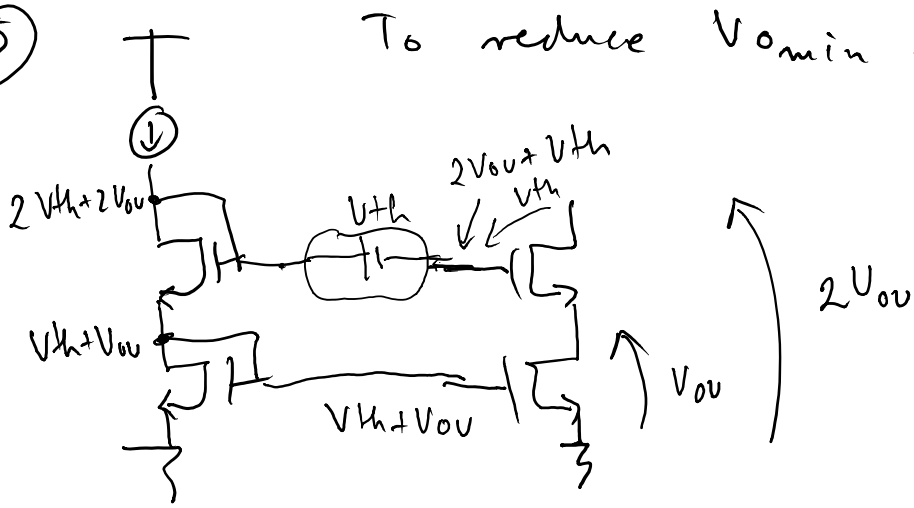
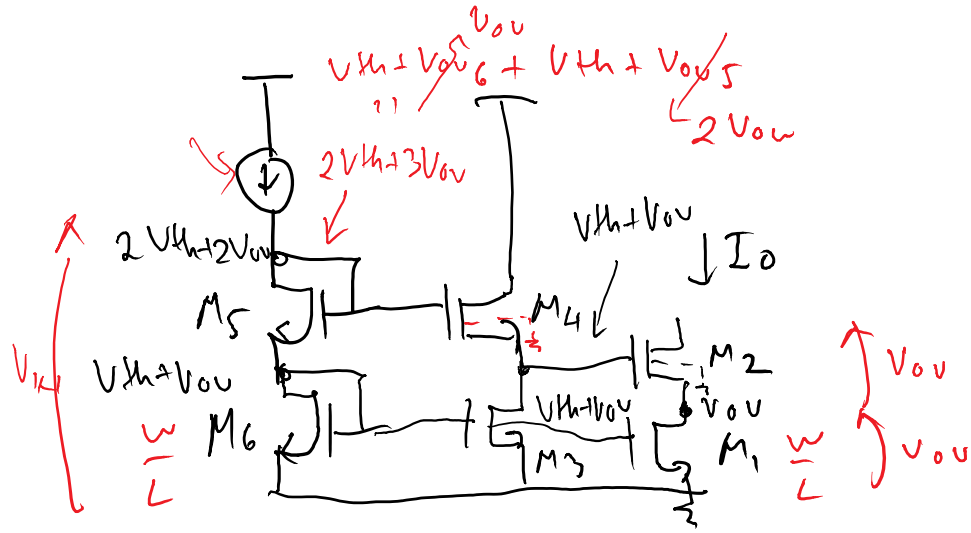
(5) To reduce $V_{o\,min}$:




$$I = \frac{k'}{2}\left(\frac{W}{L}\right)_1 \cdot V_{ov_1}^2 = \frac{k'}{2}\left(\frac{W}{L}\right)_2 V_{ov_2}^2$$

$$\frac{W}{L}\cdot V_{ov} = \underbrace{\frac{1}{4}\left(\frac{W}{L}\right)}_{\left(\frac{W}{L}\right)_5}\cdot \underbrace{(2V_{ov})^2}_{V_{ov5}}$$

$V_{o\,min} = 2V_{ov}$

$V_{GS5} - V_{GS4} - V_{GS2}$

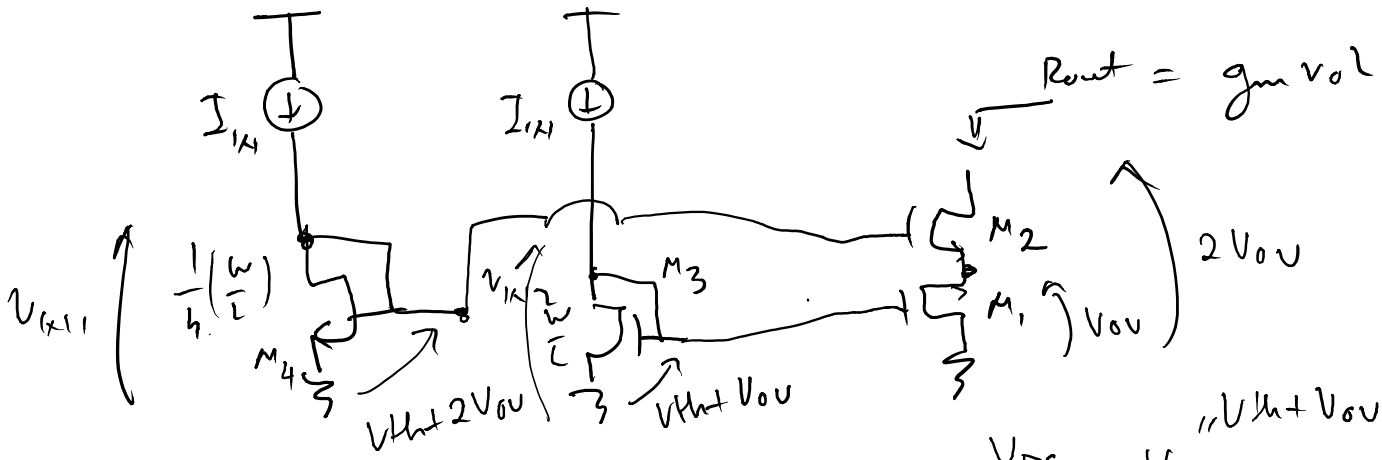
$V_{IN} = 2V_{th} + 3V_{ov}$

Systematic gain error $= \lambda(V_{DS1} - V_{DS6}) = -\lambda V_{th}$

$V_{th4} > V_{th5}$, $V_{th2} > V_{th6}$ body effect pushes $V_{S2} \downarrow$

In practice: $\left(\frac{W}{L}\right)_5 < \frac{1}{4}\left(\frac{W}{L}\right)$

(6) Eliminate B.E. as well as lower $V_{IN}$




$V_{DS1} - V_{DS3}$ $\quad$ $V_{th}+V_{OV}$

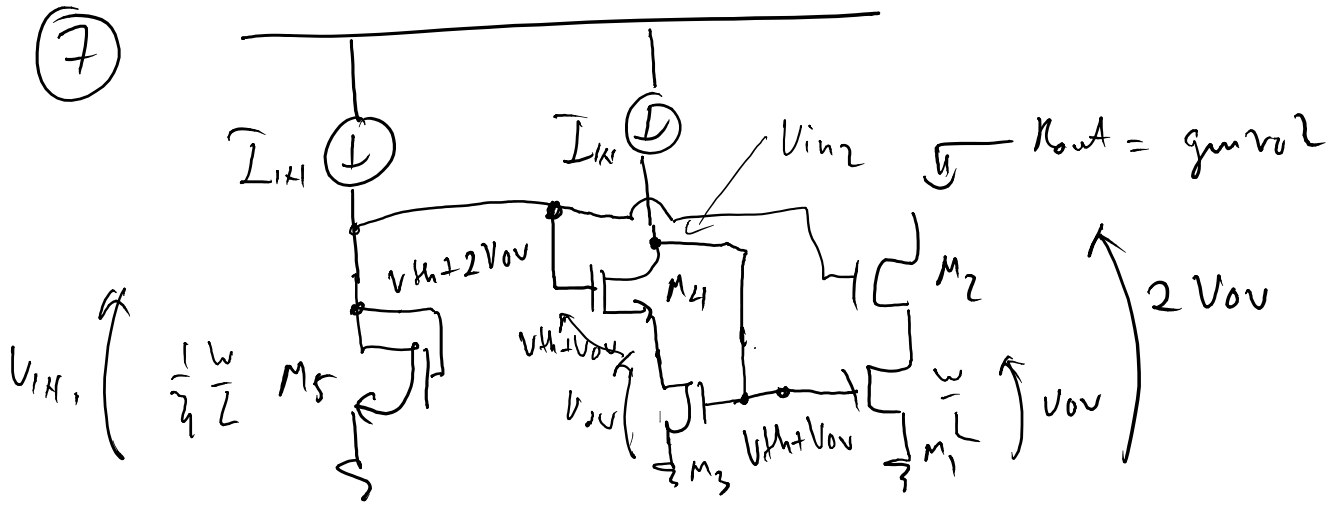
Systematic gain error $\simeq -\lambda\cdot(V_{th}) +$ B.E. from $M_2$

$V_{IN} = \max(V_{IN1}, V_{IN2}) = V_{th} + 2V_{OV}$

$V_{DS1} = V_{th} + 2V_{OV} - V_{th_2} - V_{OV} = \underbrace{(V_{th} - V_{th_2})}_{\text{B.E. error.}} + V_{OV}$

smaller than in (5)

7



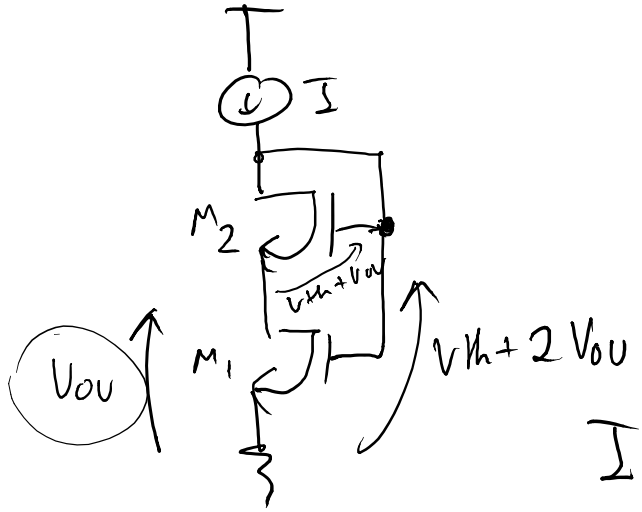

$$V_{GD_4} = V_{th} + 2V_{ov} - (V_{th} + V_{ov}) = \boxed{V_{ov} < V_{th}}$$

$$\sqrt{\frac{2I_{IN}}{k'\left(\frac{W}{L}\right)}}$$

Systematic gain error = 0

$V_{IN1} = \max(V_{IN1}, V_{in2}) = V_{th} + 2V_{ov}$ extra condition

(8) To combine $I_{IN}$ use triode device:




$M_2$ – saturation

$M_1$ – triode

$$V_{GS1} = V_{GS2} = V_{th} + V_{ov}$$

$$I = \frac{k'}{2}\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{th})^2$$

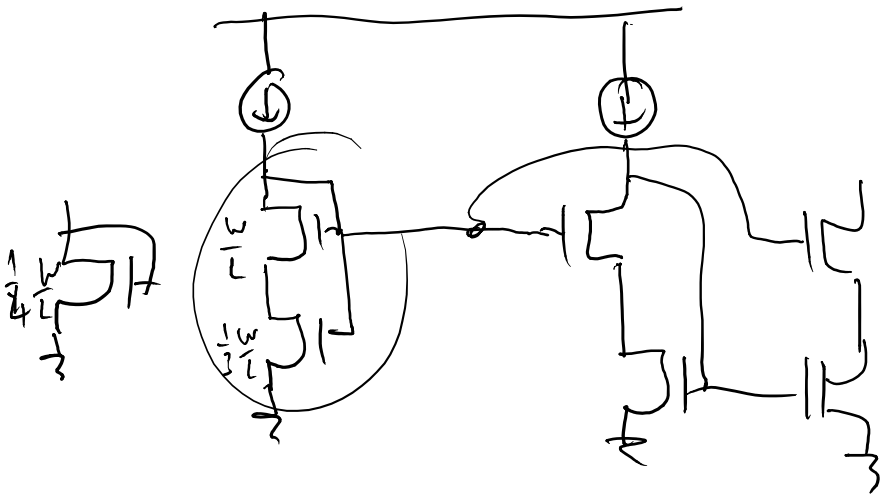
$$I = \frac{k'}{2}\left(\frac{W}{L}\right)_1 \left(2(V_{GS1} - V_{th}) \cdot V_{DS1} - V_{DS1}^2\right)$$

$$V_{GS1} = V_{th} + 2V_{ov}$$

$$\left(\frac{W}{L}\right)_2 \cdot V_{ov}^2 = \left(\frac{W}{L}\right)_1 \cdot \underbrace{\left(2(2V_{ov}) \cdot V_{ov} - V_{ov}^2\right)}_{3V_{ov}^2}$$

$$\left(\frac{W}{L}\right) = \left(\frac{W}{L}\right)_2 = 3\left(\frac{W}{L}\right)_1$$

Back to 7




9 Sooch Cascode