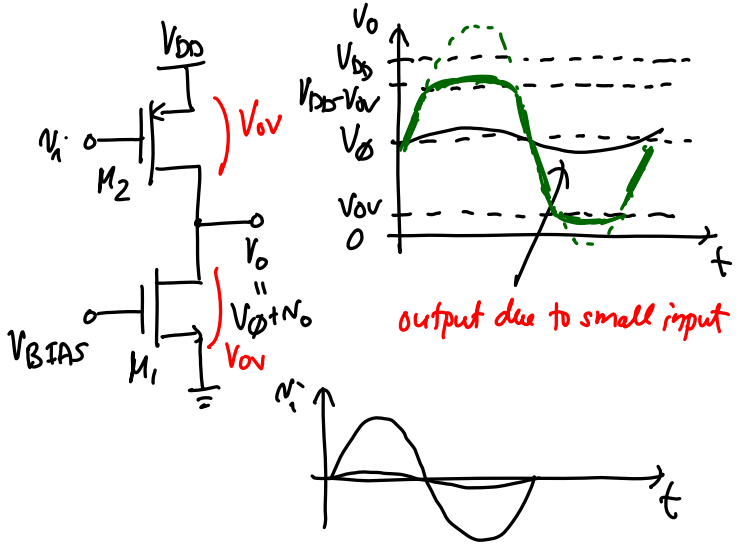
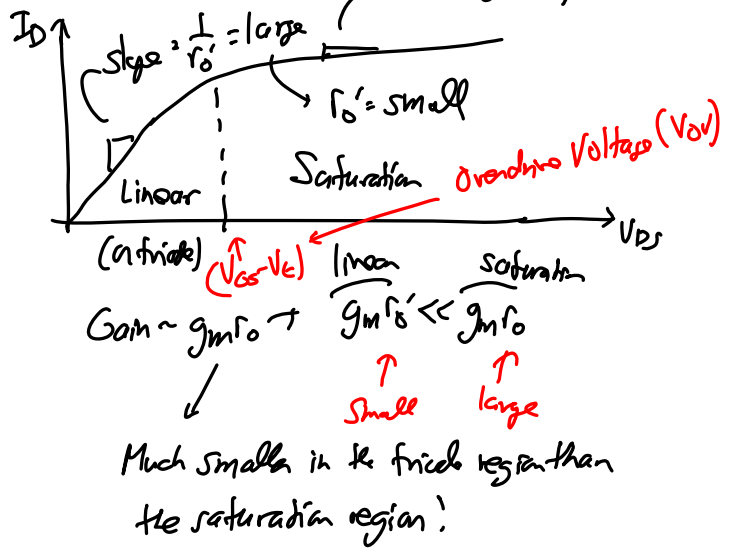
Lecture 11: High Swing Current Sources

- Announcements:
  - HW#5 online
  - Lab#1 reports are due the week of Oct. 7
    - —Turn them in to Yang in your lab section
  - Lab#2 is online: starts next week
    - —This is a hardware lab
    - —You should show up to lab
  - Office Hour Change: Yang's Thursday office hours moved to M 2:30-3:30
- Lecture Topics:
  - Output Swing & Dynamic Range
  - High Swing Current Sources
- ----------
- Last Time:

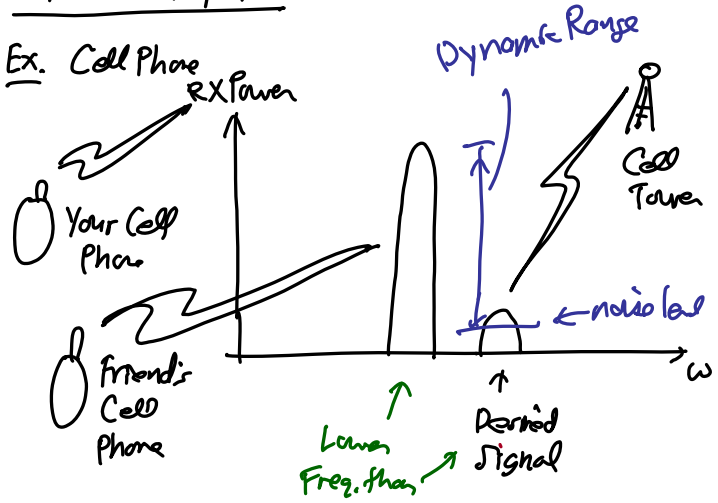
Output Swing (Headroom)

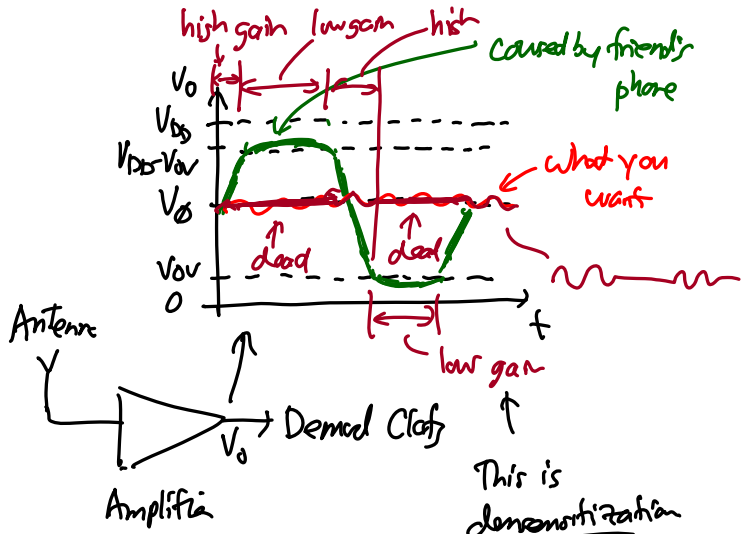


I_D vs. V_{DS} Characteristic:



Why is this important?





Dynamic Range (DR): $\frac{\text{largest output signal}}{\text{minimum signal}}$

This is output swing!

What is V_{OV}?

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_t)^2$$

V_{OV}

$$V_{OV} = \Delta V = V_{Dsat} = V_{GS}-V_t = \sqrt{\frac{2I_D}{\mu_n C_{ox}(W/L)}} = V_{OV}$$

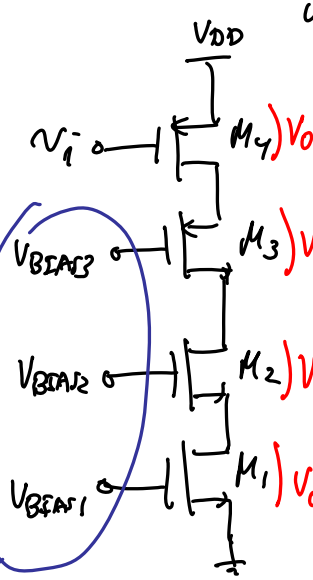
Output Swing:

$$V_{O,swing} = V_{OMAX} - V_{OMIN}$$
$$= V_{DD} - V_{OV2} - V_{OV1} \approx V_{DD} - 2V_{OV}$$

What about better amplifiers using better CMOS Sources?

Ex. Cascode Current Source w/ Cascode Drive

What is $V_{O,swing}$?



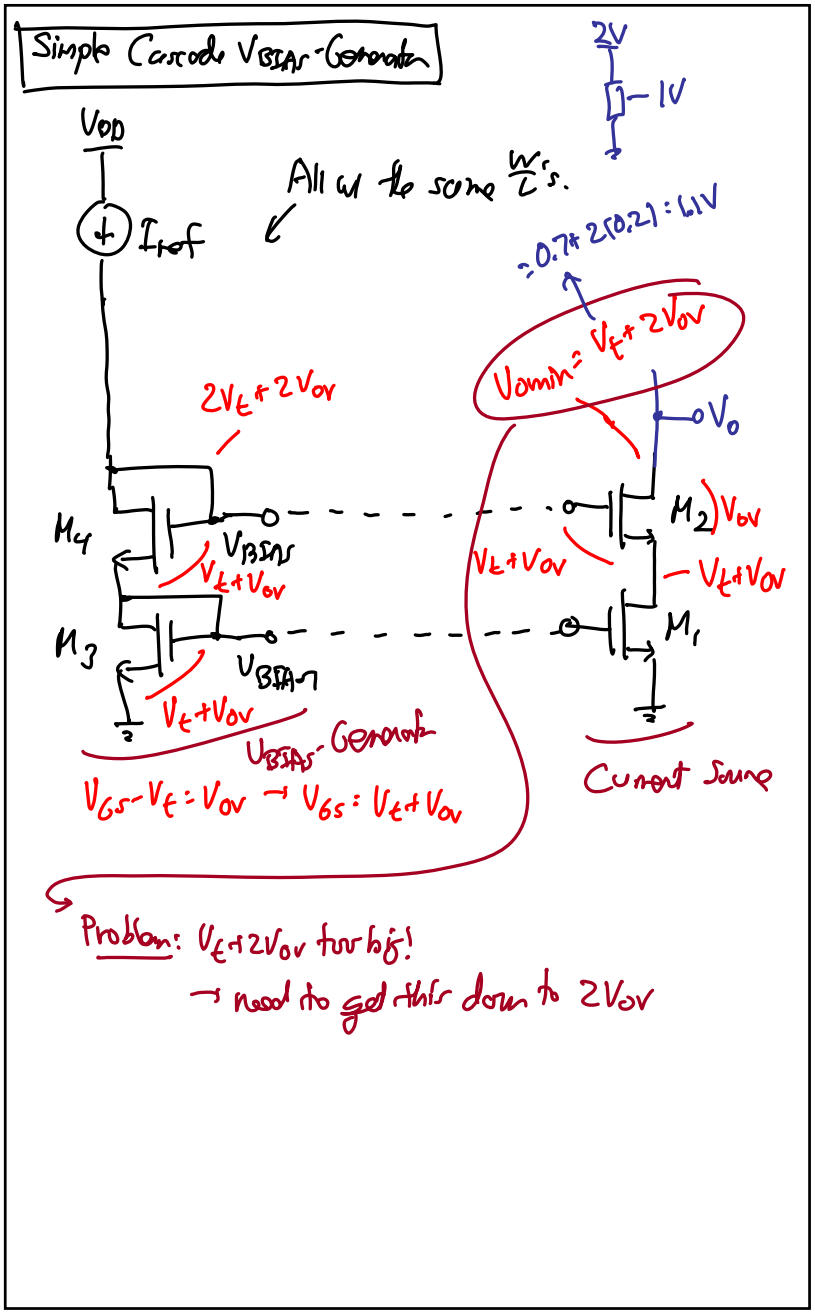
Need to maintain high R_{OP} ∴ high gain
↓
$2V_{OV}$
↓
$V_{OMAX} = V_{DD} - 2V_{OV}$

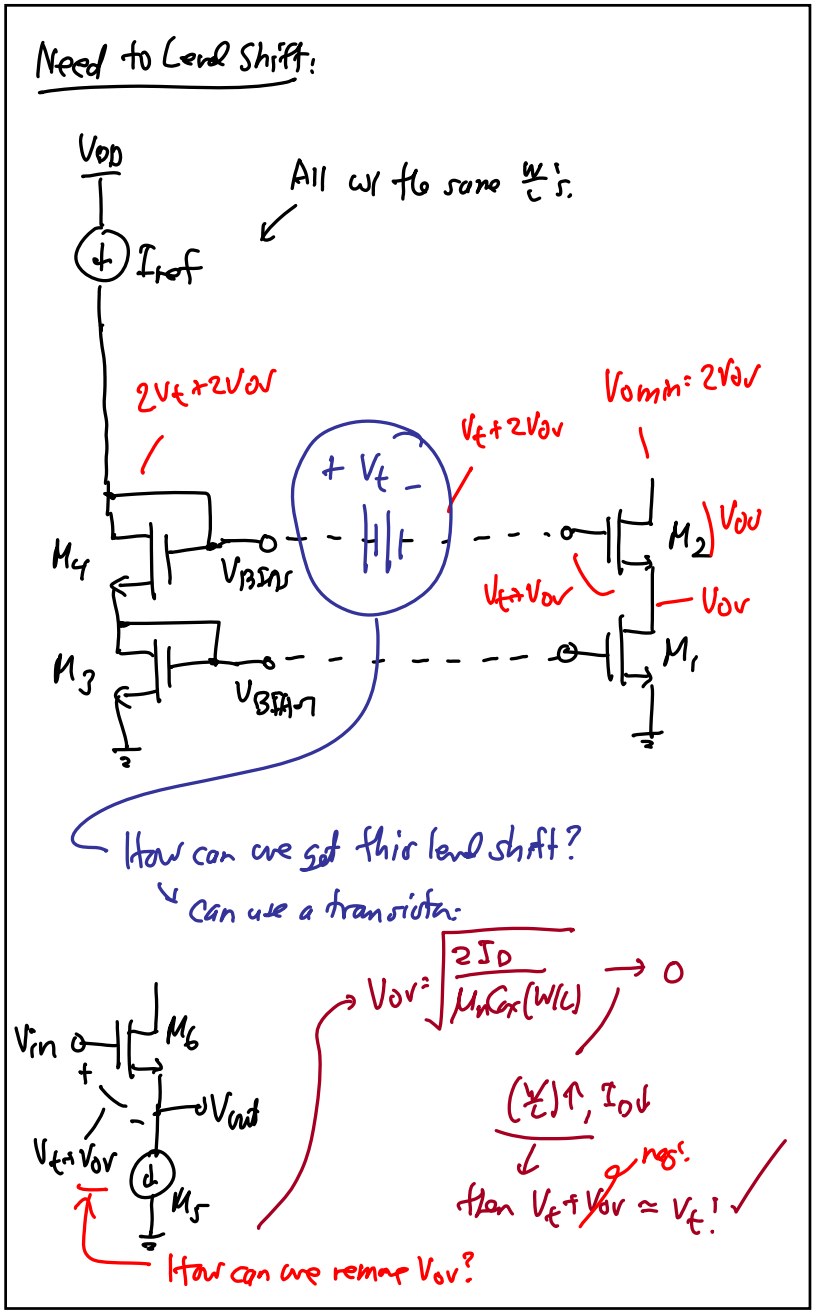
$2V_{OV}$: V_{OMIN}
↑
minimum voltage to preserve high gain

$V_{O,swing} = V_{DD} - V_{OV1} - V_{OV2} - V_{OV3} - V_{OV4} \approx V_{DD} - 4V_{OV}$
↓
$\simeq 2 - 4(0.2) = 1.2V$

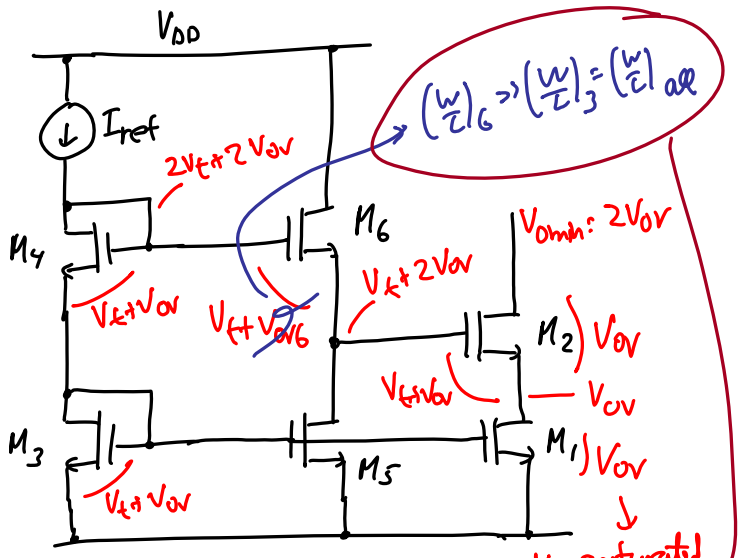
Best we can do!

Need to generate V_{BIAS} → use V_{BIAS}-generators
↓
start w/ simplest → replica biasing





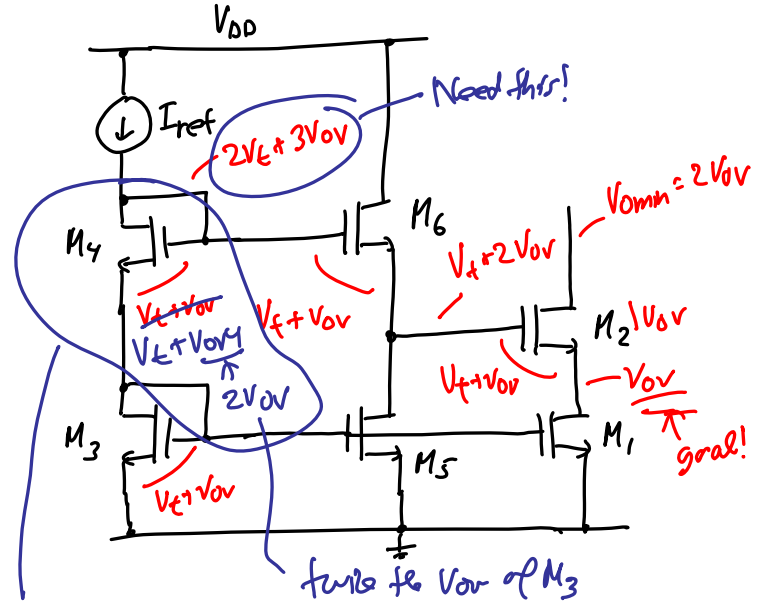
The Actual Ckt:



Problem: Don't like this!

- $(W/L)_6$ must be big to send $V_{OV6} \to 0V$
  - a $(W/L)_3 \gg (W/L)_5$ for small I_{D5}
    - consume chip area → Bad!
  - If $(W/L)_6$ not big → $V_{GS} = V_T + V_{OV6}$ (finite)
    - $V_{DS1} = V_{OV} - V_{OV6} < V_{OV}$
      - M_1 triode!

Another Option: Just accept the $V_T + V_{OV}$ level shift from the gate to source of M_6. (use the same ckt.)



Need to design M_4 so that $V_{OV4} + 2V_{OV} = 2V_{OV3}$

$$I_{D3} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_3 (V_{OV3})^2$$

$$I_{D4} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_4 (V_{OV4})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_4 (2V_{OV3})^2$$

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

$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_3 V_{OV3}^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_4 (4V_{OV3}^2)$$

$$\left(\frac{W}{L}\right)_4 = \frac{1}{4}\left(\frac{W}{L}\right)_3 \text{ ... and } \left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_5 = \left(\frac{W}{L}\right)_6$$