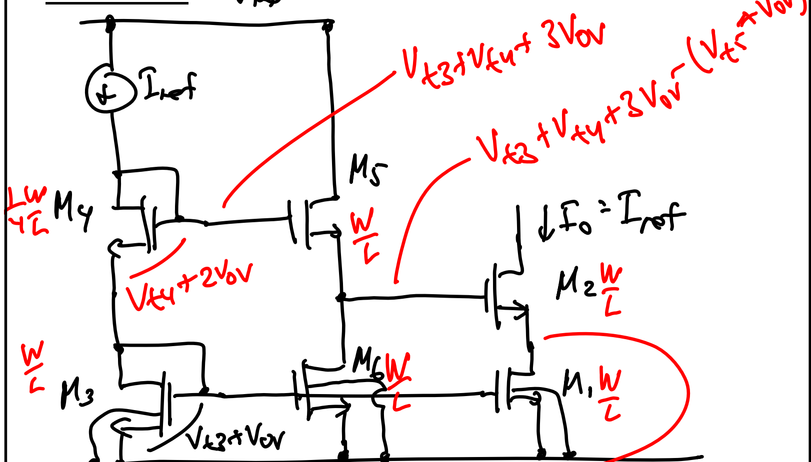
Lecture 11: High Swing Current Sources II

- **Announcements**:
  - HW#5 online
- **Lecture Topics**:
  - High Swing Current Sources (cont.)
  - Current Source Matching Considerations
  - Op Amp Review
- --
- **Last Time**:



$(V_{t3}+V_{t4}-V_{t5}+V_{t2})+V_{ov} < V_{ov}$

(−) (−)

$V_{t4} \neq V_{t5} \rightarrow V_{S4} = V_{t3}+V_{ov}$

$V_{S5} = V_{t2}+2V_{ov} \rightarrow V_{t5} > V_{t4}$

$V_{t3} \neq V_{t2} \rightarrow V_{t2} > V_{t3}$

∴ M_1 is not saturated! Bad!

Solutions:

① Tie the wells of M_4, M_5, M_2 to their sources → all V_t's the same
→ not practical → takes up area to give each device its own well!

② Bias M_4 so that $V_{DS4} > V_t + 2V_{ov}$,
(e.g., $V_{DS4} = V_t + 3V_{ov}$)
→ make M_4 smaller than $\frac{1}{4}\left(\frac{W}{L}\right)_1$

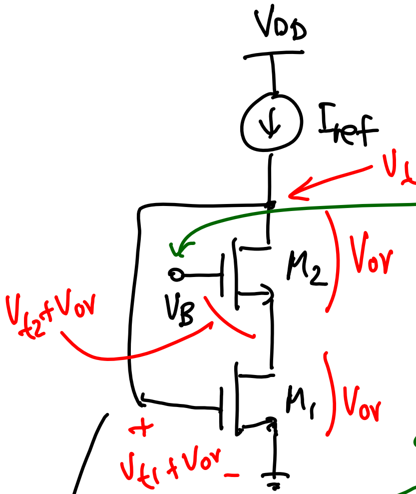
$(W/L)_4 = \frac{1}{9}(W/L)_1$

Issue: $V_{DS1} \neq V_{DS3} \rightarrow I_o = \frac{(1+\lambda V_{DS1})}{(1+\lambda V_{DS3})} I_{ref}$

$\rightarrow I_o \neq I_{ref}$

Soln: Use an alternative biasing scheme.

Alternate Biasing for Cascode

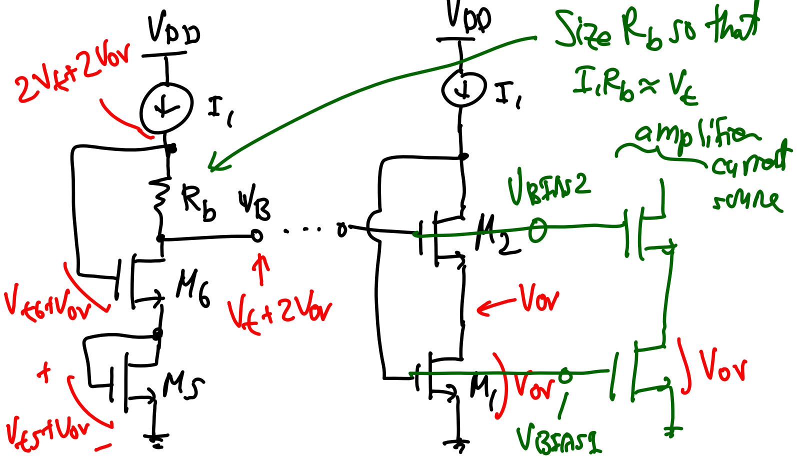


Need $V_B = V_{t2} + 2V_{ov}$ to provide max output swing where $V_{omin} = 2V_{ov}$

Need $V_{t1} > V_{ov}$ to keep M_2 saturated

make M_2 large enough so that $V_{ov} < V_{t1}$

Resistive V_B Generator

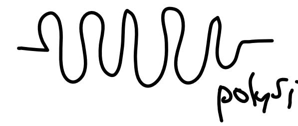


Size R_b so that $I_1 R_b \approx V_t$

Issues:

① $I_1 R_b$ not all that well-controlled.

↳ can hit the right value of R_b only to 20% (in an IC process)



↳ R_b = big → costs too much…

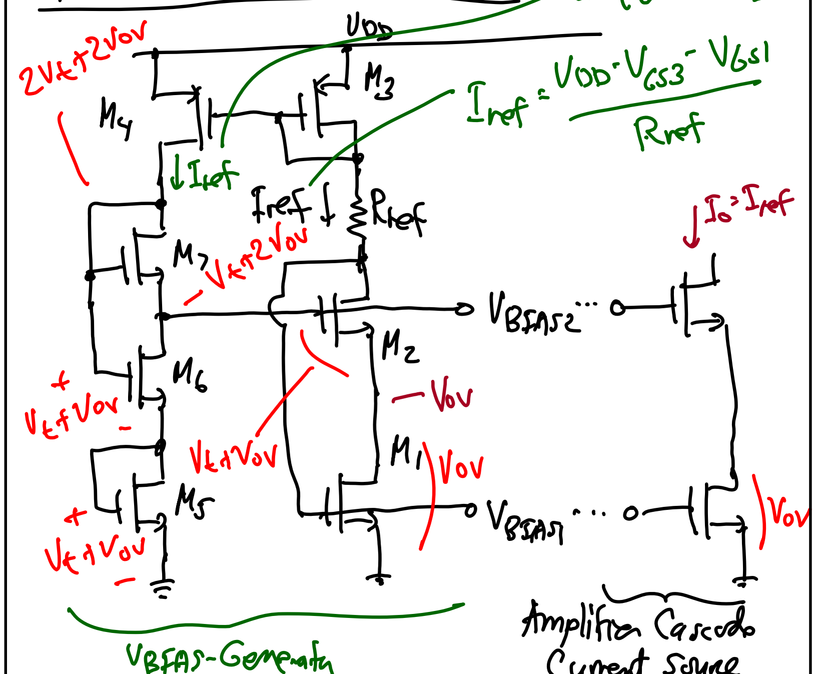
② Must still account for Body Effect.

↳ so really need: $I_1 R_b = V_{t5} + V_{t6} - V_{t2}$

Replace R_b w/ transistor level-shift:

w/ $\left(\frac{W}{L}\right)_4 = \left(\frac{W}{L}\right)_3$

$I_{ref} = \frac{V_{DD} - V_{GS3} - V_{GS1}}{R_{ref}}$



Design: (for now, ignore Body effect)

Approach 1: insist that all devices are saturated

want $V_{DS6} = V_{OV}$ → need $V_{GS7} \stackrel{?}{=} V_t$

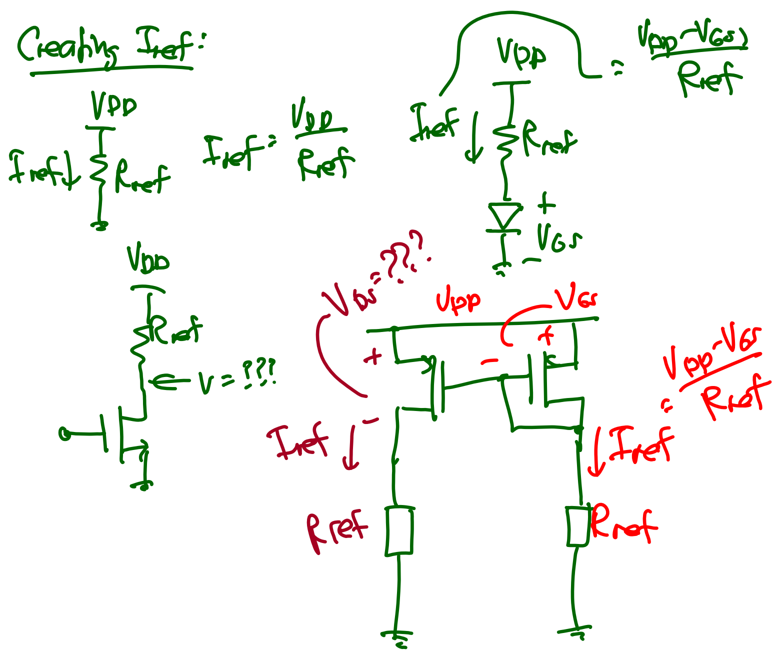
Normally, $V_{GS7} = V_t + V_{OV}$

↑ can make $V_{OV} \approx 0V$ if make M_7 huge! $\Rightarrow (W/L)_7$ = large → takes chip area → problem! → costs too much

$$V_{OV} = \sqrt{\frac{2 I_D}{\mu_n C_{ox} (W/L)_7}}$$

$(W/L)_7 \uparrow \rightarrow V_{OV} \downarrow \rightarrow 0V$

Creating Iref:



Approach 2: recognize that devices in the V_{BIAS}-Generator need NOT be saturated → some can be in the triode region!

① Allow M_7 to drop $V_{GS7} = V_t + V_{OV}$

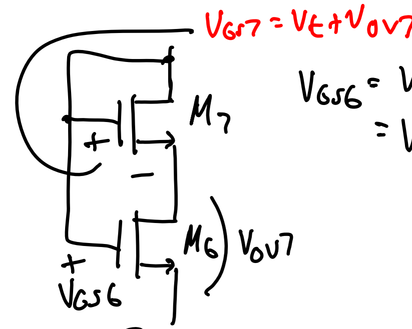
② Still need $V_{DS6} = V_{OV7}$

③ Can get this by operating M_6 in the triode region.

M_7 saturated: $I_{D7} = \frac{1}{2}\mu_n C_{ox} \left(\frac{W}{L}\right)_7 (V_{GS7} - V_t)^2$

M_6 triode: $I_{D6} = \frac{1}{2}\mu_n C_{ox} \left(\frac{W}{L}\right)_6 \left[2(V_{GS6} - V_t)V_{DS6} - V_{DS6}^2\right]$

Want: When $V_{GS7} = V_t + V_{OV7}$ → want



$V_{GS6} = V_{GS7} + V_{OV7}$
$= V_t + 2V_{OV7}$

need this to be the effective V_{OV6}

→ need $V_{OV6} = 2V_{OV7}$

Thus: $I_{D7} = I_{D6}$

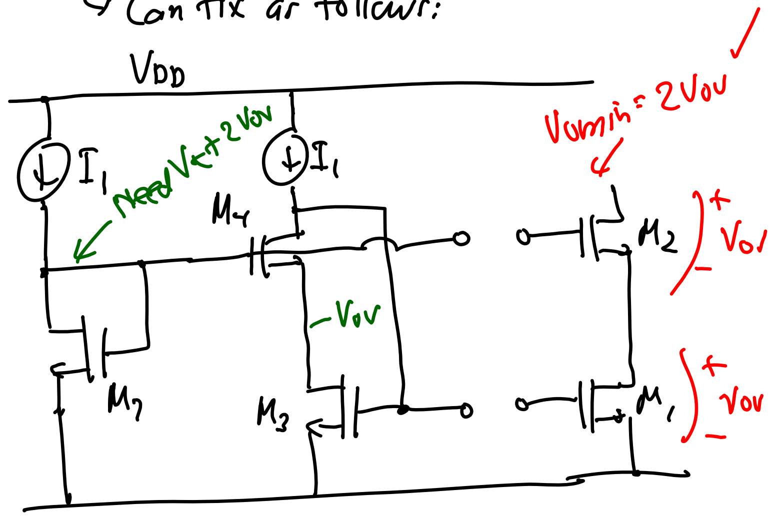
$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_7 (V_{OV7})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_6 \underbrace{\left[2(2V_{OV7})V_{OV7} - (V_{OV7})^2\right]}_{3V_{OV7}^2}$$

$$\left(\frac{W}{L}\right)_7 = 3\left(\frac{W}{L}\right)_6$$

$\left(\frac{W}{L}\right)_6 = \frac{1}{3}\left(\frac{W}{L}\right)_7$ & all other $\left(\frac{W}{L}\right)$'s $= \left(\frac{W}{L}\right)_7$

Problem: We're using too much voltage to do this!

↳ Can fix as follows:



$I_{D7} = I_{D3}$

$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_7 (2V_{ov})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_3 (V_{ov})^2$ (4)

$\therefore \left(\frac{W}{L}\right)_7 = \frac{1}{4}\left(\frac{W}{L}\right)_3 = \frac{1}{4}\left(\frac{W}{L}\right)$

↑ all the Xsistors, except M_7

