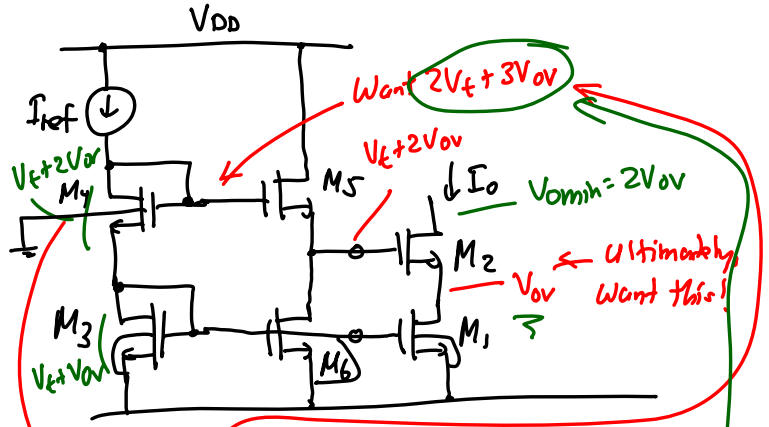
EE 140: Analog Integrated Circuits
Lecture 12: Current Source Matching

Today:

- High Swing Current Sources
- Current Source Matching Considerations
- Start Op Amps

Last Time –



↳ To get this, must size M_4 accordingly:

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

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

$V_{ov4} = 2V_{ov3}$

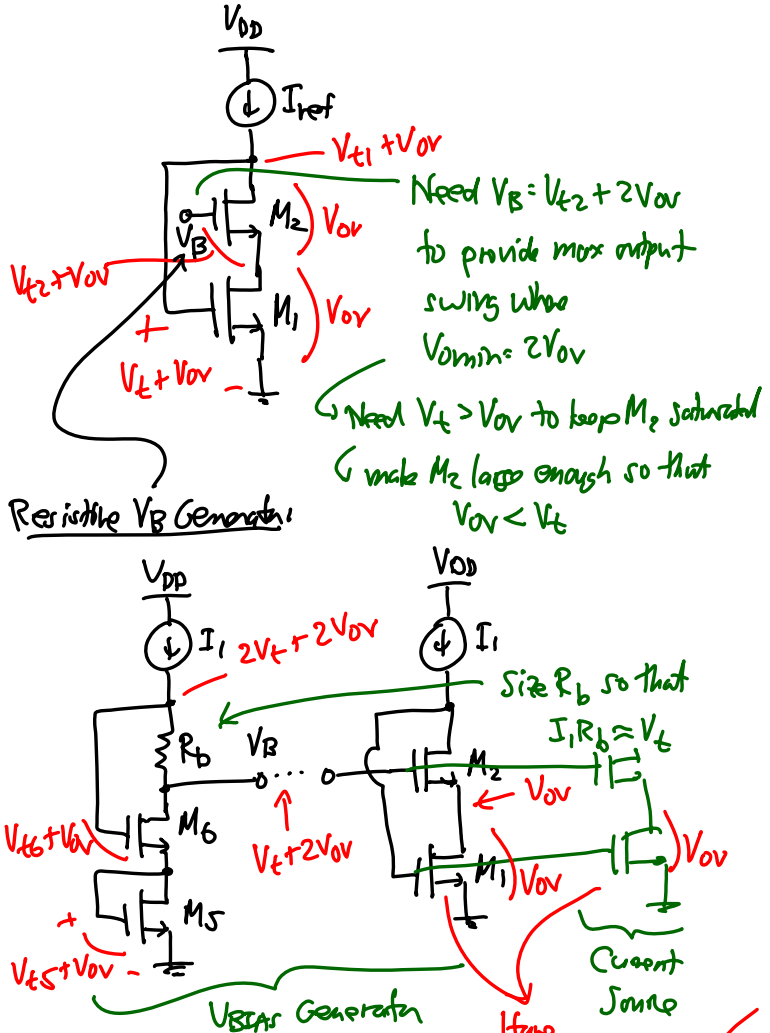
$I_{D3} = I_{D4} = I_{ref}$

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

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

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

Alternate Biasing Scheme for Cascode



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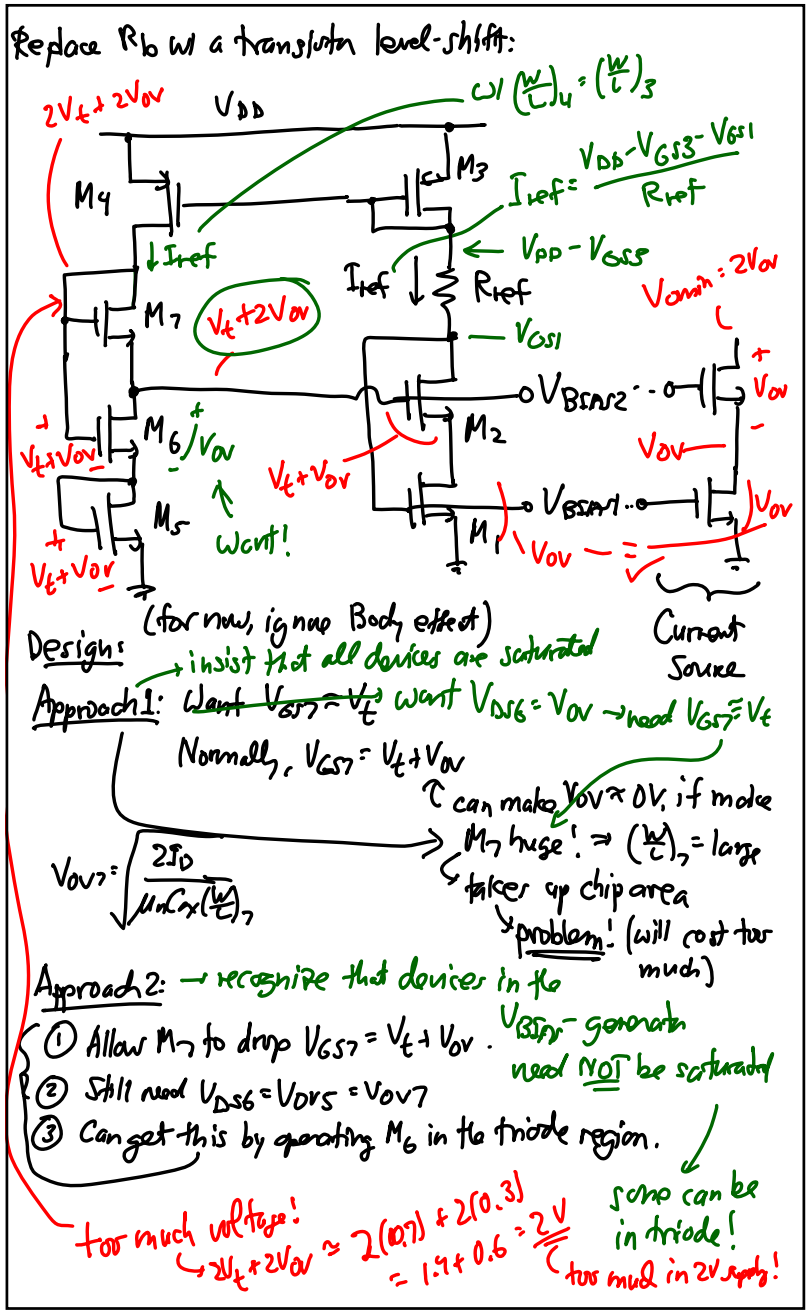
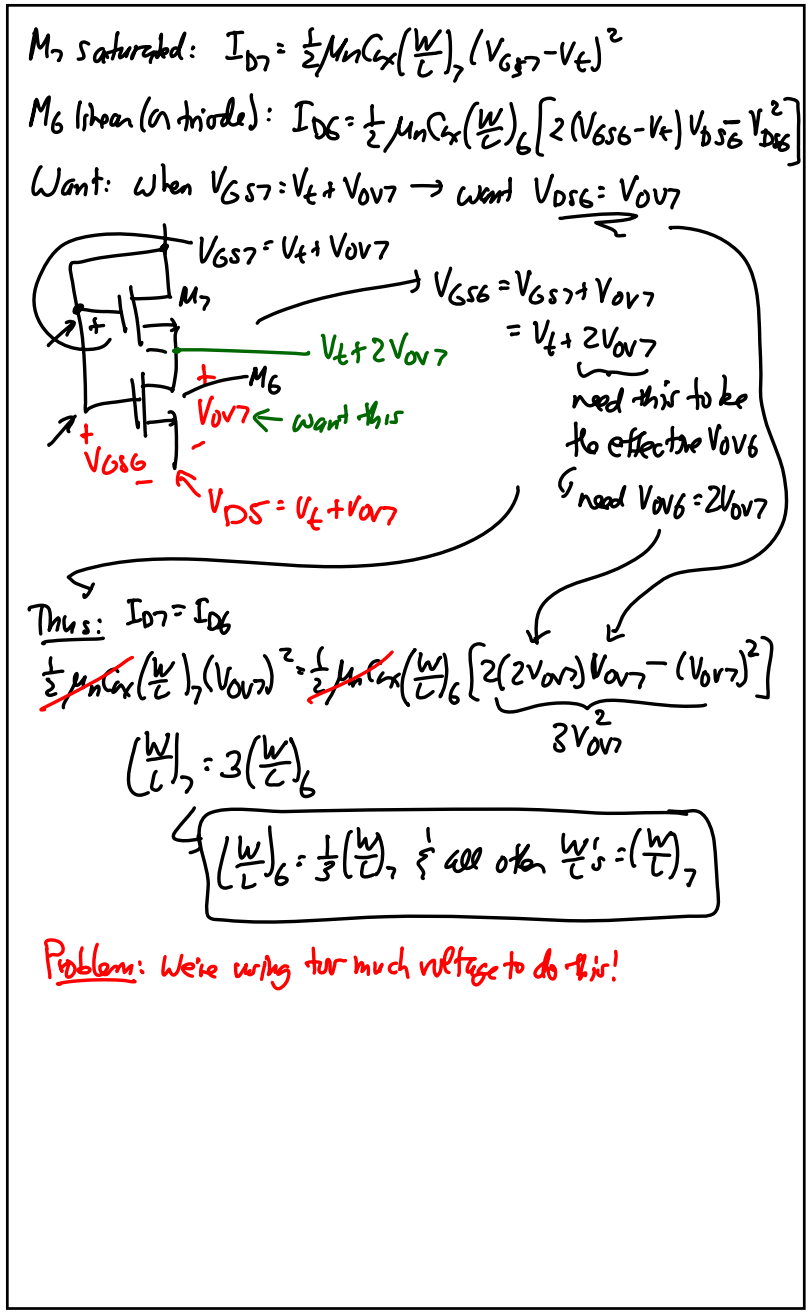
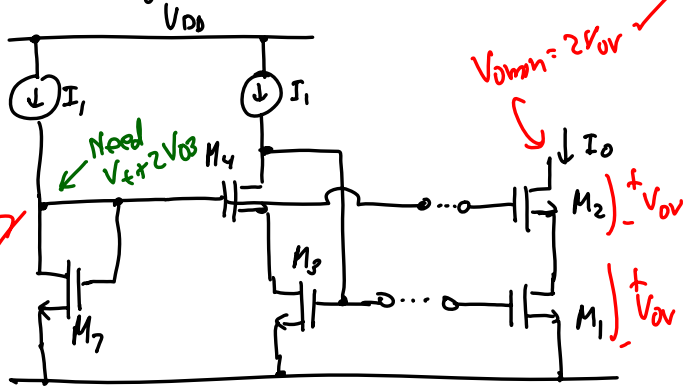
CTN 2/26/09





Too much voltage? Can fix as follows:



$I_{D7}=I_{D3}$

$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_7(2V_{OV3})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_3(V_{OV3})^2$ (4)

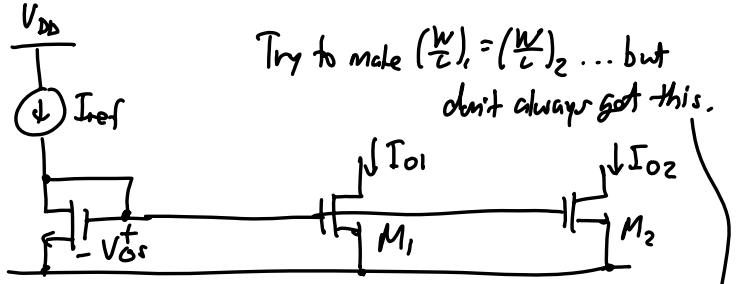
$\therefore \left(\frac{W}{L}\right)_7 = \frac{1}{4}\left(\frac{W}{L}\right)_3 = \frac{1}{4}\left(\frac{W}{L}\right)$

↑ all the Xsistrs except M_7

$V_t+2V_{OV} < 2V_t+2V_{OV}$ ✓

Note: Still must worry about Body effect!
↳ must design defensively...
↳ Make $V_{GS7} > V_t+2V_{OV3}$

Current Source Matching Considerations



Try to make $\left(\frac{W}{L}\right)_1=\left(\frac{W}{L}\right)_2$ ... but don't always get this.

In MOS, we often need matched current sources: $I_{O1}=I_{O2}$

$I_{O1}=I_{D1}=\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1(V_{GS1}-V_{t1})^2$

$I_{O2}=I_{D2}=\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2(V_{GS2}-V_{t2})^2$

due to finite fabrication tolerances...

These won't be perfectly matched if $(W/L)_1 \neq (W/L)_2$ & $V_{t1}\neq V_{t2}$

To quantify this: Define average & mismatch quantities.

Average	Mismatch
$I_D=\frac{1}{2}[I_{D1}+I_{D2}]$	$\Delta I_D = I_{D1}-I_{D2}$
$\frac{W}{L}=\frac{1}{2}\left[\left(\frac{W}{L}\right)_1+\left(\frac{W}{L}\right)_2\right]$	$\Delta\left(\frac{W}{L}\right)=\left(\frac{W}{L}\right)_1-\left(\frac{W}{L}\right)_2$
$V_t=\frac{1}{2}[V_{t1}+V_{t2}]$	$\Delta V_t = V_{t1}-V_{t2}$

$\frac{\Delta I_D}{I_D} \triangleq$ fractional current mismatch

$\frac{\Delta(W/L)}{(W/L)} \triangleq$ fractional (W/L) mismatch

$\frac{\Delta V_t}{V_t} \triangleq$ " V_t "

Rearranging,

$I_{D1} = I_D + \frac{\Delta I_D}{2}$ $\quad \left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right) + \frac{\Delta(W/L)}{2}$ $\quad V_{t1} = V_t + \frac{\Delta V_t}{2}$

$I_{D2} = I_D - \frac{\Delta I_D}{2}$ $\quad \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right) - \frac{\Delta(W/L)}{2}$ $\quad V_{t2} = V_t - \frac{\Delta V_t}{2}$

Plug these into the current equation:

neglect very small terms

$$I_{D1} = \cancel{I_D} + \frac{\Delta I_D}{2}$$

$$= \frac{1}{2}\mu_n C_{ox}\left[(W/L) + \frac{\Delta(W/L)}{2}\right]\left[\overbrace{V_{GS} - V_t}^{V_{OV}} - \frac{\Delta V_t}{2}\right]^2$$

$$= \frac{1}{2}\mu_n C_{ox}\left[(W/L) + \frac{\Delta(W/L)}{2}\right]\left[V_{OV}^2 - \cancel{2}V_{OV}\frac{\Delta V_t}{\cancel{2}} + \cancel{\frac{\Delta V_t^2}{4}}\right]$$

$$= \frac{1}{2}\mu_n C_{ox}\left[(W/L)V_{OV}^2 + \frac{\Delta(W/L)}{2}V_{OV}^2 - (W/L)V_{OV}\Delta V_t - \cancel{\frac{\Delta(W/L)}{2}V_{OV}\Delta V_t}\right]$$

$$= \underbrace{\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)V_{OV}^2}_{I_D} + \underbrace{\frac{1}{2}\mu_n C_{ox}V_{OV}^2\left[\frac{\Delta(W/L)}{2} - \frac{(W/L)}{V_{OV}}\Delta V_t\right]}_{\text{factor out } \left(\frac{W}{L}\right)}$$

$$\frac{\Delta I_D}{2} = \overbrace{\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)V_{OV}^2}^{I_D}\left[\frac{1}{2}\frac{\Delta(W/L)}{(W/L)} - \frac{\Delta V_t}{V_{OV}}\right]$$

$$\therefore \quad \boxed{\frac{\Delta I_D}{I_D} = \frac{\Delta(W/L)}{(W/L)} - \frac{\Delta V_t}{(V_{OV}/2)}}$$

this could be (-) so this doesn't necessarily help!

Fractional Current Mismatch

Geometry (i.e., Layout) Based Component ↑ Independent of Bias Point!

Increases (i.e., gets worse) as V_{OV} is reduced!

↳ Today: $V_{DD} \downarrow \rightarrow V_{OV} \downarrow$ w/ each generation of technology → matching more difficult!