Current Mirrors

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Announcements

• Preliminary Project Report due today
• HW8 due 4/27
• Project Report due May 2
  • Email it to me by 5PM
• Exam 3 is on Tuesday May 9
  • Focus on MOSFETs
  • 1PM-3PM
  • 1 standard 8.5x11 note sheet (front & back)
  • Bring your calculator
Current Source Properties

• Output Resistance

- Finite output resistance degrades current source accuracy and amplifier gain

• Other important properties:
  - Voltage headroom (compliance voltage)
  - Accuracy
  - Noise
How Should We Bias Our Circuits?

- Resistive Biasing
  - Assuming saturation
    \[ I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_G - V_{Tn})^2 \]
    \[ = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \left( \frac{R_{G2}}{R_{G1} + R_{G2}} Vdd - V_{Tn} \right)^2 \]

- \( I_D \) is sensitive to
  - Supply (Vdd)
  - Process (\( V_{Tn} \) and \( \mu_n C_{ox} W/L \))
  - Temperature (\( V_{Tn} \) and \( \mu_n \))
IC Biasing

- In IC design we often assume that we have **one** precise current source and we copy its value to our circuits.
Simple Current Mirror

- That copy circuit is a current mirror
- Simple Current Mirror

\[ I_D = I_{REF} = \frac{1}{2} \mu_n C_{ox} \left( \frac{W}{L} \right)_1 (V_G - V_{Tn})^2 \]

\[ V_G = \sqrt{\frac{2I_{REF}}{\mu_n C_{ox} \left( \frac{W}{L} \right)_1}} + V_{Tn} \]

- If \( V_G \) is applied to another transistor

\[ I_{out} = \frac{1}{2} \mu_n C_{ox} \left( \frac{W}{L} \right)_2 \left( \sqrt{\frac{2I_{REF}}{\mu_n C_{ox} \left( \frac{W}{L} \right)_1}} + V_{Tn} - V_{Tn} \right)^2 \]

\[ I_{out} = \left( \frac{W}{L} \right)_2 I_{REF} \]
Ideal Current Mirror Example

- This bias scheme reduces sensitivity to process, voltage, and temperature variations

\[ I_1 = 1\text{mA} \]
\[ I_2 = 1\text{mA} \]
\[ I_3 = 0.5\text{mA} \]
\[ I_4 = 1.5\text{mA} \]
What is $I_D$?

- Need to insure that M3 remains in saturation

\[
V_s = V_G - (V_{ovl} + V_{Tn}) = \left( \frac{R_{G2}}{R_{G1} + R_{G2}} \right) Vdd - \frac{2I_D}{\mu_n C_{ox} \left( \frac{W}{L} \right)_1} + V_{Tn}
\]