EE 105 Midterm II

Spring 2005

Prof. Roger T. Howe

April 13, 2005

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Your Name (Last, First)

Guidelines

Closed book and notes; one 8.5” x 11” page (both sides) of your own notes is allowed. You may use a calculator. Do not unstaple the exam. Show all your work and reasoning on the exam in order to receive full or partial credit.

Score

<table>
<thead>
<tr>
<th>Problem</th>
<th>Points Possible</th>
<th>Score</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
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<tr>
<td>2</td>
<td>18</td>
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<td>3</td>
<td>17</td>
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<tr>
<td>Total</td>
<td>50</td>
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1. Phasor Analysis

This circuit is a model of a small-signal amplifier. The element values are:

- Source resistance $R_s = 20 \, \text{kΩ}$
- Input resistance $R_{in} = 5 \, \text{kΩ}$
- Input capacitance $C_{in} = 25 \, \text{pF}$
- Current gain $A' = 100$
- Load resistance $R_L = 25 \, \text{kΩ}$

(a) [4 pts.] Find the phasor current $I'$ in terms of the phasor source voltage $V_s$ and $R_s$, $R_{in}$, and $C_{in}$. There is no need to substitute numerical values for the elements.
(b) [4 pts.] Sketch the magnitude of $V_{out}/V_s$ using straight-line approximations.
(c) [4 pts.] Sketch the phase of $V_{out}/V_s$ using straight-line approximations.

(d) [3 pts.] If the phasor source voltage $V_s = (2.5mV)e^{j0^\circ}$ at a frequency of $10^4$ rad/sec, what is $v_{out}(t)$ based on the information in your Bode plots?
2. MOSFET single stage amplifier [18 pts.]

(a) [2 pts.] Find the numerical value of the bias current $I_{\text{BIAS}}$ such that the DC output current $I_{\text{OUT}} = 0$ A. The effect of channel-length modulation can be neglected for this part.

(b) [3 pts.] Find the DC reverse bias voltage across the photodiode, $V_R$, in Volts.

<table>
<thead>
<tr>
<th>Given:</th>
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<tbody>
<tr>
<td>$W = 50 , \mu\text{m}$, $L = 0.5 , \mu\text{m}$</td>
</tr>
<tr>
<td>$\mu_n C_{ok} = 50 , \mu\text{A/V}^2$</td>
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<tr>
<td>$V_{Th} = 0.5 , \text{V}$</td>
</tr>
<tr>
<td>$\lambda_n = 0.025 , \text{V}^{-1}$</td>
</tr>
<tr>
<td>neglect $g_{mb}$</td>
</tr>
<tr>
<td>$R_L = 20 , \text{k}\Omega$</td>
</tr>
<tr>
<td>$I_{\text{SUP}} = 200 , \mu\text{A}$</td>
</tr>
<tr>
<td>$r_{oc} = 80 , \text{k}\Omega$</td>
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</tbody>
</table>
(c) [3 pts.] The photodiode's small-signal model is a current source \( i_s(t) \) in parallel with a source resistance of \( R_s = 20 \text{ k}\Omega \). (i) label the two-port model as CS, CG, or CD and (ii) fill in the block with the circuit elements for the correct amplifier type (transconductance, current, or voltage). There is no need to evaluate the two-port model parameters for this part.

(d) [3 pts.] What is the numerical value of the input resistance \( R_{\text{in}} \) of this amplifier?

(e) [3 pts.] What is the numerical value of the output resistance \( R_{\text{out}} \) of this amplifier?
(f) [4 pts.] If the photodiode's source current is $i_s = 15 \ \mu A$, find the numerical value of the output current $i_{out}$ in $\mu A$. 


3. Voltage supply [17 points]

(a) [3 pts.] Find the numerical value of \( v_A \) in Volts. Neglect the backgate effect and channel-length modulation.

(b) [4 pts.] Find the width of transistor \( M_3 \) (in \( \mu \text{m} \)) such that the output voltage \( v_{\text{OUT}} = 1.5 \text{ V} \). You can neglect channel-length modulation and the backgate effect. If you couldn't solve part (a), you can assume that \( v_A = .75 \text{ V} \) for this part.
(c) [4 pts.] Draw the small-signal circuit for finding the Thévenin resistance $R_s$ looking into the output voltage terminals (see schematic on previous page). You can ignore the backgate transconductance for this part. *There is no need to solve for $R_s$."

(d) [3 pts.] Find the numerical value of the Thévenin resistance $R_s$ looking into the output voltage terminals. If you couldn't solve part (b), you can assume that the $W_3 = 20 \, \mu m$ for this part. You can also ignore the backgate transconductance for this part; you should also make judicious approximations.
(e) [3 pts.] The bulk terminal of \( M_3 \) is connected to ground. Using your results from part (b) for the width of \( M_3 \), what is the numerical value of the output voltage \( v_{\text{OUT}} \) in Volts? Ignore channel-length modulation. If you couldn't solve part (b), you can assume that the \( W_3 = 20 \ \mu\text{m} \) for this part.

\[
\begin{align*}
\mu_n C_{\text{ox}} &= 50 \ \mu\text{A}/\text{V}^2, \ V_{\text{TO}_n} = 0.5 \ \text{V}, \ \lambda_n = 0.1 / \text{L V}^{-1} \\
\mu_p C_{\text{ox}} &= 25 \ \mu\text{A}/\text{V}^2, \ V_{\text{TO}_p} = -0.5 \ \text{V}, \ \lambda_p = 0.1 / \text{L V}^{-1} \\
\gamma_n &= 0.5 \ \text{V}^{1/2}, \ -2\phi_p = 0.9 \ \text{V} \\
(W/L)_1 &= 4 \ \mu\text{m} / 1 \ \mu\text{m} \\
(W/L)_2 &= 8 \ \mu\text{m} / 1 \ \mu\text{m} \\
(W/L)_3 &= ? \ \mu\text{m} / 1 \ \mu\text{m} \\
R_A &= 5 \ \text{k}\Omega
\end{align*}
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