Mid-Term Exam, ECE-137B
Wednesday, May 6, 2009

Closed-Book Exam

There are 2 problems on this exam, and you have 50 minutes.
1) show all work. Full credit will not be given for correct answers if supporting work is not shown.
2) please write answers in provided blanks
3) Don’t Panic!
4) 137a, 137b crib sheets, and 2 pages personal sheets permitted.

Do not turn over the cover page until requested to do so.

Name:

_________________________________

Use any and all reasonable approximations. 5% accuracy is fine if the method is correct.

<table>
<thead>
<tr>
<th>Time function</th>
<th>LaPlace Transform</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ(t)</td>
<td>1</td>
</tr>
<tr>
<td>U(t)</td>
<td>1/s</td>
</tr>
<tr>
<td>e^{-αt}U(t)</td>
<td>\frac{1}{s + α}</td>
</tr>
<tr>
<td>e^{-αt}cos(ωd t)U(t)</td>
<td>\frac{s + α}{(s + α)^2 + ω_d^2}</td>
</tr>
<tr>
<td>e^{-αt}sin(ωd t)U(t)</td>
<td>\frac{ω_d}{(s + α)^2 + ω_d^2}</td>
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</table>

<table>
<thead>
<tr>
<th>Problem</th>
<th>Points Received</th>
<th>Points Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>1b</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>1c</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>1d</td>
<td>20</td>
<td></td>
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<tr>
<td>1e</td>
<td>10</td>
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<tr>
<td>2a</td>
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</tr>
<tr>
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<tr>
<td>2c</td>
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<tr>
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<td>10</td>
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<tr>
<td>total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Problem 1, 60 points

Q1 and Q2 are mobility-limited FETs with 180nm gate length
Thresholds: +0.3V for the NFETs, -0.3V for the PFETs. $\lambda = 0$ Volts$^{-1}$
For the NFETs: $I_D = 3.7(mA/V^2) \cdot (W_g / 1\mu m)(V_{gs} - V_{th})^2$
For the PFETs: $I_D = 3.7(mA/V^2) \cdot (W_g / 2\mu m)(V_{gs} - V_{th})^2$

The power supplies are +2V and -2V. The drain currents of Q1 and Q2 are both 1mA.
$V_{gs}$ of Q1 is 0.4 V. $V_{gs}$ of Q2 is -0.4V. The drain of Q1 is at +1.0V. The drain of Q2 is at 0V.

The blocking and bypass capacitors (Cin, Cout, Cg) are all extremely large.
$R_{gen}=1$kOhm. $R_L = 300$ Ohms. $R_{g1} = R_{gs}=1$ MOhm.
Part a, 10 points
Find the following:
$R_{g2} =$ ____________
$R_{g3} =$ ____________
$R_{D2} =$ ____________
$I_0 =$ ____________

Draw all DC node voltages on the circuit diagram below.
Part b. 10 points

*Mid Band Analysis:*
Find the following:

- Transconductance of Q1 = \[ \text{__________} \]  
- Transconductance of Q2 = \[ \text{__________} \]
- Voltage gain of Q2 = \[ \frac{V_{d2}}{V_{r2}} = \text{__________} \]  
- Input impedance of Q2 = \[ \text{__________} \]
- Voltage gain of Q1 = \[ \frac{V_{d1}}{V_{g1}} = \text{__________} \]  
- Amplifier input impedance = \[ \text{__________} \]
- \[ \frac{V_{\text{out}}}{V_{\text{in}}} = \text{_______________} \]  
- \[ \frac{V_{\text{out}}}{V_{\text{gen}}} = \text{_______________} \]
Part c: 10 points
The FETs have an oxide thickness of 1nm, have SiO2 (\( \varepsilon_r = 3.8 \)) as the gate dielectric. Recalling that \( \varepsilon_0 = 8.854 \cdot 10^{-12} \text{ F/m} \), and assuming that \( C_{gs} = c_{ox} L_g W_g \), find Cgs of Q1 and Q2. Using the over-simplified relationship \( C_{gd} = (1 F/\mu m) \cdot W_g \), find Cds of Q1 and Q2.

Cgs1=_____________________    Cgs2=______________
Cgd1=_____________________    Cgd2=______________
Part d: 20 points
USING either MOTC or the results of single-stage nodal analysis, find all three pole frequencies, and the zero frequency, of the transfer function $V_{out}/V_{gen}$. Give the frequencies of these in Hz. Feel free to use the separated-pole approximation if it is justified.

$f_{p1} =$__________, $f_{p2} =$__________, $f_{p3} =$__________

$f_{z1} =$__________
Part e: 10 points

Draw a clean asymptotic Bode Magnitude plot of \( V_{out}/V_{gen} \) as a function of frequency in Hz. Be sure to label and dimension the axes clearly, label pole and zero frequencies and gain slopes. Be sure to use the semi-log paper correctly.
Problem 2, 40 points

Part a 10 points

Small signal analysis. Ignore the DC bias; you don't need it.

*The FET has lambda=0 hence Gds=0. Also, Cgs=Cgd=0 fF*

Replacing the transistor with its high frequency small-signal model, draw a small-signal equivalent circuit diagram.
Part b, 10 points

**USING NODAL ANALYSIS**, compute \( \frac{V_{out}(s)}{V_{gen}(s)} \) in ratio-of-polynomials form:

\[
\frac{V_{out}(s)}{V_{gen}(s)} = \frac{V_{out}}{V_{gen_{mid-band}}} \times (s \tau)^m \times \frac{1 + b_1 s + b_2 s^2 + \ldots}{1 + a_1 s + a_2 s^2 + \ldots}
\]

*here \( m \), an integer, can be positive or negative or zero*
Part c, 10 points

\( gm = 10 \text{ mS} \quad R_L = 300 \text{ Ohm}, \ C_1 = 1 \text{pF}, \ C_L = 2 \text{pF}. \)

Find the frequencies of any zeros (there may be zero, one or two present) in the transfer function:
\( f_{z1} = \_\_\_\_, \ f_{z2} = \_\_\_, \ _\_\_\_\_, \ _\_\_. \)

There may be either 1 or 2 poles of the transfer function.

If the poles are real, give the 1 or 2 pole frequencies in Hz:
\( f_{p1} = \_\_\_, \ f_{p2} = \_\_\_\_\_\_. \)

If there are 2 poles, and they are complex, give \( f_n = \frac{\omega_n}{2\pi} \) and the damping factor \( \zeta : \)
\( f_n = \frac{\omega_n}{2\pi} = \_\_\_, \ \zeta = \_\_\_\_. \)
Part d, 10 points

If \( \text{Vin}(t) \) is a 100mV step-function, find and plot \( \text{Vout}(t) \). Be sure to label and dimension the axes clearly, and to clearly label key features of the time waveform.