Instructions
Read all of the instructions and all of the questions before beginning the exam.

There are 5 problems in this exam. The total score is 100 points. Points are given next to each problem to help you allocate time. Do not spend all your time on one problem.

IMPORTANT

- If you do not put your answers within the boxes labeled ‘Solution’ THEY WILL NOT BE COUNTED (no matter how correct they may be in the bottom left back corner of the third to last page of the exam.)

- If you have more than one solution in the box, that box will be given zero points.

Unless otherwise noted on a particular problem, you must show your work in the space provided, on the back of the exam pages or in the extra pages provided at the back of the exam.

Be sure to provide units where necessary.

GOOD LUCK!

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>POINTS</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>15</td>
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<tr>
<td>5</td>
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<td>30</td>
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</table>
Problem 1 Bode plots (15 points)

Consider the circuit below. The box represents a missing circuit component. \( H(\omega) = \frac{V_{out}}{V_{in}} \) where \( V_{out} \) and \( V_{in} \) are phasors.

We would like the Bode plot of the magnitude of the transfer function, \( |H(\omega)| \), to be as shown below.

a) What element would you place inside the box? Circle one below. (5 points)

b) We would like \( \omega_c = 100 \) rad/s (see plot above). If \( R = 1 \) kΩ, what is the value of the component in a)? (5 points)

Solution:
c) What expression would you multiply \( H(\omega) \) by to make the Bode plot look like the one below? Please keep the expression symbolic. (5 points)

Solution:
Problem 2 (20 points)
Consider the circuit below. Please apply the “switch with resistor” model of a transistor when solving this problem. Assume $R_{DS}$ is the ‘on’ resistance and $|V_{th,n}| = |V_{th,p}| << V_{DD}$.

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a) If $v_{in}(t)$ is as plotted above, please provide a differential equation in $v_{out}(t)$. (5 points)

**Solution:**

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b) Please provide an expression for $v_{out}(t)$. (5 points)

**Solution:**
c) Consider the circuit below. Please apply the “switch with resistor” model of a transistor when solving this problem. Assume $|V_{th,n}| = |V_{th,p}| << V_{DD}$.

If $v_{in}(t)$ is as plotted above, please provide a differential equation in $v_{out}(t)$. (5 points)

| Solution: |
d) Given $v_{in}(t)$ plotted below, plot $v_{out}(t)$ for $t>0$ for the circuit below. Assume $v_c(t \leq 0) = 0$ V. (5 points)

Solution:
Problem 3 (20 points)
Please consider the circuit below.

a) What is $v_c(t=0)$? (2.5 points)

Solution:

b) What is $i_L(t=0)$? (2.5 points)

Solution:
c) Please provide a differential equation in $i_L(t)$ (and only in $i_L(t)$) for $t \geq 0$. (5 points)

Solution:


d) Please provide an expression for $i_L(t)$ for $t \geq 0$. Assume $L = 1 \mu H$, $R = 100 \Omega$, and $C = 1 \mu F$. (5 points)

Solution:


e) Please provide an expression for $v_C(t)$ for $t \geq 0$. (5 points)

Solution:
Extra Space
Problem 4 (15 points)
a) Consider the circuit below. All inputs and outputs are digital.

Provide a logical expression that describes $V_{\text{out}}$ as function of the inputs. (7.5 points)

Solution:

b) Draw a single CMOS digital logic gate that performs the following function. (7.5 points)

$$OUT = \overline{(A \lor B) \land (C \lor D)}$$

Solution:
Problem 5 (30 points)

For the following three circuits, provide an expression for the transfer function $H(\omega) = \frac{V_{OUT}}{V_{IN}}$ where $V_{OUT}$ and $V_{IN}$ are phasors. (10 points each)

a) 

\[ H(\omega) = \]

\[ \begin{array}{c}
\text{Solution:} \\
\hline
H(\omega) = \\
\end{array} \]
Solution:

\[ H(\omega) = \]
Solution:

\[ H(\omega) = \]
<table>
<thead>
<tr>
<th>Factor</th>
<th>Bode Magnitude</th>
<th>Bode Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>20 ( \log K )</td>
<td>( \pm 180^\circ ) if ( K &lt; 0 )</td>
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<tr>
<td></td>
<td>0 dB</td>
<td>0° if ( K &gt; 0 )</td>
</tr>
<tr>
<td><strong>Zero @ Origin</strong></td>
<td>( (j\omega)^N )</td>
<td>( (90N)^\circ )</td>
</tr>
<tr>
<td></td>
<td>0 dB</td>
<td>0°</td>
</tr>
<tr>
<td><strong>Pole @ Origin</strong></td>
<td>( (j\omega)^{-N} )</td>
<td>((-90N)^\circ)</td>
</tr>
<tr>
<td></td>
<td>0 dB</td>
<td>0°</td>
</tr>
<tr>
<td><strong>Simple Zero</strong></td>
<td>( (1 + j\omega/\omega_c)^N )</td>
<td>( (90N)^\circ )</td>
</tr>
<tr>
<td></td>
<td>0 dB</td>
<td>0°</td>
</tr>
<tr>
<td><strong>Simple Pole</strong></td>
<td>( \left( \frac{1}{1 + j\omega/\omega_c} \right)^N )</td>
<td>((-90N)^\circ)</td>
</tr>
<tr>
<td></td>
<td>0 dB</td>
<td>0°</td>
</tr>
<tr>
<td><strong>Quadratic Zero</strong></td>
<td>( [1 + j2\xi \omega/\omega_c + (j\omega/\omega_c)^2]^N )</td>
<td>( (180N)^\circ )</td>
</tr>
<tr>
<td></td>
<td>0 dB</td>
<td>0°</td>
</tr>
<tr>
<td><strong>Quadratic Pole</strong></td>
<td>( \left[1 + j2\xi \omega/\omega_c + (j\omega/\omega_c)^2 \right]^N )</td>
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<tr>
<td></td>
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