) at this value of \(E_m\)? Determine the recommended maximum supply voltage \(V_{DD}\). Assume \(V_G=3\text{V}\) and that this value of \(V_G\) produces the maximum \(I_{sub}\).

b. What is the breakdown voltage of the device with \(V_G=3\text{V}\), assuming that the device breaks down at \(E_m=4\times10^5\text{V/cm}\)?