EE4280 Analog Integrated Circuits Analysis and Design II **2020 Spring**

Homework I – due date: 03/27 (Friday) 10AM **(No late homework!!!)**

- Please submit your report with the correct file name (HW1_105061703.pdf or HW1_105061703.doc) to our course website (iLMS system) by the deadline. No hardcopy will be accepted this time.
- Please replace 105061703 with your own student ID.
- Use cic018.l for simulations. Do not change any of the model parameters.

1) Consider a common-source amplifier with resistor load (R_L) of 600 Ω, V_{DD} = 1.8 V, $V_{in,DC}$ = 0.9 V, temp = 27°.

a) Consider only the thermal noise of R_L.

i. Calculate the output noise power (in terms of V^2/Hz).

ii. Calculate the total rms output noise voltage over the frequency range from DC to 1 GHz.

iii. With load capacitor (C_L) of 100 fF, calculate the total rms output noise voltage over the entire frequency range.

b) Use **HSpice** to design the common-source amplifier with the following specifications.

> R_L = 600 Ω, C_L = 100 fF, V_{DD} = 1.8 V, $V_{in,DC}$ = 0.9 V, temp = 27°, $V_{out,DC} \geq V_{in,DC}$, voltage gain of at least 2 V/V, 3-dB bandwidth of at least 2 GHz, and as little power as possible.

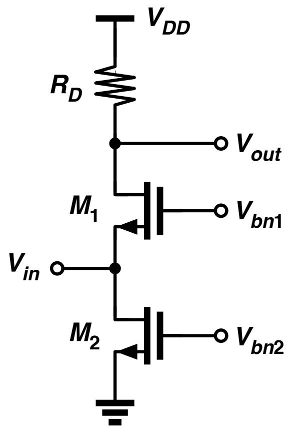
i. With **dc** analysis, report the following of your final design.
- Size (W/L) of the transistor.
- Power consumption.
- Output DC voltage ($V_{out,DC}$).

ii. With **ac** analysis from 1 kHz to 100 GHz, plot the frequency response from V_{in} to V_{out} over 1 kHz to 100 GHz.
- Use log scale for x-axis.
- Use dB20 scale for y-axis.
- Mark (x, y) at frequency = 1 kHz.
- Mark (x, y) at 3-dB bandwidth.

iii. With **noise** analysis from 1 kHz to 100 GHz, report the following.
- Plot output noise power spectral density (PSD) in terms of V^2/Hz over 1 kHz to 100 GHz.
  - Use log scale for x-axis.
  - Use absolute magnitude for y-axis.
  - Integrate the above waveform (output noise PSD) over 1 kHz to 100 GHz.

- Compare the result with your hand calculations from question set of 1-a-iii). Explain the difference.
- From the question above, calculate the total rms output noise voltage contributed by the transistor for the frequency ranges from 1 kHz to 100 GHz.
- Assume a constant voltage gain over this frequency range, calculate the total rms input-referred noise voltage of your design.

2) Assume $\lambda = \gamma = 0$. Consider the following circuit.



a) Calculate the dc voltage gain.
b) Calculate the output swing.
c) Calculate the input-referred thermal noise voltage (in terms of $\mathrm{V}/\sqrt{\mathrm{Hz}}$) and input-referred thermal noise current (in terms of $\mathrm{A}/\sqrt{\mathrm{Hz}}$).
d) Use $\mu_n C_{ox} = 303\ \mu\mathrm{A/V}^2$ and $\mu_p C_{ox} = 91\ \mu\mathrm{A/V}^2$ for the calculation. Set $V_{DD} = 1.8$ V. $I_{D,M1} = I_{D,M2} = I_{RD} = 1$ mA and $(W/L)_1 = 6\ \mu\mathrm{m}/0.18\ \mu\mathrm{m}$. Design R_D and $(W/L)_2$ so that the dc voltage gain is at least 3 V/V, output swing is at least 1.2 V, and the input referred thermal noise voltage and current are minimized. Describe how the circuit is designed.

e) From the results above, use **HSpice** to simulate the design.
   i. Keep the device sizes unchanged. Adjust the bias voltages ($V_{in,DC}$, V_{bn1}, and V_{bn2}) so that no DC current flows through V_{in} and the bias current is less than 1 mA while maintaining all transistors in saturation.
   ii. With **dc** analysis, report the following.
   Hint: You may just open the input port when designing the bias condition of the circuit, so that there is no DC current flowing through the input port.
   - Bias voltages $V_{in,DC}$, V_{bn1}, and V_{bn2}.
   - Power consumption.
   - Output DC voltage ($V_{out,DC}$).

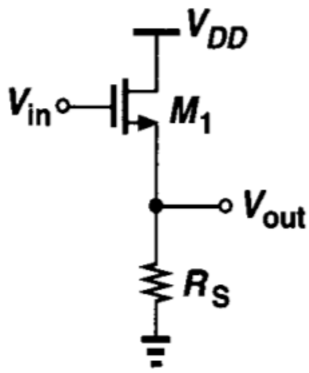
iii. With **ac** analysis from 1 kHz to 100 GHz, plot the frequency response from V_{in} to V_{out} over 1 kHz to 100 GHz.

- Use log scale for x-axis.
- Use dB20 scale for y-axis.
- Mark (x, y) at frequency = 1 kHz.

iv. With **noise** analysis from 1 kHz to 100 GHz, report the following.

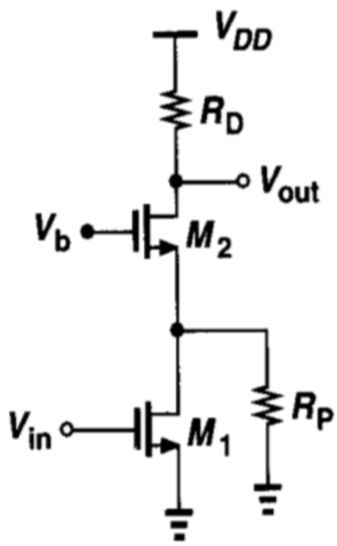
- Plot output noise power spectral density (PSD) in terms of V^2/Hz over 1 kHz to 100 GHz.
  - Use log scale for x-axis.
  - Use absolute magnitude for y-axis.
  - Mark (x, y) at frequency = 1 GHz and 10 GHz on the figure.
  - Calculate the input-referred thermal noise voltage at these two frequencies and compare the results with that from question set of 2-d).

3) Calculate the input-referred thermal noise voltage (in terms of $V/\sqrt{Hz}$) of the following circuit. Assume $\lambda = \gamma = 0$.



4) For the following circuit, assume $\lambda = \gamma = 0$. Calculate the input-referred thermal noise voltage (in terms of $V/\sqrt{Hz}$) with and without R_P.

<u>**Hint:**</u> You can model the noise from M_2 as a voltage source in series with its gate.



5) Consider the following circuit. Assume $\lambda = \gamma = 0$.

a) Calculate the input-referred thermal noise voltage in terms of $\text{V}/\sqrt{\text{Hz}}$.

b) If the thermal noise contributed by R_S is the same as that contributed from M_1, how is the dc voltage drop across R_S compared to the overdrive voltage of M_1?