

Lecture 11: High Swing Current Sources

Announcements:

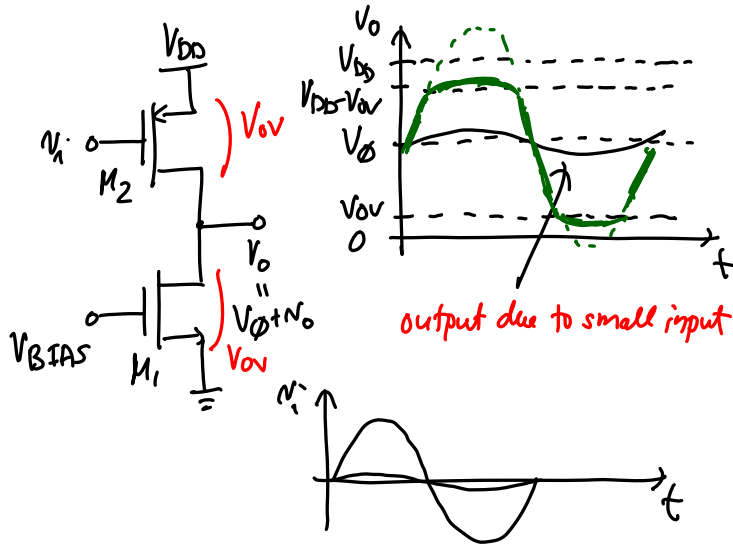
- ↳ HW#5 online
- ↳ Lab#1 reports are due the week of Oct. 7
 - Turn them in to Yang in your lab section
- ↳ Lab#2 is online: starts next week
 - This is a hardware lab
 - You should show up to lab
- ↳ Office Hour Change: Yang's Thursday office hours moved to M 2:30-3:30

Lecture Topics:

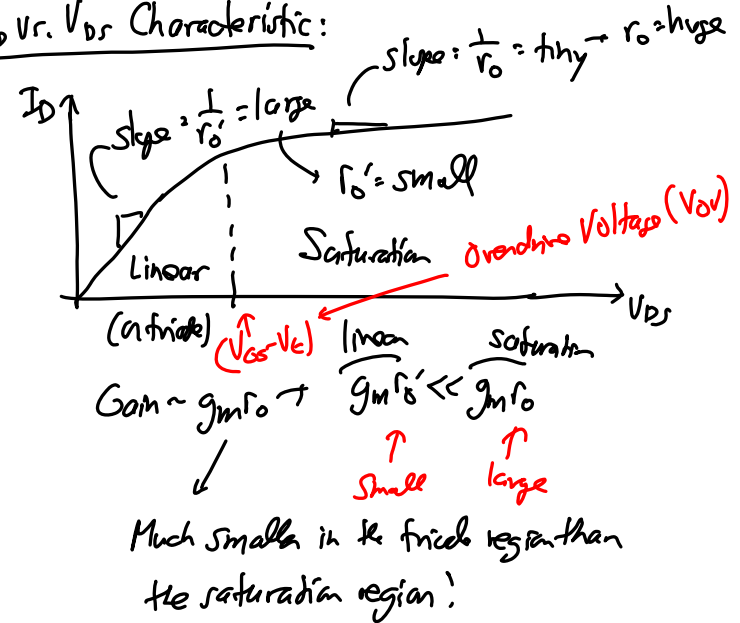
- ↳ Output Swing & Dynamic Range
- ↳ High Swing Current Sources

Last Time:

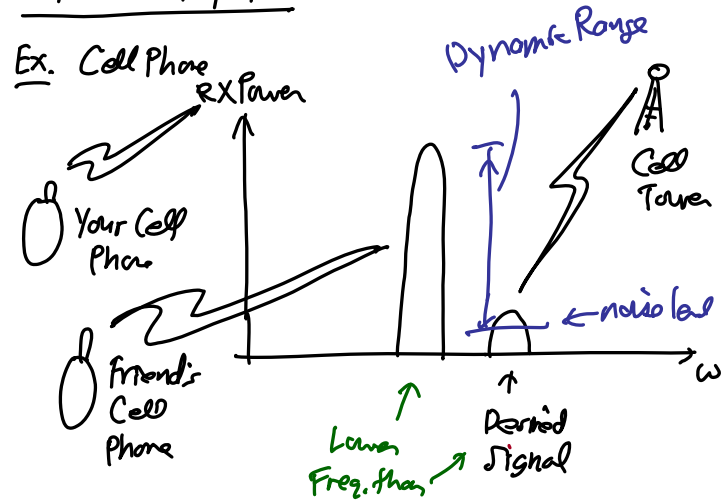
Output Swing (Headroom)



I_D vs. V_{DS} Characteristic:



Why is this important?



Antenna
Amplifier
Demod. Clk
This is demodulation

high gain
low gain
high
caused by friend's phone
what you want
dead
low gain

Dynamic Range (DR): largest output signal
minimum signal
This is output swing!

What is V_{ov} ?

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

$$V_{ov} = \Delta V = V_{DSAT} - V_{GS} - V_t = \sqrt{\frac{2I_b}{\mu_n C_{ox} \left(\frac{W}{L}\right)}} = V_{ov}$$

Output Swing:

$$V_{oswing} = V_{omax} - V_{omin}$$

$$= V_{DD} - V_{ov2} - V_{ov1} \approx V_{DD} - 2V_{ov}$$

What about better amplifiers using better current sources?

Ex. Cascode Current Source w/ Cascode Drive

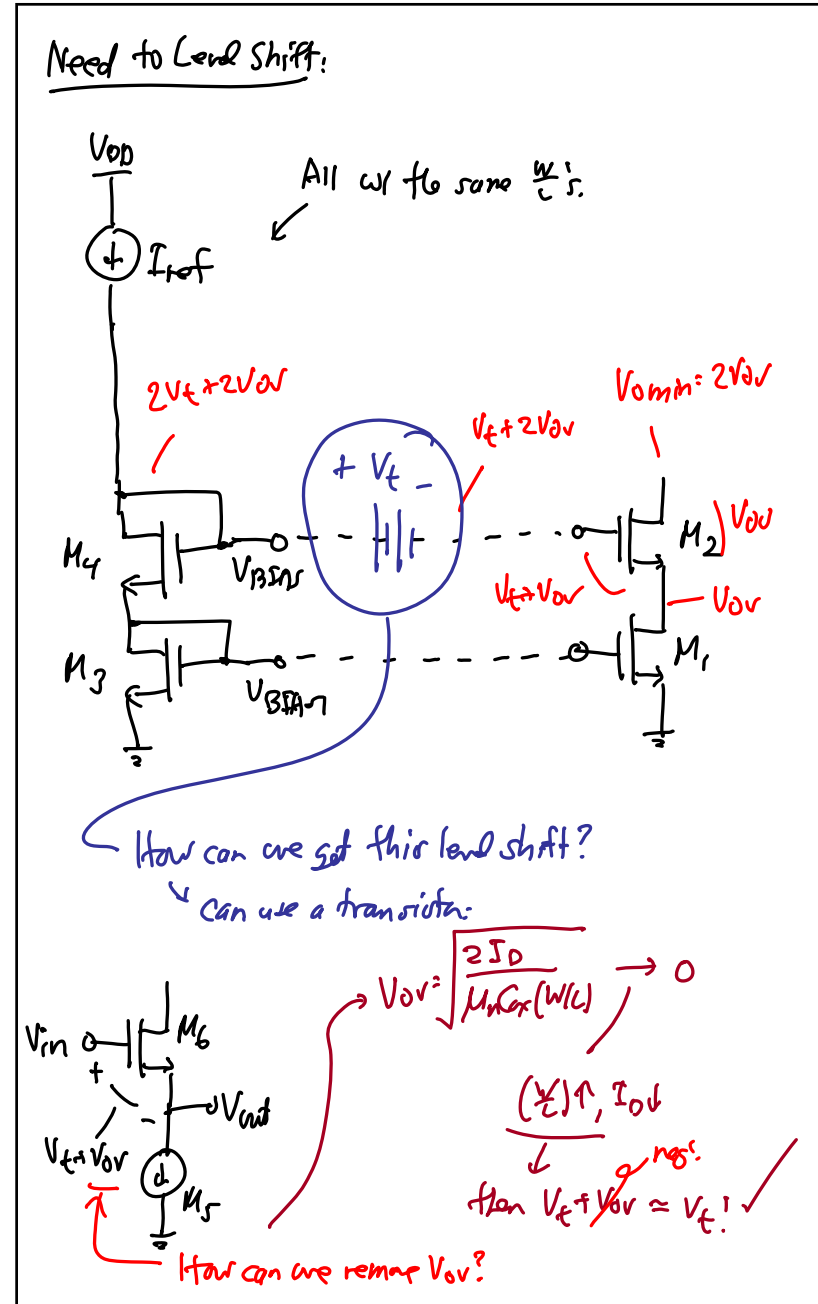
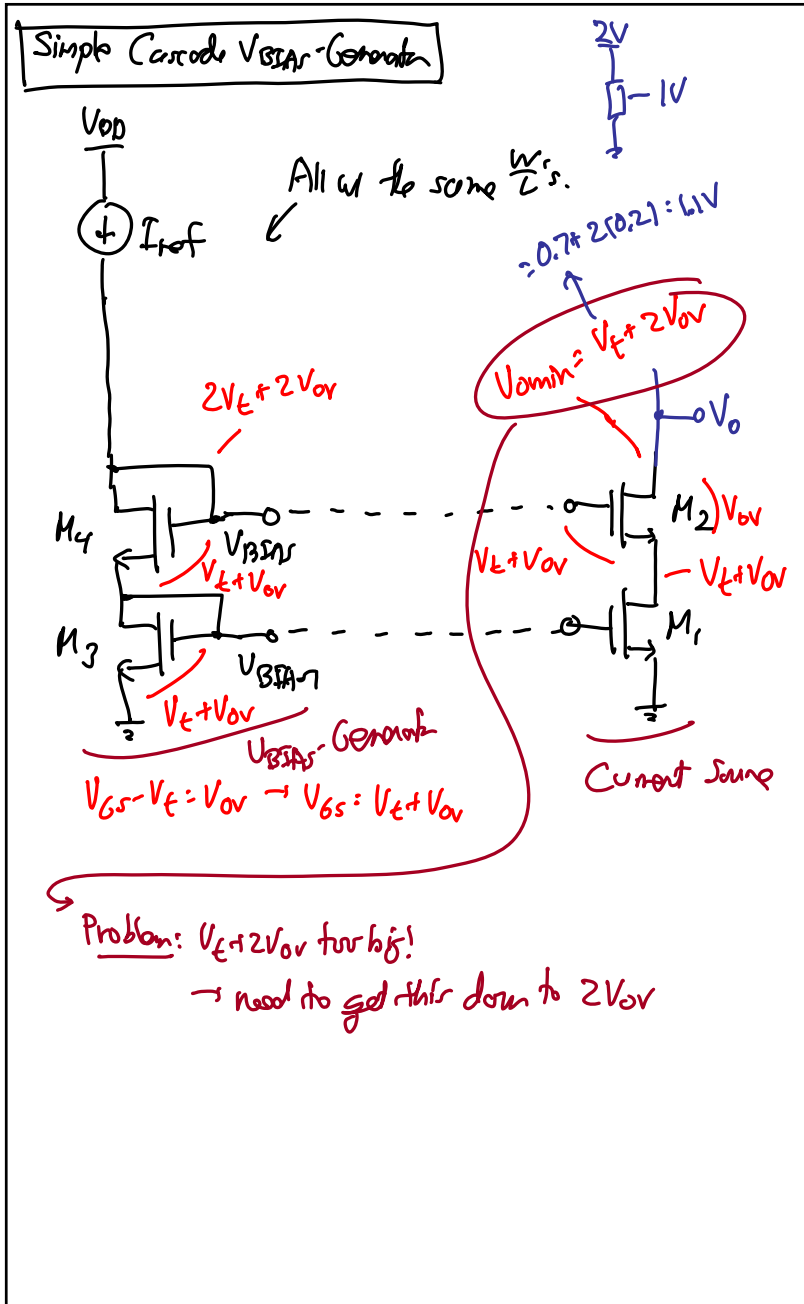
What is V_{oswing} ?

Need to maintain high R_{op} \therefore high gain
 $2V_{ov}$
 $V_{omax} = V_{DD} - 2V_{ov}$

$2V_{ov} = V_{omin}$
 minimum voltage to preserve high gain

$V_{oswing} = V_{DD} - V_{ov1} - V_{ov2} - V_{ov3} - V_{ov4} \approx V_{DD} - 4V_{ov}$
 $\approx 2 - 4(0.2) = 1.2V$
 Best we can do!

Need to generate V_{BIASn} . \rightarrow use V_{BIAS} generator
 \downarrow
 start w/ simplest \rightarrow replica biasing



The Actual Ckt:

$(\frac{W}{L})_6 \gg (\frac{W}{L})_3 = (\frac{W}{L})_{all}$

$V_{omh} = 2V_{ov}$

M_1 saturated

Problem: Don't like this!

- $(\frac{W}{L})_6$ must be big to send $V_{ov6} \rightarrow 0V$
- $(\frac{W}{L})_3 \gg (\frac{W}{L})_5$ for small I_{D5}

consume chip area!

IF $(\frac{W}{L})_6$ not big $\rightarrow V_{GS} = V_E + V_{ov6}$ (fringe) **Bad!**

$V_{ovr} = V_{ov} - V_{ov6} < V_{ov}$

M_1 triode!

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

$V_{omh} = 2V_{ov}$

twice the V_{ov} of M_3

Need to design M_4 so that $V_{ov4} \cdot 2V_{ov} = 2V_{ov3}$

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

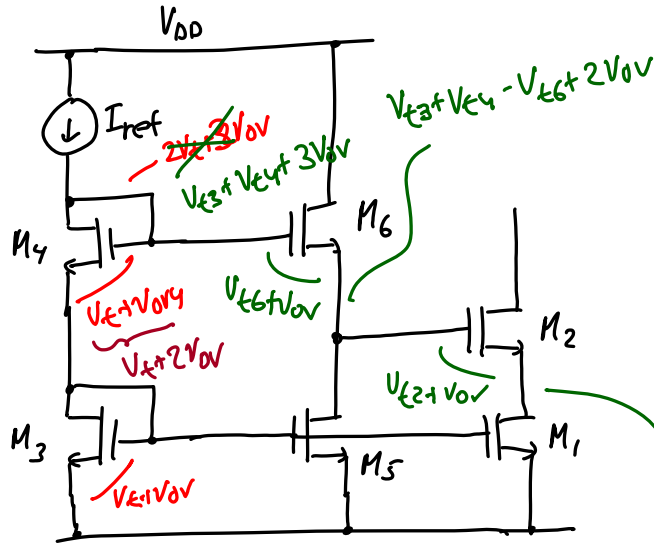
$I_{D4} = \frac{1}{2} \mu_n C_{ox} (\frac{W}{L})_4 (V_{ov4})^2 = \frac{1}{2} \mu_n C_{ox} (\frac{W}{L})_4 (2V_{ov3})^2$

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

~~$\frac{1}{2} \mu_n C_{ox} (\frac{W}{L})_3 V_{ov3}^2 = \frac{1}{2} \mu_n C_{ox} (\frac{W}{L})_4 (4V_{ov3}^2)$~~

$(\frac{W}{L})_4 = \frac{1}{4} (\frac{W}{L})_3 \dots$ and $(\frac{W}{L})_1 = (\frac{W}{L})_2 = (\frac{W}{L})_3 = (\frac{W}{L})_5 = (\frac{W}{L})_6$

Problem: Body effect $M_4, M_6, M_2 \rightarrow$ increases V_{GS} 's



$$\begin{aligned}
 V_{GS4} = V_{GS6} &\rightarrow \left. \begin{aligned} V_{GS4} &= V_t + V_{OV4} \\ V_{GS6} &= V_t + 2V_{OV} \end{aligned} \right\} V_{GS6} > V_{GS4} \\
 V_t &= V_{GS6} - \gamma(\sqrt{2\alpha_4 + V_{GS6}} - \sqrt{2\alpha_4}) \rightarrow V_{GS6} \rightarrow V_{GS4}
 \end{aligned}$$

Problem if this makes $V_{DS1} < V_{OV}$ ($M_1 \rightarrow$ triode)

What is this voltage?

very bad!

$$V_{GS4} + V_{GS3} - V_{GS6} - V_{GS2} + V_{OV}$$

$$\underbrace{(V_{GS4} - V_{GS6})}_{(-)} + \underbrace{(V_{GS3} - V_{GS2})}_{(-)} + V_{OV} < V_{OV}$$

$V_{DS1} < V_{OV}$
 M_1 not saturated!