Mid-Term Exam, ECE-137B
MONDAY May 14, 2007

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>$\delta(t)$</td>
<td>1</td>
</tr>
<tr>
<td>$U(t)$</td>
<td>$\frac{1}{s}$</td>
</tr>
<tr>
<td>$e^{-\alpha t}U(t)$</td>
<td>$\frac{1}{s+\alpha}$</td>
</tr>
<tr>
<td>$e^{-\alpha t}\cos(\omega_d t)U(t)$</td>
<td>$\frac{s + \alpha}{(s + \alpha)^2 + \omega_d^2}$</td>
</tr>
<tr>
<td>$e^{-\alpha t}\sin(\omega_d t)U(t)$</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>10</td>
<td>10</td>
</tr>
<tr>
<td>1b</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>1c</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>1d</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>1e</td>
<td>10</td>
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</tr>
<tr>
<td>2a</td>
<td>10</td>
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</tr>
<tr>
<td>2b</td>
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</tr>
<tr>
<td>2c</td>
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<td></td>
</tr>
<tr>
<td>total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Problem 1, 70 points

The supplies are +/- 2 Volts

Q1: $|V_{th}|=0.3$ Volt,
$v_{sat} C_{ox} W_g =20$ mA/V,
$\lambda=0$, $C_{gs}=20$ fF,
$C_{gd}=0$ fF

Q2: $\beta=\infty$, $\tau_r=1$ ps,
$C_{je}=5$ fF, $C_{cb}=10$ fF,
$V_d=\infty$ Volts

Rgen=100 kOhm.
RL=100 Ohm
Ie2=1 mA
Rg1= 1 MOhm

The DC drain voltage of Q1 is to be 1 volts.
The DC drain current of Q1 is to be 5 mA.
Cin and Cout are AC short-circuits at all frequencies of interest---THEREFORE DO NOT TREAT THEM AS CAPACITORS in an MOTC analysis.
Part a, 10 points

Find the following

\[ R_{g2} = \quad \quad \quad \quad \quad R_{d1} = \quad \quad \quad \quad \quad \]

\[(C_{je} + \gamma_{diff}) \text{ of } Q2 = \quad \quad \quad \quad \quad \]
Part b, 10 points

*Mid Band Analysis:*
Find the mid-band small signal voltage gain of Q2 (the small signal voltage at the emitter of Q2 divided by the small signal voltage at the base of Q2)

\[ \text{Av}_2 = \text{___________} \]

Find the mid-band small signal voltage gain of Q1 (the small signal voltage at the drain of Q1 divided by the small signal voltage at the gate of Q1)

\[ \text{Av}_1 = \text{___________} \]

Find \( \text{Vin/Vgen} \)

\[ \text{Vin/Vgen} = \text{___________} \]
Part c: 20 points
USING MOTC, you will find the two dominant pole frequencies of the transfer function.
Give the frequencies of these in Hz:

Component of $a_1$ due to $C_{gs}$ of transistor Q1 = ___________ seconds.
Component of $a_1$ due to $C_{cb}$ of transistor Q2 = ___________ seconds.
Component of $a_1$ due to $(C_{je} + \gamma_{diff})$ of transistor Q2 = ___________ seconds.
a1 = ___________ seconds.
Part d: 20 points

Component of $a_2$ due to $C_{g1}$ and $C_{cb2} = \underline{\text{____________________}}$ seconds$^2$.

Component of $a_2$ due to $C_{g1}$ and $(C_{je} + \gamma_{\text{diff}}) = \underline{\text{____________________}}$ seconds$^2$.

Component of $a_2$ due to $C_{cb2}$ and $(C_{je} + \gamma_{\text{diff}}) = \underline{\text{____________________}}$ seconds$^2$.

$a_2 = \underline{\text{____________________}}$ seconds$^2$

$f_{p1} = \underline{\text{____________}}, \ f_{p2} = \underline{\text{____________}}$
Part e: 10 points
The circuit has 2 zeros its transfer function.
Give the frequencies of these in Hz:

\[ f_{z1} = \text{___________} \]
\[ f_{z2} = \text{___________} \]
Problem 2, 30 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, $C_{gs}=C_{gd}=0\ fF$

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 $V_{\text{out}}(s)/V_{\text{gen}}(s)$ in ratio-of-polynomials form:

\[
\frac{V_{\text{out}}(s)}{V_{\text{gen}}(s)} = \frac{V_{\text{out}}}{V_{\text{gen}_{\text{mid-band}}}} \times \frac{1 + b_1 s + b_2 s^2 + \ldots}{1 + a_1 s + a_2 s^2 + \ldots} = \ldots
\]
Part c, 10 points

\( gm = 100 \text{ mS} \). \( RL = 1 \text{ kOhm} \). \( Le = 1 \text{ nH} \)

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

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

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