Lecture 10: High Swing Current Sources

- Announcements:
  - Monday Labs: due to holiday next week, shift to the following Monday
  - Monday Lab#1's are due in the 140 Box on Tuesday next week (per Travis's email)
- Lecture Topics:
  - Output Swing (Headroom) (cont.)
  - High Swing Current Sources
  - Current Source Matching Considerations
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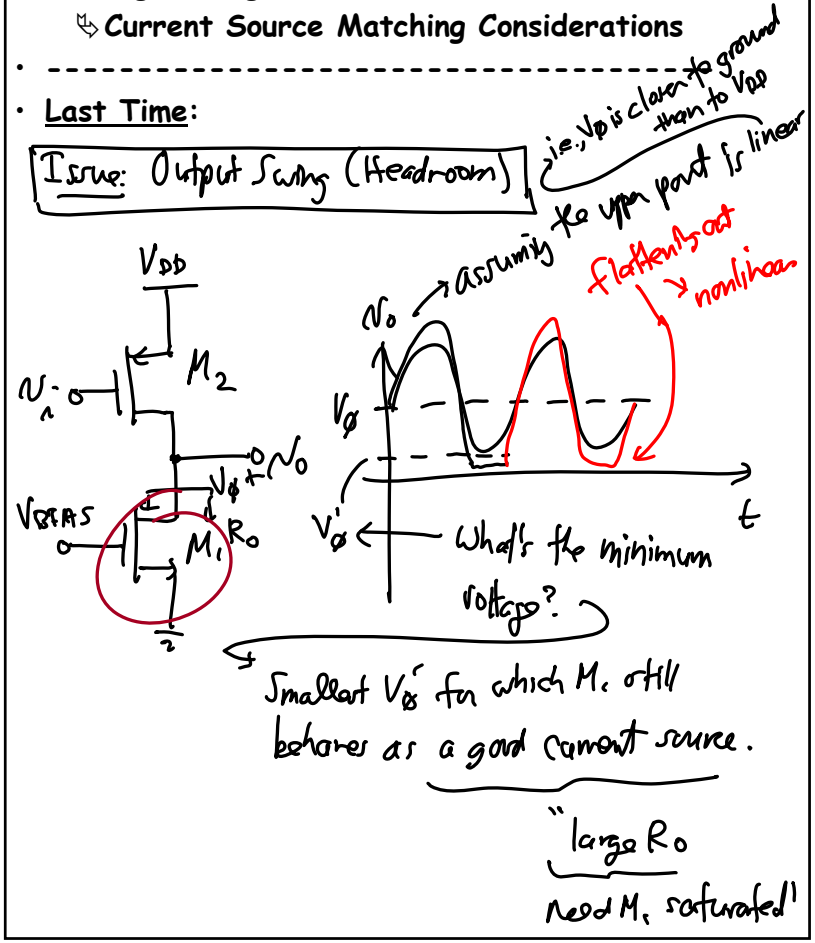
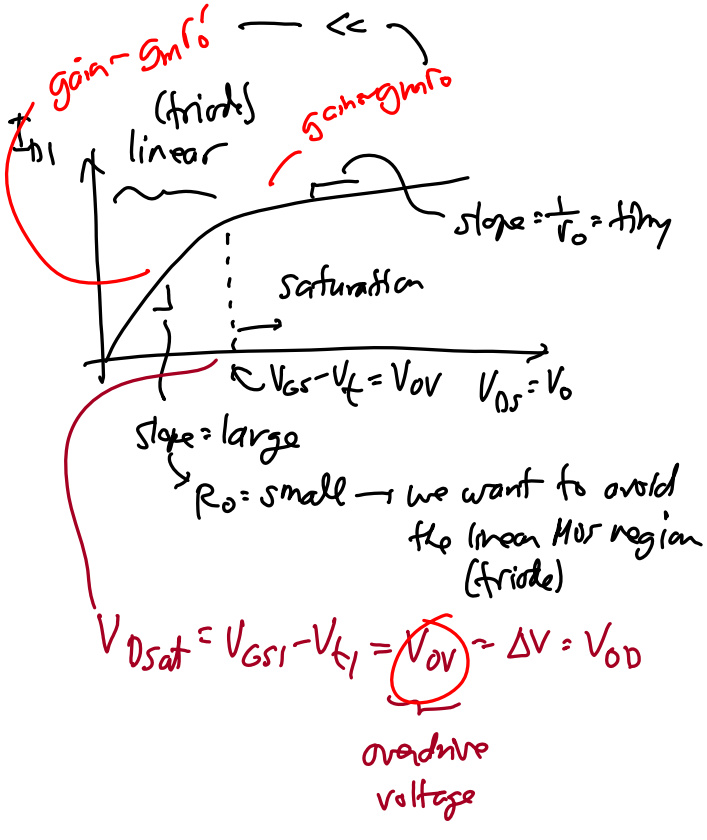
- Last Time:

Issue: Output Swing (Headroom)





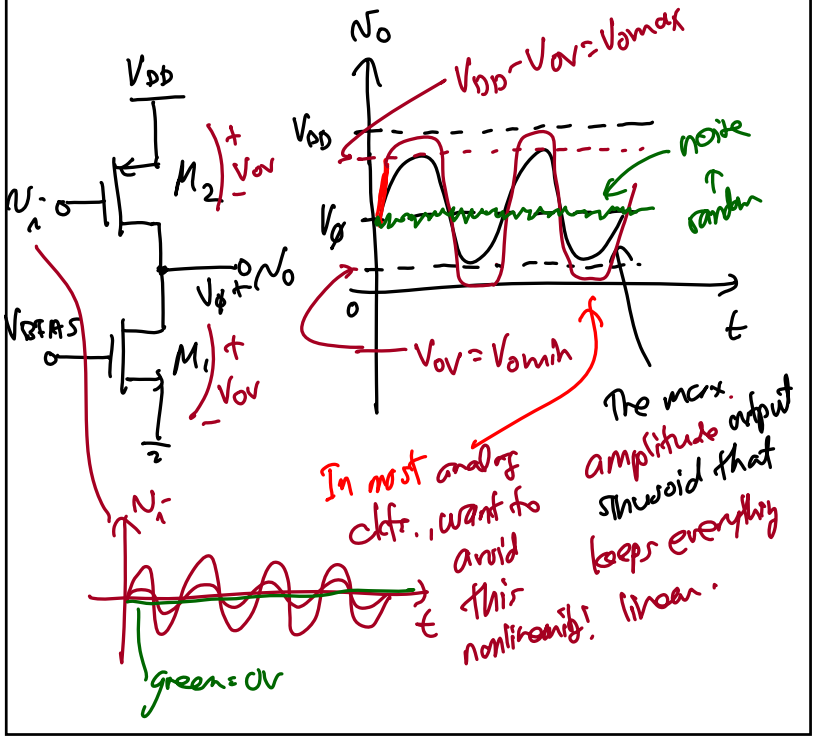
The min. voltage that still keeps M_1 as a good current source:

$V_{o,min} = V_{D,sat} = V_{ov}$

$\therefore$ the output swing is:

$$V_{swing,pp} = V_{DD} - V_{ov,cascode} - V_{ov,2} = V_{DD} - 2V_{ov}$$

(peak-to-peak)



Dynamic Range = DR = $\frac{\text{maximum output signal}}{\text{minimum input signal}}$

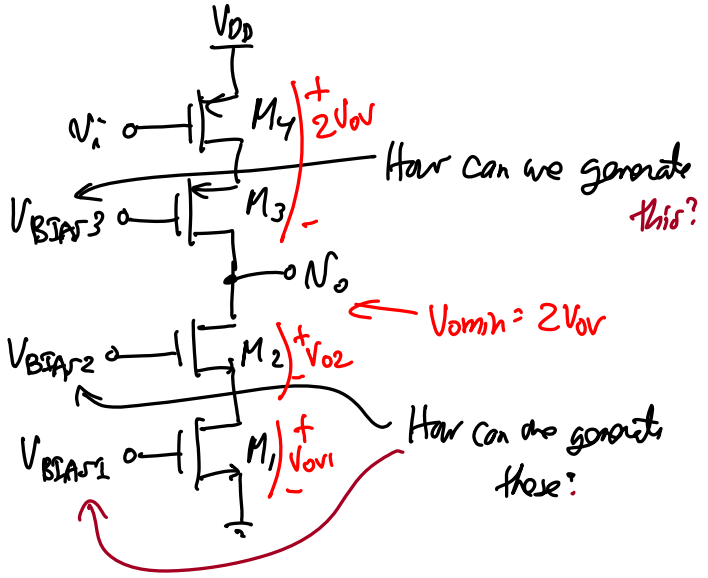
Want to max this!

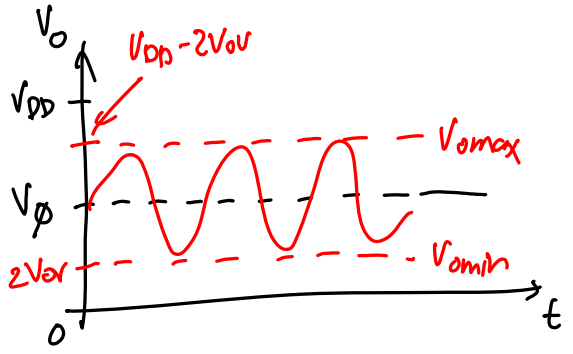
Determined by Output Swing!

Determined by Noise!

We care about this a lot!

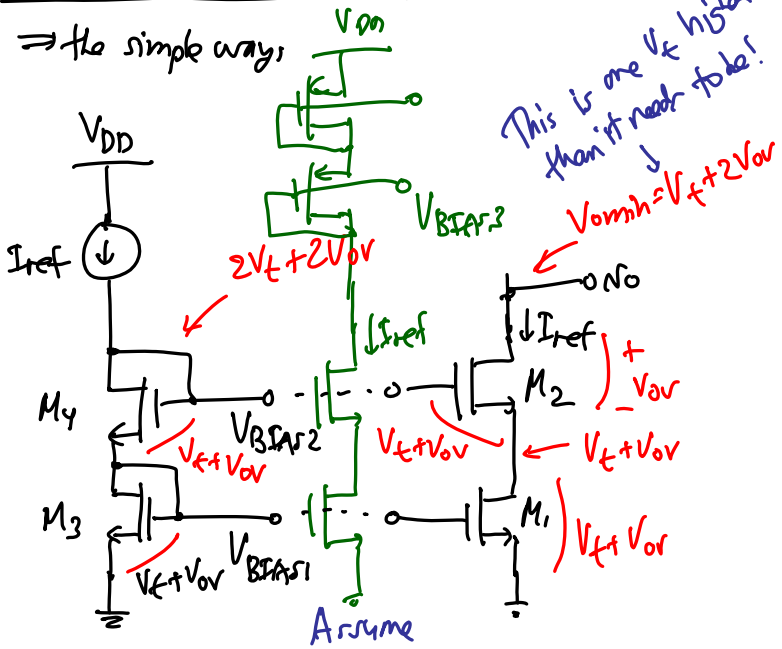
What about a ckt. using a better current source, like a cascode current source?





MOS Cascode Current Source

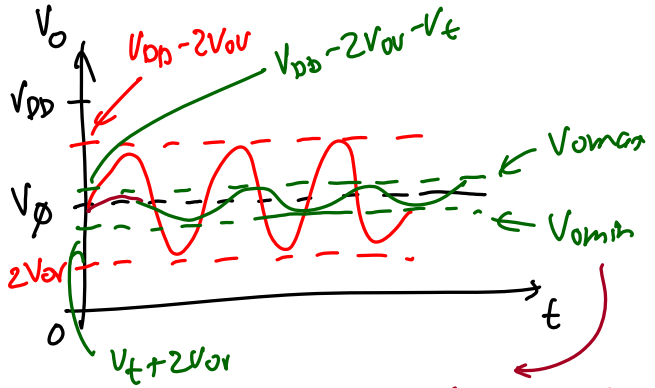
⇒ the simple way:



$M_1=M_2=M_3=M_4$

$V_{GS}=V_t+V_{ov}$

$(V_{ov}=V_{GS}-V_t)$



Problem: DR shrinks! (for simple cascode current source)

How bad is the problem?

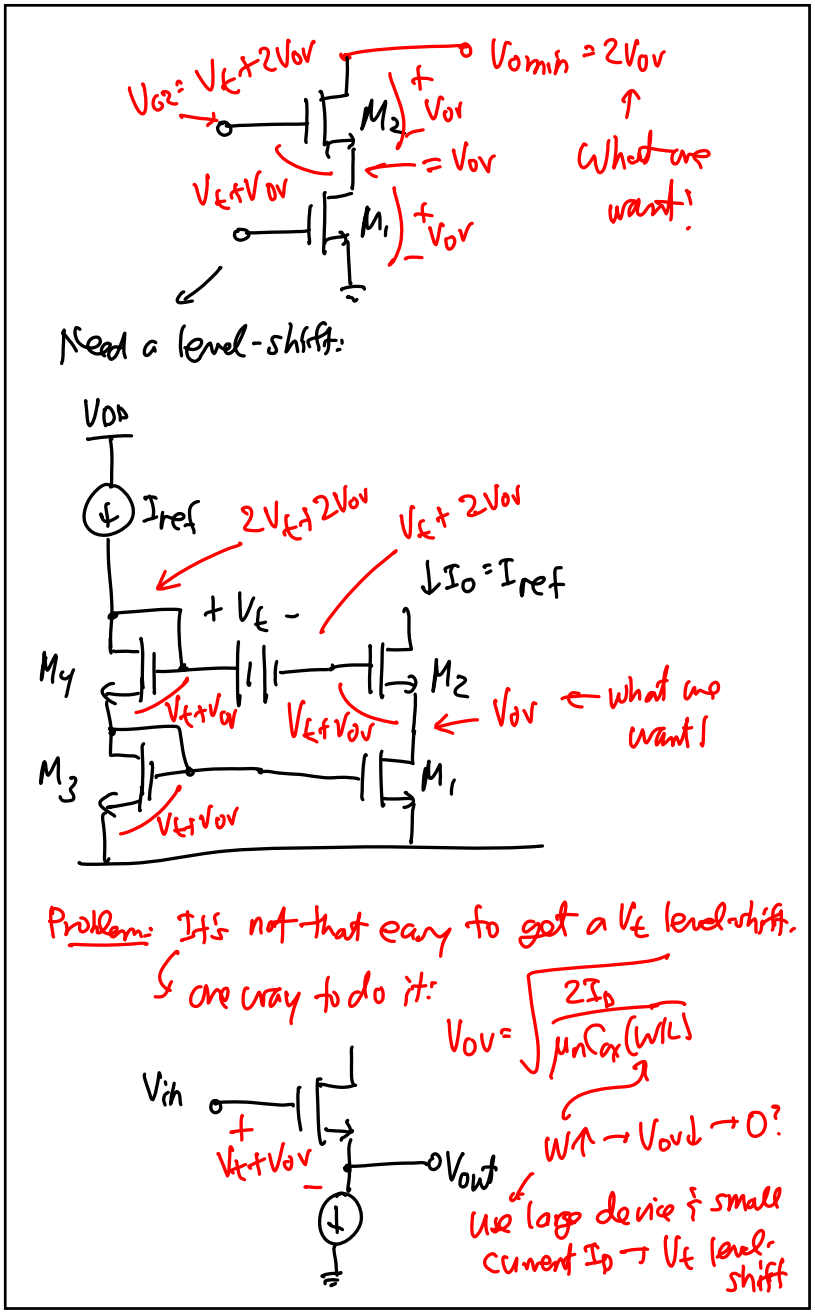
$V_{omin}=V_t+2V_{ov}$

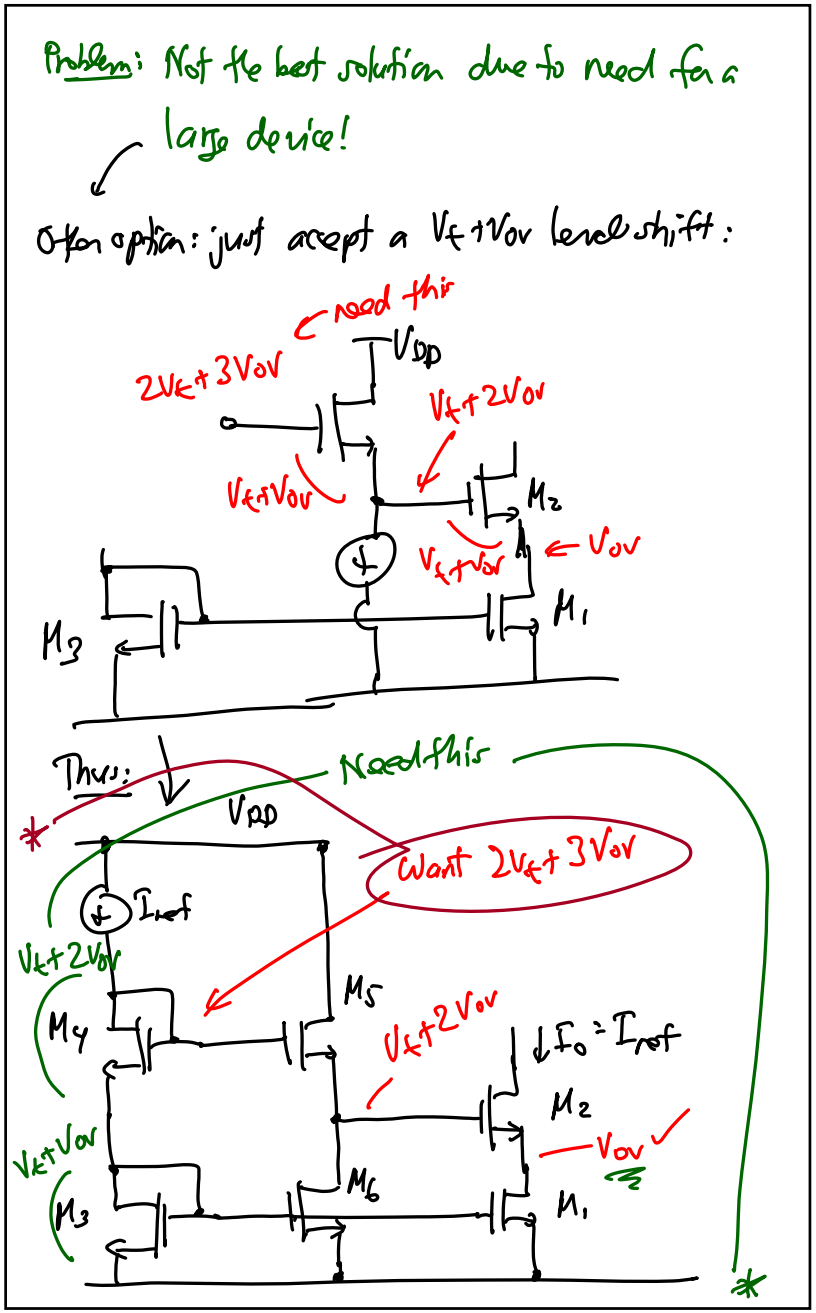
(typ.) $\simeq 0.7+2(0.3)=1.3V$

This is a lot in a 2V supply technology → not permissible in a $V_{DD}=1.1V$ technology

Soln: High Swing Cascode (V_{BIAS} -generation)

⇒ Basic Idea: level-shift down to move the V_{G2} of M_2 to get:





* — To get this, must size M_4 accordingly:

$$I_{D3} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_3 (V_{ov3})^2$$

$$I_{D4} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_4 \underbrace{(2V_{ov3})}_{V_{ov4}=2V_{ov3}}{}^2$$

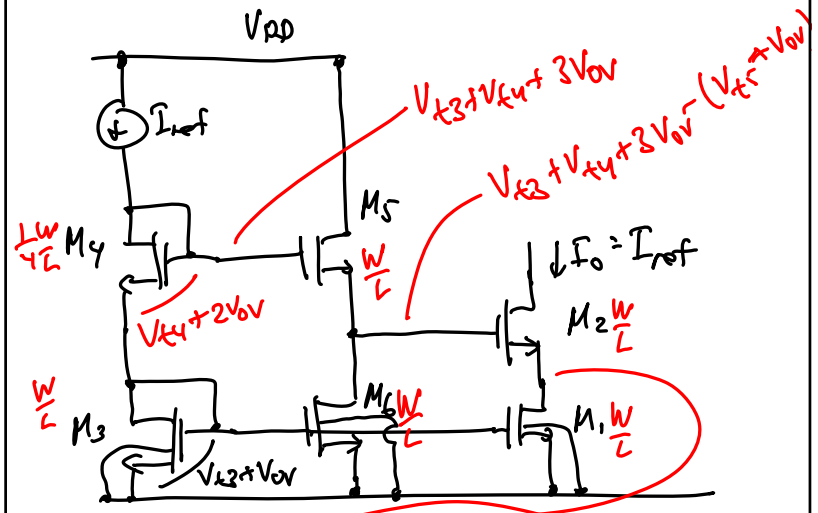
$$I_{D3} = I_{D4} = I_{ref}$$

$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_3 (V_{ov3})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_4 (2V_{ov3})^2$$

$$\boxed{\left(\frac{W}{L}\right)_4 = \frac{1}{4}\left(\frac{W}{L}\right)_3} \quad *$$

... and $\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6$

Problem: Body effect in M_4, M_5, & M_2.
↳ will increase their V_t's!



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

$V_{t4} \neq V_{t5} \rightarrow V_{s4} = V_{t3} + V_{ov}$

$V_{s5} = V_{t2} + 2V_{ov} \rightarrow V_{t5} > V_{t4}$

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

$\therefore M_1$ 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 $V_{OS4} > V_t + 2V_{OV}$,

e.g., $V_{OS4} = V_t + 3V_{OV}$

make M_4 smaller than $\frac{1}{4}\left(\frac{W}{L}\right)_1$

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

Issue: $V_{DS1} \neq V_{DS3} \rightarrow I_O = \dfrac{(1+\lambda V_{DS1})}{(1+\lambda V_{DS3})} I_{REF}$

$I_O \neq I_{REF}$

Solution: → next time.