ECEN 474
Homework #4

Due: 10-19-2012, 5:00PM

Homeworks will not be received after due.

Instructor: Sam Palermo

1. (60 points) Wilson Current Mirror
   a) Derive the following expression for the low-frequency output impedance of the Wilson current mirror shown below. Assume that $\gamma=0$ for all transistors and that the input reference current source is ideal (infinite output impedance). What specifically is $A_V$? (10 points)
   $$r_{out} \approx g_m 4 \left( 1 + A_V \right) \frac{1}{g_m^2} r_o 4$$

   b) Design the current mirror with a 1:2 input current to output current ratio to satisfy the following specifications.
      - $I_{in}=50 \mu A$
      - Low-frequency output impedance $\geq 2M\Omega$ for an output voltage $\geq 1V$.

   Design procedure counts for 25 points.

   Turn in the following to validate the design performance:
   - Schematic with transistor sizes, DC operating points, and the bias current labeled (5 points)
   - Print-out with small-signal device parameters for $V_{out}=1V$. Highlight the critical small-signal parameters, such as $g_m$, $g_{ds}$, etc. (5 points)
   - Characterize the current mirror by performing a DC sweep of $V_{out}$ from 0-2V and plotting the output current. (5 points)
   - Use the above DC sweep data to plot the output impedance vs $V_{out}$. (5 points)
   - Plot the AC frequency response of the output impedance from 10Hz=100MHz with $V_{out}=1V$. Use a log-log scale to clearly identify the location of poles and zeros. Explain the frequency response. (5 points)
2. **(20 points)** Open-Circuit Time Constants Bandwidth Estimation
Use the open-circuit time constants bandwidth estimation technique outlined in Lecture 10 to estimate the bandwidth of the cascode amplifier below. Assume that both transistors are operating in saturation, $\gamma = \lambda = 0$, and the same following element values:

$C_{gs}=220fF$, $C_{sb}=130fF$, $C_{gd}=45fF$, $C_{db}=90fF$, $g_m=12mA/V$

![Cascode Amplifier Diagram](image)

3. **(20 points)** Noise Analysis
Derive an expression for the input referred voltage noise density of the circuit below. Assume $M1$ and $M2$ are both in saturation. Specify the result as the noise from $M1$ multiplied by a factor that is a function of the $g_m/I_D$ of the two transistors. What does this imply about the $g_m/I_D$ you should choose for $M1$ vs $M2$? You can neglect flicker noise for this analysis.

![Noise Circuit Diagram](image)

4. **(20 points: Extra Credit for Undergrads, Not Extra Credit (Required) for Graduate Students)**
Noise Analysis
Derive an expression for the input referred voltage noise density of the two-stage amplifier circuit below. Assume all transistors are operating in saturation and that you can neglect body effect. In order to minimize the input referred voltage noise density, how should both the gain of the first stage and $g_{m2}$ be optimized, i.e. should either of them be minimized or maximized?

![Two-Stage Amplifier Diagram](image)