Lecture 10: High Swing Current Sources II

- **Announcements:**
  - This is the make-up lecture for yesterday's lecture
  - Reminder: Lab#2 starts next week
  - No Monday lab section next week due to holiday
  - Monday lab sections will start Lab#2 Monday the week after next

- **Lecture Topics:**
  - High Swing Current Sources (cont.)
  - Current Source Matching Considerations
  - Op Amp Review

- **Last Time:**
  - Looking for current sources that maximize the output swing available for an amplifier

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Problem: Not that easy to get an exact level shift.  
\[
V_{\text{out}} = \frac{2I_D}{\sqrt{\frac{1}{2}f_C^2}} 
\]

\[
V_{\text{in}} - V_{\text{out}} = V_{\text{in}} + V_T - V_T - \frac{V_{\text{in}}}{R_S} 
\]

Problem: Don't like this.  
\[
\left( \frac{V_T}{2} \right)_S \text{ must be big to send } V_{\text{out}} \to 0 \]

\[
\text{if not } V_{\text{in}} < V_{\text{out}} \text{ then } \text{Bad!} 
\]

Any other option: just accept a \( V_T + V_{\text{out}} \) level shift.
The circuit:

\[ I_{D3} = \frac{1}{2} \frac{1}{L_{M1}} \left( \frac{W}{L} \right)^2 (V_{0V3})^2 \]

\[ I_{D4} = \frac{1}{2} \frac{W_{M1}}{L_{M1}} (\frac{W}{L})_4 (2V_{0V3})^2 \]

\[ X = \frac{W_{M1}}{L_{M1}} (\frac{W}{L})_5 (V_{0V3})^2 = \frac{1}{2} \frac{1}{L_{M1}} \left( \frac{W}{L} \right)^2 (2V_{0V3})^2 \]

\[ \left( \frac{W}{L} \right)_4 = \frac{1}{4} \left( \frac{W}{L} \right)_3 \]

\[ \left( \frac{W}{L} \right)_5 = \left( \frac{W}{L} \right)_2 \left( \frac{W}{L} \right)_3 \]

... and \( \left( \frac{W}{L} \right)_6 \)

Problem: Body effect in \( M_4, M_5, M_2 \)

Will increase their \( V_t \)!
High Swing Current Sources II

**Problem:**
- $V_{S3} = 0V$? $V_{T3} < V_{T2}$
- $V_{T2} = V_{DD}$

**Analysis:**
- $V_{T2} + V_{Ch} = V_{T2} + V_{Ch} + V_{DD}$
- $V_{Ch} + V_{DD} = V_{DD}$

**Solution:**
1. Tie the wells of $M4, M5, M6$ to their sources.
2. Bias $M4$ so that $V_{GS4} > V_{t2} + 2V_{NV}$
   - $V_{GS4} = V_{t2} + 2V_{NV}$

**Note:**
- $M1$ is not saturated
- $V_D = \frac{V}{2} \mu A_{CN}(V_{DD} - V_{t2})^2 (1 + \lambda V_{DD})$

**Conclusion:**
- Use an alternate binary scheme.
**Alternate Binary Scheme for Cascade**

want only $V_{OV}$ across $M_3$ to make it a $V_{ON}$:

- **Problem:** Need $V_{BSA1}$ and $V_{BSA2}$
- **Solution:** $V_{BSA1} = V_{t_1 + 2V_{OV}}$

**Resistor $V_{BSA2}$ Consideration:**

- **Goal:** Current Source
- **Constraint:** $V_{BSA2}$

Size $R_b$ so that $I_{R_b} = V_{t_6}$

**Issue:**

1. $I_{R_b}$ not all that well controlled.
2. Resistors are a consumptive.
3. Body effect complicates things:

   - really need: $I_{R_b} = V_{t_5} + V_{t_7} - V_{t_4}$

   Replace $R_b$ with a transistor level shift:

   - pinned to $V_{DD}$

**Equations:**

- $V_{DD}$
- $V_{BSA2}$
- $V_{t_6}$
- $V_{t_7}$
- $V_{t_8}$
- $V_{t_9}$
- $V_{t_10}$
- $V_{t_11}$
- $V_{t_12}$
Design:

**Approach 1:** Want $V_{GS} = V_T$, so must make $(w/l) > \text{105s}$. So that:

$V_{OV} = \frac{2I_T}{\mu_n C_0 (w/l)} \rightarrow 0, \text{ for}$

Solution: Problem two mid chip ampl.

**Approach 2:** Recognize that devices in the

$V_{GS}$ generation don't all need to be saturated — some can be linear.