Mid-Term Exam, ECE-137B
Tuesday, April 28, 2015

Closed-Book Exam

There are 2 problems on this exam, and you have 75 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.
Use any, all reasonable approximations. 5% accuracy is fine if the method is correct.

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

Name: ___________________________________

<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+\alpha} )</td>
</tr>
<tr>
<td>e^{-αt} cos(\omega_d t)U(t)</td>
<td>( \frac{s + \alpha}{(s + \alpha)^2 + \omega_d^2} )</td>
</tr>
<tr>
<td>e^{-αt} sin(\omega_d t)U(t)</td>
<td>( \frac{\omega_d}{(s + \alpha)^2 + \omega_d^2} )</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem</th>
<th>Points Received</th>
<th>Points Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>6</td>
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</tr>
<tr>
<td>1b</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>1c</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>1d</td>
<td>14</td>
<td></td>
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<tr>
<td>1e</td>
<td>14</td>
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<tr>
<td>1f</td>
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<td>2a</td>
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<tr>
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</tr>
<tr>
<td>total</td>
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</tbody>
</table>
Problem 1, 60 points

Q1 has 1.0 nm oxide thickness, $\varepsilon_r=3.8$, 22 nm gate length, and a 0.2 V threshold. Mobility is 400 cm$^2/(\text{V-s})$, saturation drift velocity is 1E7 cm/s, $\lambda=0$ Volts$^{-1}$, $C_{gs}=\varepsilon_r\varepsilon_{ox}L_gW_g/T_{ox}+(0.5\text{fF}/\mu\text{m})\cdot W_g$ and $C_{gd}=(0.5\text{fF}/\mu\text{m})\cdot W_g$.

Hints:

$$\varepsilon_r\varepsilon_{ox}/T_{ox}=3.36\cdot10^{-2}\text{F/m}^2, \quad (\mu\varepsilon_{ox}W_g/2L_g)=(3.06\cdot10^{-2}\text{A/V}^2)\cdot(W_g/1\mu\text{m})$$

$$(c_{ox}v_{sat}W_g)=(3.36\cdot10^{-3}\text{A/V}^1)\cdot(W_g/1\mu\text{m}), \quad (v_{sat}L_g/\mu)=55\text{mV}.$$  

The power supplies are +2V and -2V. The drain currents of Q1 is 1mA. $V_{gs}$ of Q1 is 0.24 V. The drain of Q1 is at +1.0V.

$R_{gen}=50\text{Ohm}$. $R_I=3\cdot R_D$

$C_{in}=1\text{nF}$, $C_{out}=2\text{nF}$
Part a, 6 points
Find the following:

- $R_{ss} =$ ________________  
- $R_p =$ ________________
- $W_g =$ ________________  
- $R_L =$ ________________

Draw all DC node voltages on the circuit diagram below.
Part b, 8 points

small-signal parameters

Find the following

\[ C_{gs} = \text{________________} \quad C_{gd} = \text{________________} \]
\[ g_m = \text{________________} \quad f_t = \text{________________} \]
Part c: 8 points

Mid Band Analysis:
Find the following:

\[ R_{\text{in, Amplifier}} = \underline{} \]
\[ R_{\text{eq}} = \underline{} \]
\[ V_{\text{out}} / V_{\text{in}} = \underline{} \]
\[ V_{\text{in}} / V_{\text{gen}} = \underline{} \]
Part d: 14 points

High-Frequency Analysis:
Find the frequencies, in Hz, of the two poles limiting the high-frequency response of the amplifier. Show your analysis (do not simply state that the input pole of a common-gate amplifier is approximately at $f_r$)

$$f_{p1, HF} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

$$f_{p2, HF} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.$$
Part e: 14 points

*Low-Frequency Analysis:*
Find the frequencies, in Hz, of the two poles limiting the low-frequency response of the amplifier. Show your analysis.

\[ f_{p1,LF} = \quad \quad \quad f_{p2,LF} = \quad \quad \quad . \]
Part f: 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 \( G_{ds} = 0 \). Also, \( C_{gs} = C_{gd} = 0 \) \( \text{fF} \)

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
\( g_m = 10 \text{ mS}, \quad R_i = 1 \text{ kOhm}, \quad C_1 = 1 \text{ pF}, \quad C_2 = 2 \text{ pF} \)

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

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:
\( f_{p1} = \text{___________}, \quad f_{p2} = \text{___________} \)

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

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