Name:

Student ID Number:

注意事項:

• 不作弊，也不幫助他人作弊。否則須接受任何懲罰。
• 可以帶一張 A4 紙之筆記。不可以看書或其他筆記。
• 試卷總共有 7 頁。請馬上檢查！
• 考題總共有 5 題。總分是 100 分。
• 考試時間有 100 分鐘。
• 可以用中文或英文作答。答案請寫清楚。
• 答案直接寫在試卷上。試卷背面也可以寫。如果寫在背頁，請在正頁註明，以免被漏看。
• $G = 10^9$, $M = 10^6$, $k = 10^3$, $m = 10^{-3}$, $\mu = 10^{-6}$, $n = 10^{-9}$, $p = 10^{-12}$, $f = 10^{-15}$.

<table>
<thead>
<tr>
<th>考題</th>
<th>滿分</th>
<th>得分</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10</td>
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<td>3</td>
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<td>4</td>
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<td></td>
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<tr>
<td>5</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>總分</td>
<td>100</td>
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</table>
1. 20 Points
Consider the folded-cascode opamp shown below, where \( C_{L1} \) and \( C_{L2} \) are the output capacitive loading, and \( C_{f1} \) and \( C_{f2} \) form the simplified schematic of the common-mode feedback. \( I_1 - I_3 \) are ideal current sources. all MOSTs are biased in the active (saturation) region. Consider only the following device parameters in calculation.

<table>
<thead>
<tr>
<th>Unit</th>
<th>M1, M2</th>
<th>M3, M4</th>
<th>M5, M6</th>
<th>M7, M8</th>
</tr>
</thead>
<tbody>
<tr>
<td>( g_m ) (( \mu ))</td>
<td>800</td>
<td>1000</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>( g_o ) (( \mu ))</td>
<td>30</td>
<td>25</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>( C_{gs} ) (fF)</td>
<td>100</td>
<td>60</td>
<td>25</td>
<td>100</td>
</tr>
</tbody>
</table>

Define the differential-mode and common-mode signals as:

\[
V_{id} = V_{i1} - V_{i2} \\
V_{ic} = \frac{V_{i1} + V_{i2}}{2} \\
V_{ad} = V_{o1} - V_{o2} \\
V_{oc} = \frac{V_{o1} + V_{o2}}{2}
\]

a. [5 pts] Find the dc differential-mode voltage gain, \( A_{dm}(0) = \frac{V_{ad}}{V_{id}} \).

b. [4 pts] Find the maximum slew rate \( SR = \frac{dV_{ad}}{dt} \). Assume \( g_o = 0 \).

c. [5 pts] Find the unity-gain frequency of the differential-mode voltage gain, \( A_{dm} = \frac{V_{ad}}{V_{id}} \). Assume \( g_o = 0 \) and neglect non-dominant poles.

d. [6 pts] Find the closed-loop bandwidth of the common-mode feedback. Assume \( g_o = 0 \) and neglect non-dominant poles.
1. (Continued)
2. 10 Points
Consider the latch shown below. Let
\[ g_{m1} = 100 \mu \text{s} \quad g_{m2} = 150 \mu \text{s} \quad C_1 = 200 \text{ fF} \quad C_2 = 150 \text{ fF} \]

a. Find the regeneration time constant of the latch.
3. 15 Points
Consider the following analog switch circuit. The input $V_i$ varies between 0.25 V and 1.75 V. The nMOST has a dimension of $W = 20 \mu m$ and $L = 1 \mu m$, and the following device parameters:

<table>
<thead>
<tr>
<th>Name</th>
<th>$V_t$</th>
<th>$\mu C_{ox}$</th>
<th>$C_{ox}$</th>
<th>$\gamma$</th>
<th>$\lambda$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>V</td>
<td>$\mu A/V^2$</td>
<td>$fF/\mu m^2$</td>
<td>$V^{1/2}$</td>
<td>$V^{-1}$</td>
</tr>
<tr>
<td>nMOST</td>
<td>0.55</td>
<td>200</td>
<td>4.7</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

a. [5 pts] Find the worst-case small-signal bandwidth of this circuit when $\phi$ is high?

b. [5 pts] Find the worst-case switching error. Consider only the effect of fast-gating charge injection.

c. [5 pts] Find the aperture jitter (sampling timing variation). Assume the 100% to 0% fall time $t_f$ is 2 nsec.
4. 30 Points
Consider the sample-and-hold amplifier (SHA) shown below. The opamp is ideal, except it has a finite dc gain $A_1 = 100$ and an input offset voltage $V_{OS}$. The analog switches are ideal, except that, when switching, they inject a constant charge of $\Delta Q = 100$ mV/pF into the terminals having ac or dc current path to ground. Let $V_i = 1$ V.

a. [15 pts] Assume $V_{OS} = 0$ V, find $V_o$ at $t_1$, $t_2$, $t_3$, and $t_4$.

b. [15 pts] Assume $V_{OS} = 0.2$ V, find $V_o$ at $t_1$, $t_2$, $t_3$, and $t_4$. 

![Sample-and-hold amplifier diagram](image-url)
5. 25 Points
Consider the oscillator shown below. For the M1 stage, its transfer function can be expressed as

$$H_1(j\omega) = \frac{V_1}{V_2} = -\frac{g_{m1}R_1}{1 + j2Q \cdot \Delta\omega} \quad \omega_r = \frac{1}{\sqrt{L_1C_1}} \quad Q = \omega_r R_1 C_1 \quad \Delta\omega = \omega - \omega_r$$

Let

$$g_{m1} = 5 \text{ m}\mu \quad L_1 = 10 \text{ nH} \quad C_1 = 10 \text{ pF} \quad R_1 = 200 \text{ } \Omega \quad C_2 = 1 \text{ pF} \quad R_2 = 200 \text{ } \Omega$$

a. [13 pts] Find the oscillating frequency of the oscillator.

b. [12 pts] Find the minimum value of M2’s $g_{m2}$ for the oscillator to oscillate.