• Closed book.
• Up to four sheets 8.5” by 11”, two-sided of handwritten notes.
• Write results on exam sheets only.
• Clearly mark results and cross out erroneous attempts. Show derivations.
• Up to 5 points per problem extra credit for properly derived and presented results.

Name:  ________________________________

SID:  ________________________________

Scores:

Problem 1  ______
Problem 2  ______
Problem 3  ______
Problem 4  ______
Problem 5  ______

Total  ______
1. [15 points] **Noise**

For the current source shown below calculate

a) The low-frequency thermal noise density at the output, \( \sqrt{\frac{I^2_{o,n}}{\Delta f}} \) in pA/rt-Hz @ R.T.

b) The flicker noise corner frequency.

Given: \( I_{D1}=400\mu A, I_{D2}=100\mu A, V_{d1\text{star}}=V_{d2\text{star}}=200mV, \gamma=1, K_f=10^{-28}AF, C_{ox}=10fF/\mu m^2, k_BT=4x10^{-21}kgm^2s^{-2} \)
2. [15 points] MOS S/H
The circuit below operates from a two-phase non-overlapping 0V/3V clock. The switch $\Phi_{1\text{late}}$ opens shortly after the switch clocked with $\Phi_1$.

a) Calculate the maximum value of $W$ for which the charge injected onto $C$ at the end of phase 1 results in a sampling error of less than 30mV. Assume fast gating and that the channel charge splits equally between source and drain.

b) Assuming that the source $V_i$ has zero output resistance and $W=5\mu m$ (not the correct answer for a), what is the worst-case relative settling accuracy for $t_{\text{settle}}=5\text{ns}$ (ignore charge injection)?

Parameter: $V_{THN}=1V$, $\mu_nC_{ox}=200\mu A/V^2$, $C_{ox}=5fF/\mu m^2$, $C_{ol}^{'}=0fF/\mu m$, $C=1pF$. Assume square-law behavior and ignore the body-effect.
3. [15 points] **OTA Compensation**

The diagram below illustrates an alternative method for removing the feedforward zero arising from Miller compensation. The openloop frequency response of this amplifier is

\[
a(s) = -v_i \cdot \frac{(s \cdot C_1 \cdot g_{m3} - s \cdot C_c \cdot g_{m1} + s \cdot C_c \cdot g_{m3} + g_{m1} \cdot g_{m2})}{(C_2 \cdot s \cdot C_1 + C_2 \cdot s \cdot C_c + C_c \cdot s \cdot C_1 + g_{m2} \cdot C_c) \cdot s}
\]

a) Find the value of \(g_{m3}\) that moves the zero of \(a(s)\) to infinity.
b) Compare this approach to using a nulling resistor. List key advantages or disadvantages of the proposed solution.
4. [15 points] **Matching**

Derive an expression for the standard deviation of the relative current mismatch \( \Delta I_D/I_D \) of the circuit below. State your result as a function of \( W, L, V_{TH}, \) terminal voltages, and \( A_1, A_2 \) describing technology mismatches as

\[
\sigma^2_{\Delta (W/L)} = \frac{A_1}{WL} \quad \text{and} \quad \sigma^2_{\Delta V_{th}} = \frac{A_2}{WL}.
\]

Given: \( L=1\mu \text{m}, W=80\mu \text{m}, V_{\text{star}}=300\text{mV}, A_1=10^{-4}\mu \text{m}^2, A_2=10^{-5}\text{V}^2\mu \text{m}^2 \)
5. [15 points] **Amplifier scaling**
Fill in the table below. The column headings are amplifier characteristics (bandwidth, phase margin, settling time, and total integrated thermal noise at the output). The amplifier is used in an SC gain stage providing constant voltage gain. The first column lists amplifier parameters. In each empty cell indicate how the amplifier characteristics change when the parameter listed in the first column is increased. Use the following code: up and down arrows for increase/decrease, equal sign for no significant change and question mark if it is impossible to answer the question with the information given.
Ignore all capacitors except those explicitly shown. As shown, the amplifier has ~80° phase margin.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$f_{-3dB}$</th>
<th>phase margin</th>
<th>settling time</th>
<th>$\frac{v^2}{v_{oT}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{b1}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{b2}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_c$</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$C_L$</td>
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<td></td>
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</tr>
<tr>
<td>$L_5$</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$L_1 &amp; L_2$</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$L_3 &amp; L_4$</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

![Amplifier Circuit Diagram]

$V_{DD}$

$M1$

$M2$

$M3$

$M4$

$M5$

$V_{i1} = V_o$

$V_{i2}$

$C_c$

$C_L$

$I_{b1}$

$I_{b2}$

$V_o$

$L_1$ & $L_2$

$L_3$ & $L_4$