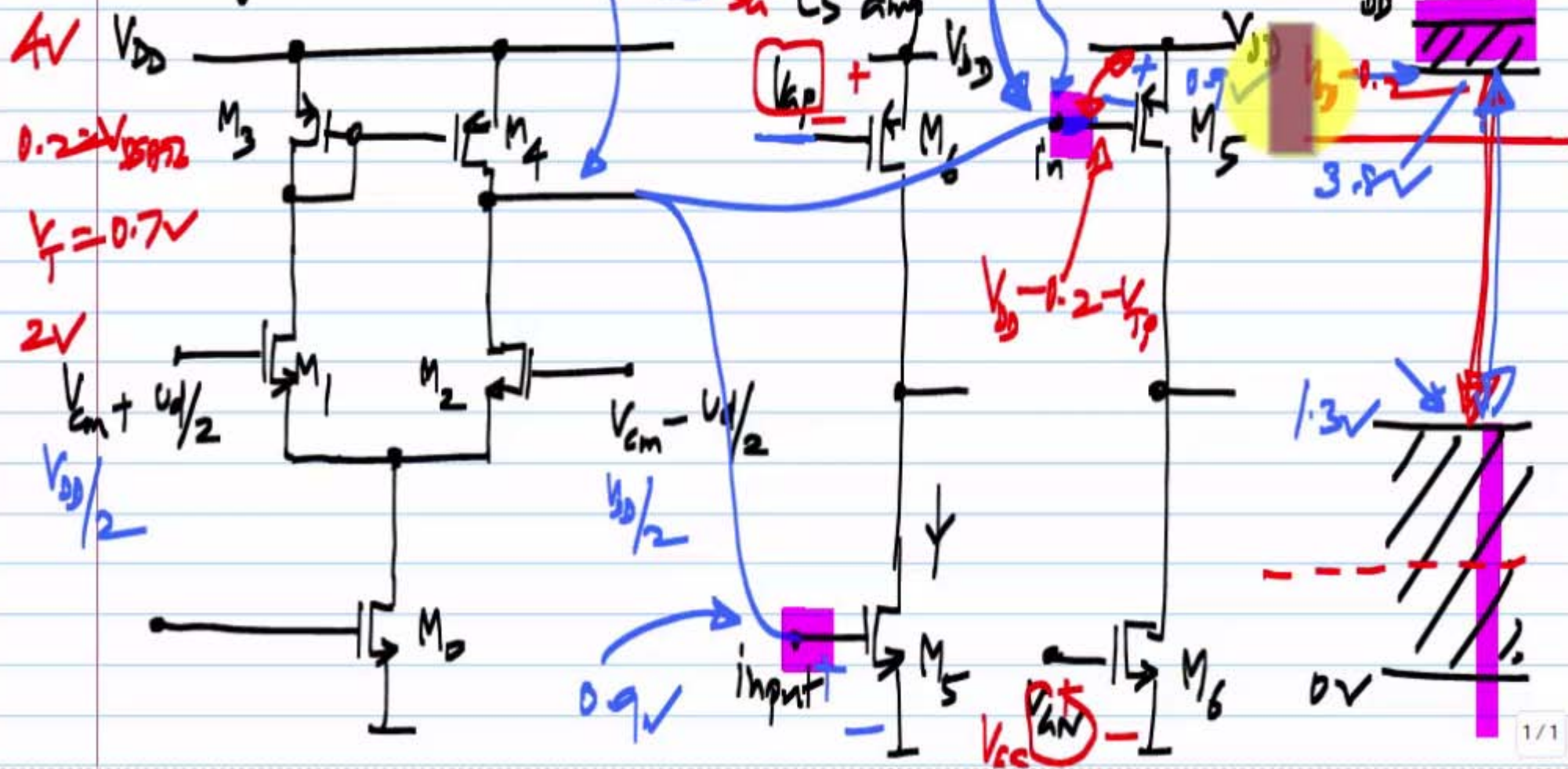


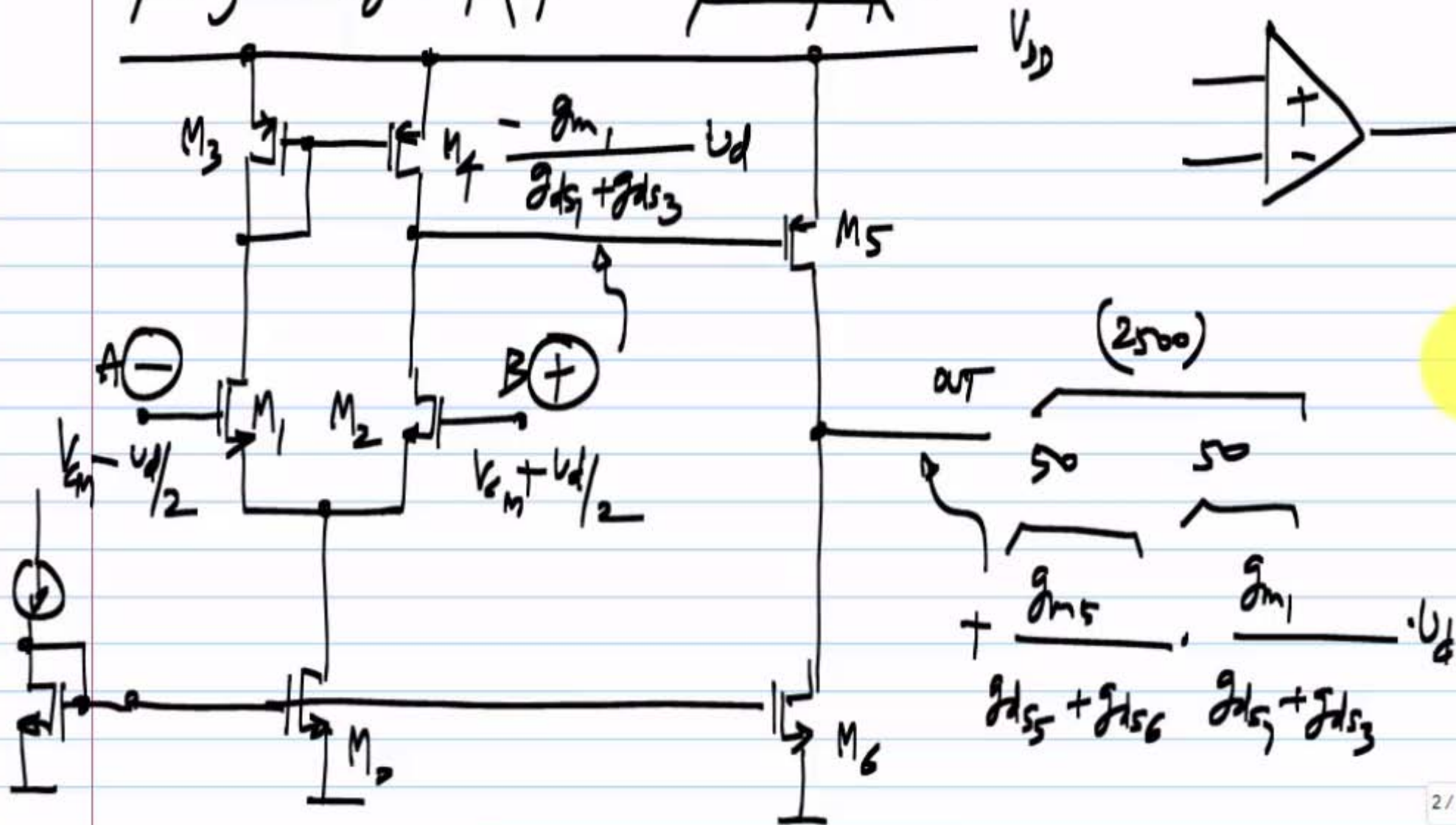
## Two stage opamp

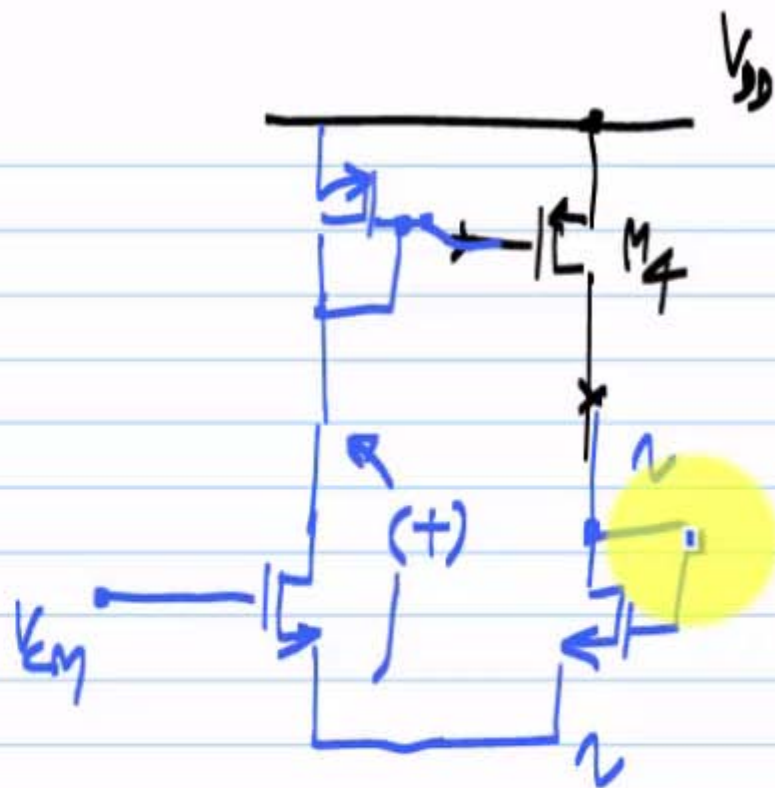
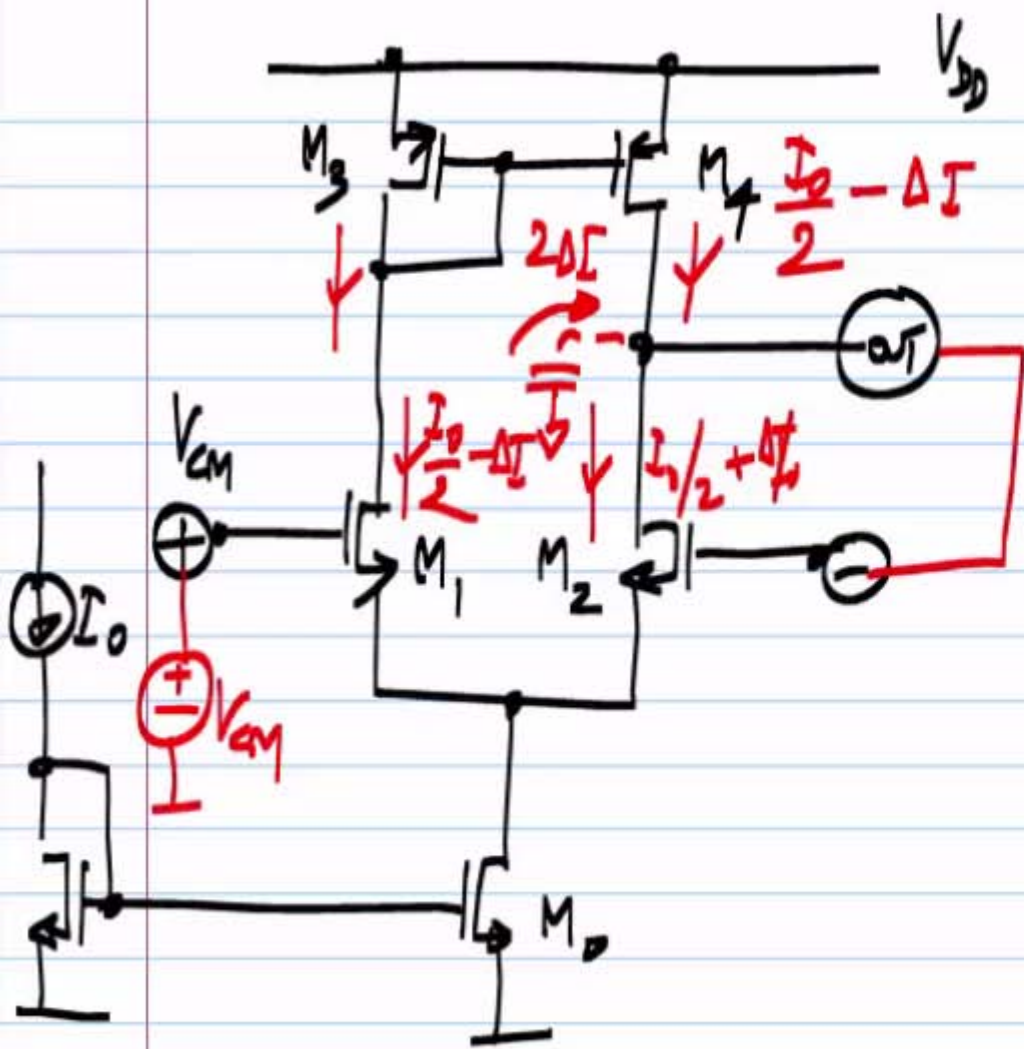
Note Title

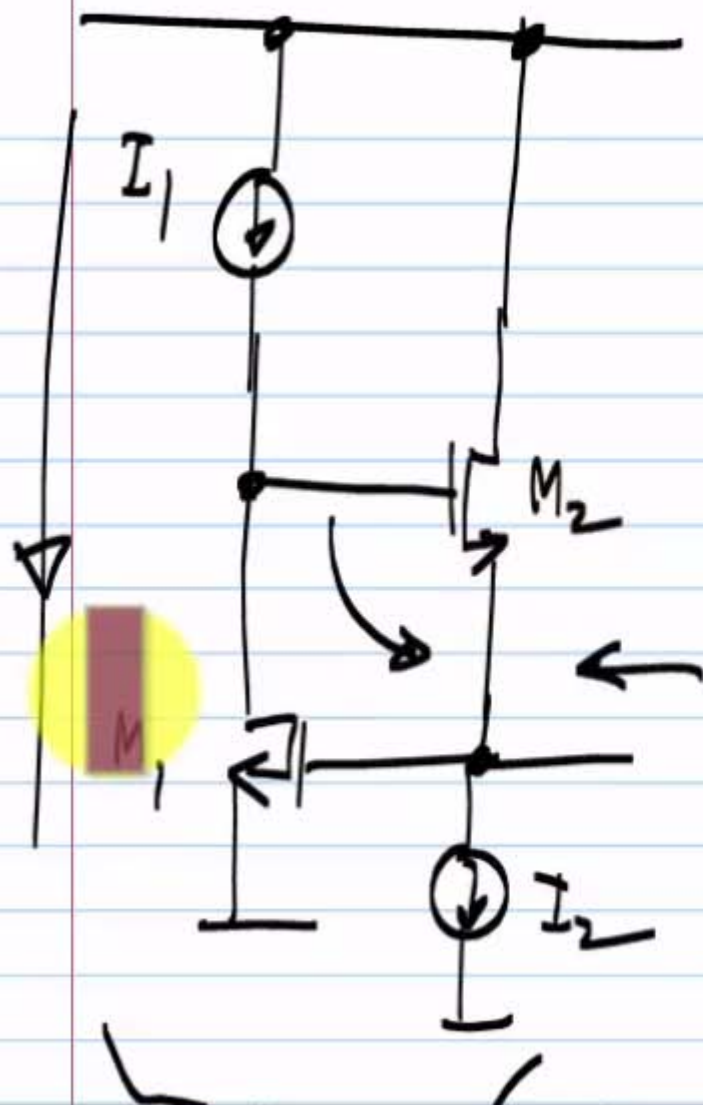


single stage opamp

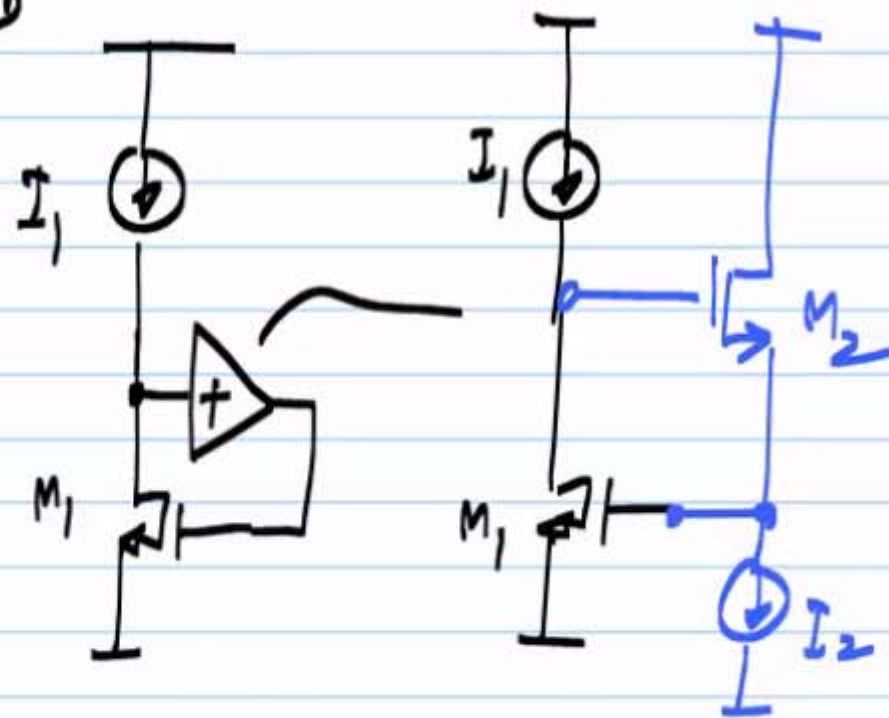
CS amplifier

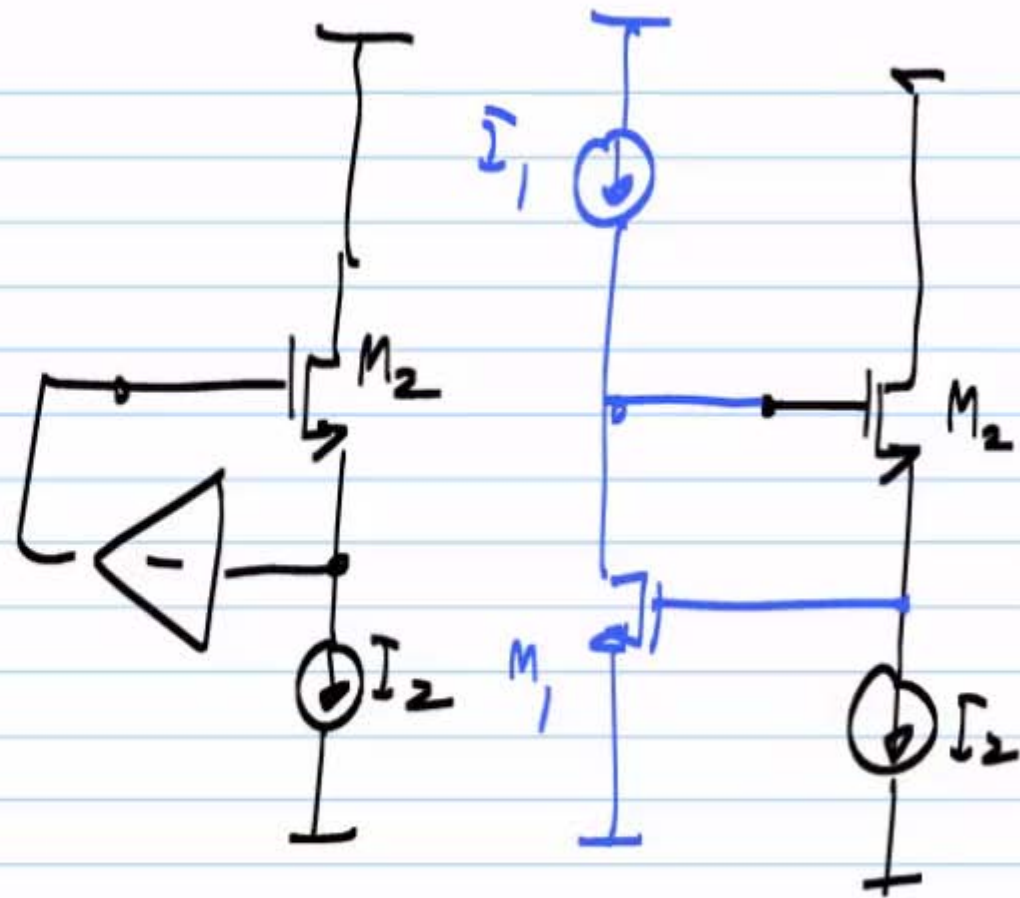
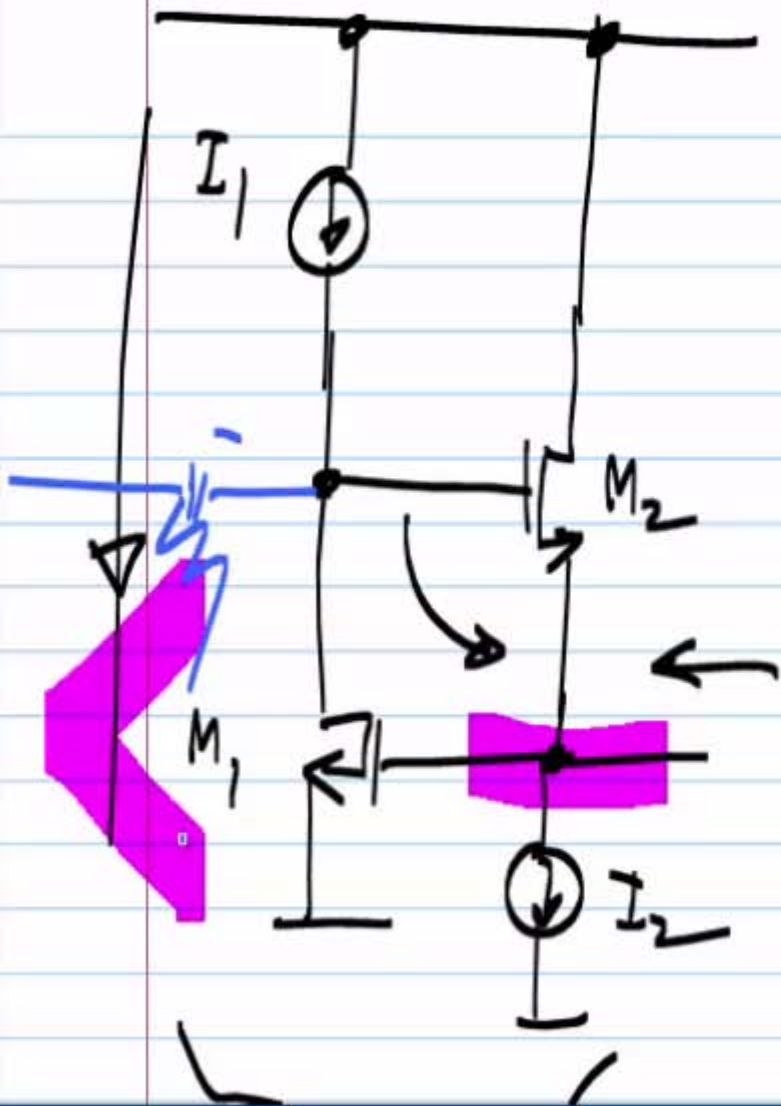






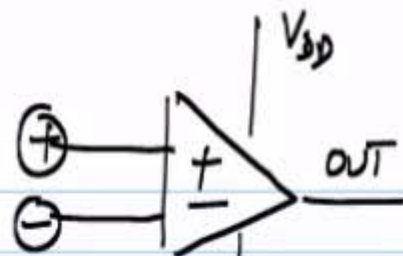
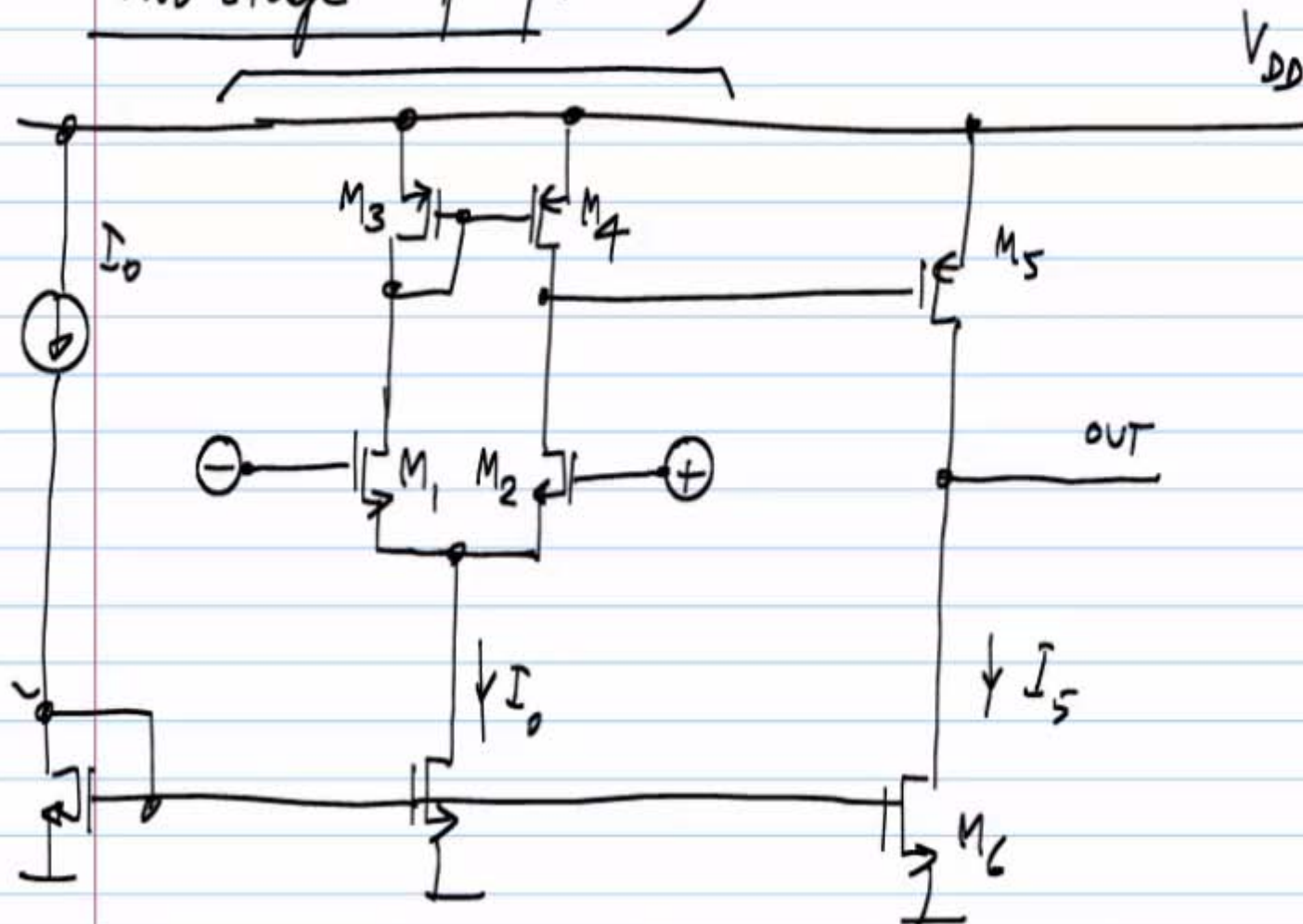
$V_{DD}$





Two stage opamp:

Single stage opamp



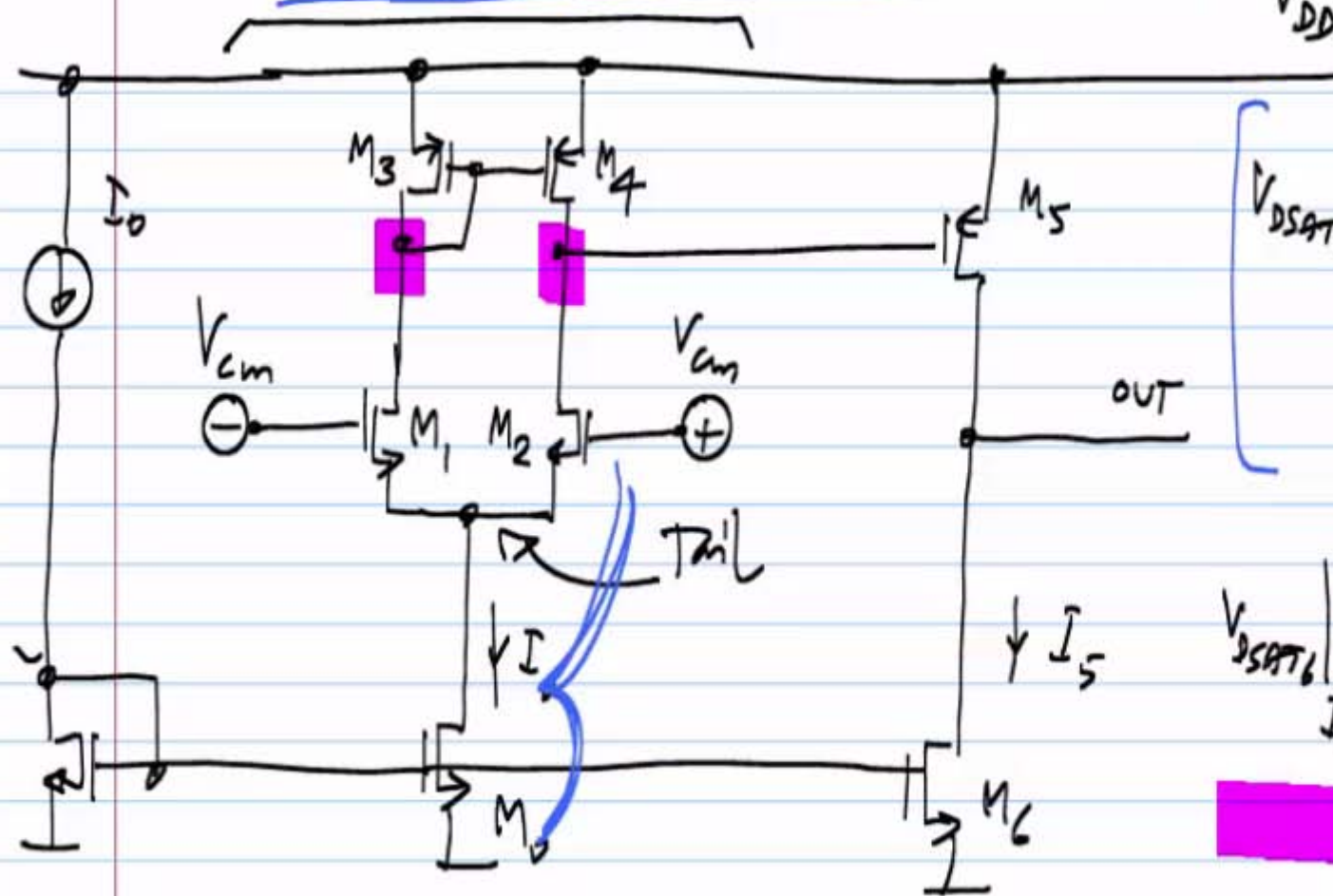
dc gain:

$$A_0 = \frac{g_{m1}}{g_{ds1} + g_{ds3}}$$

$$\frac{g_{m5}}{(g_{ds5} + g_{ds6})}$$

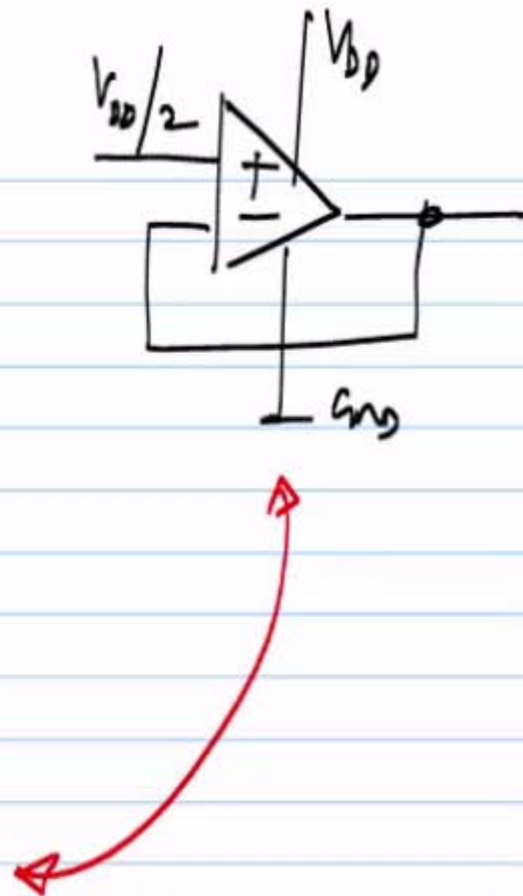
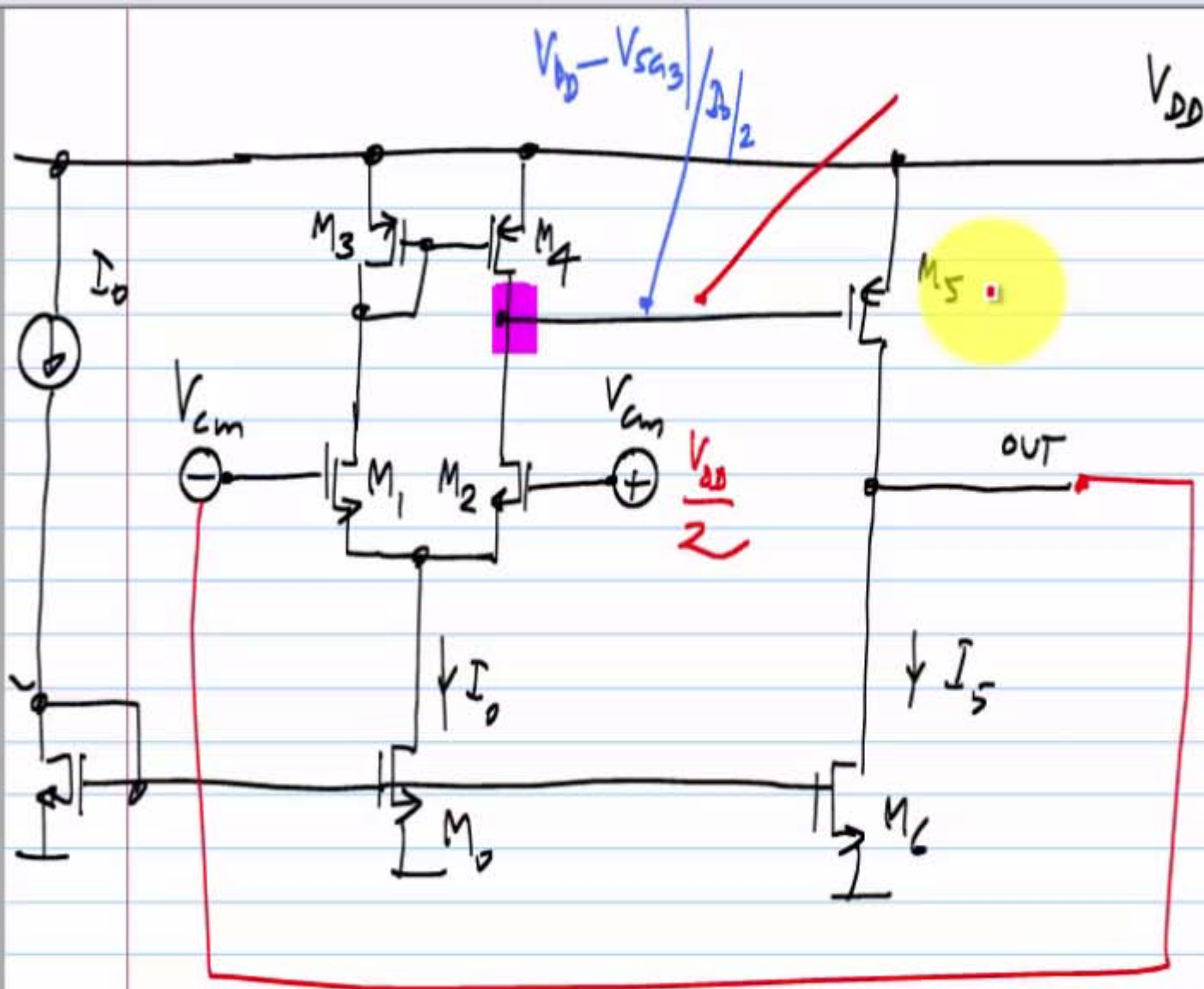
$$R_{out} = \frac{1}{g_{ds5} + g_{ds6}}$$

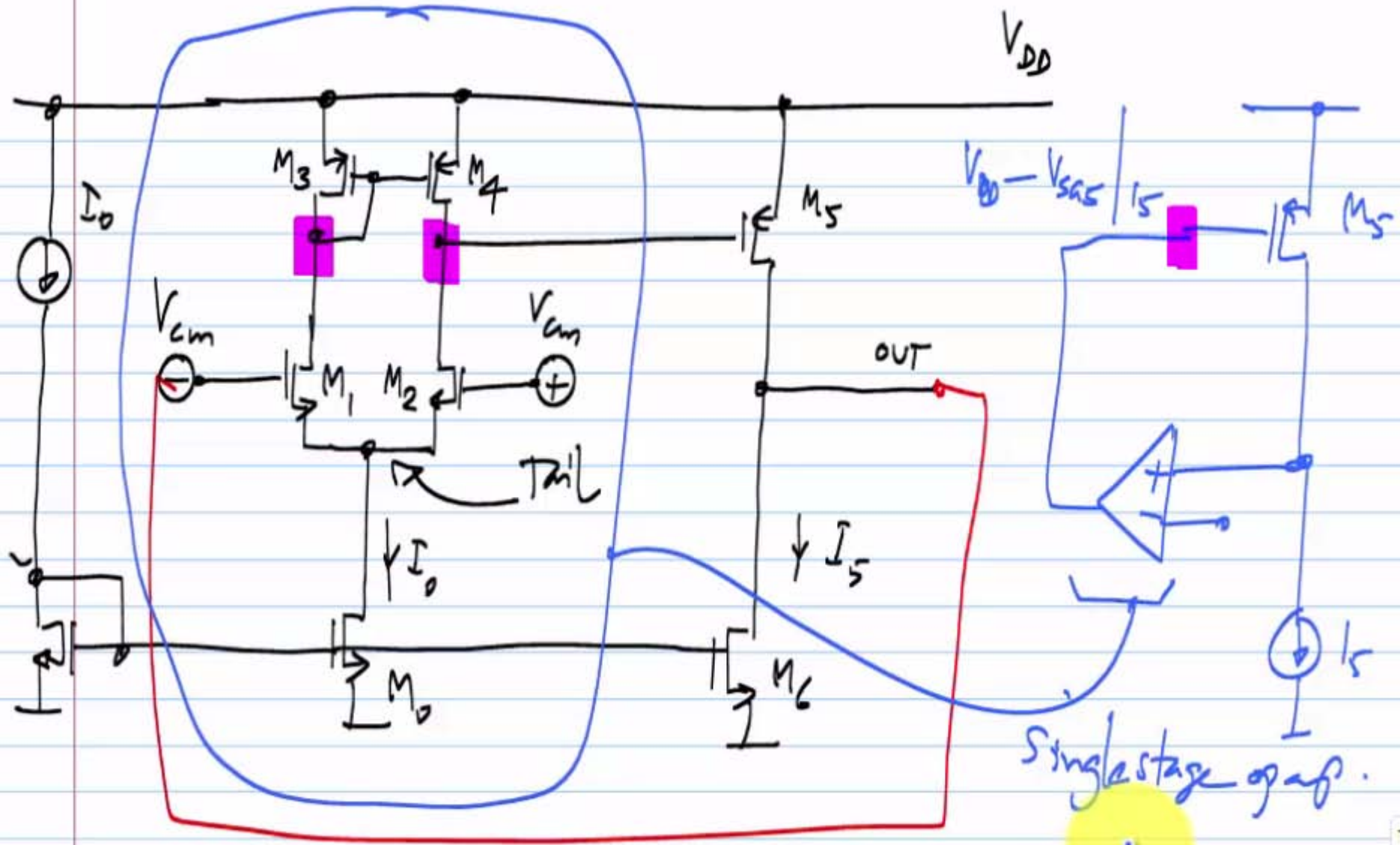
output: single  $V_{DSAT}$  away from  $V_{DD}$ , gnd: widest output swing

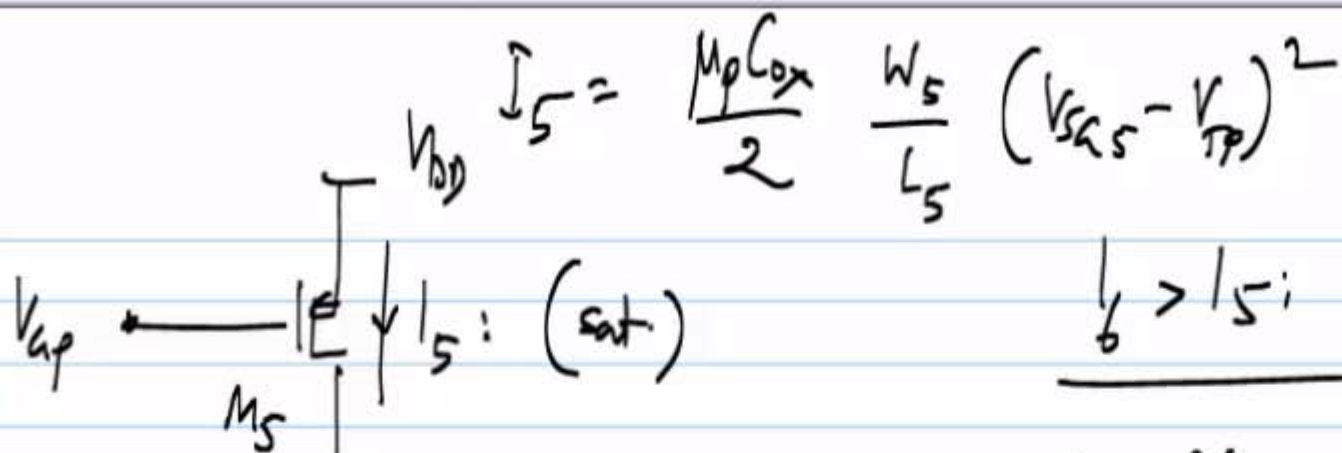


$$\left[ V_{DSAT0} \left| \frac{I_3}{I_5} \right| + V_{DSAT1} \left| \frac{I_3}{I_5} \right| + V_{TN} < V_{cm} \right. \\ \left. < V_{DD} - V_{DSAT3} \left| \frac{I_3}{I_5} \right| + V_{TN} \right]$$

$$V_{DSAT6} \left| \frac{I_5}{I_5} \right| < V_{out} < V_{DD} - V_{DSAT5} \left| \frac{I_5}{I_5} \right|$$



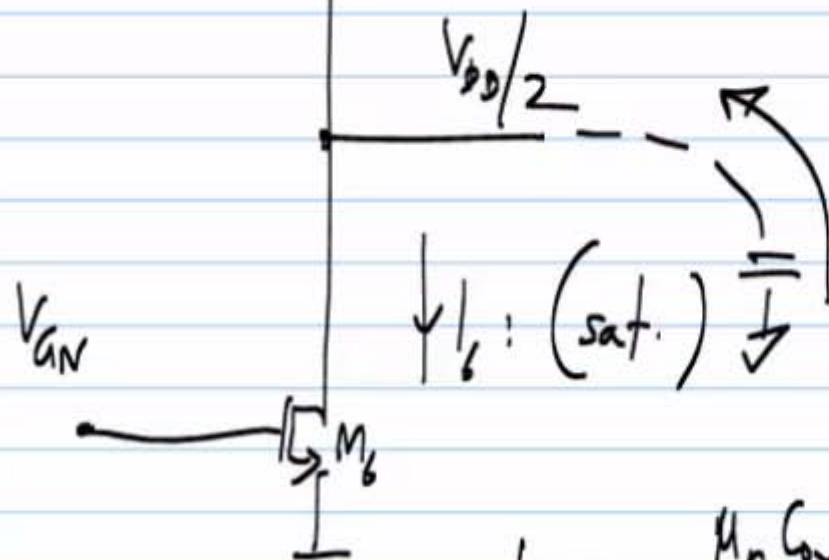




$$I_6 > I_5$$

$I_5$  flows through  $M_6$

triode



$$I_6 = \frac{\mu_n C_{ox}}{2} \frac{W_6}{L_6} (V_{GS6} - V_{TN})^2$$

## Systematic offset

In closed loop, the o/p of the first stage changes to  $V_{DD} - V_{GS5}|_{I_5}$  (from  $V_{DD} - V_{GS3}|_{I_{b/2}}$ )

$$\Rightarrow V_{off} = \frac{V_{GS3}|_{I_{b/2}} - V_{GS5}|_{I_5}}{A_1} \quad A_1 = \frac{g_{m1}}{g_{ds1} + g_{ds3}}$$

Fix: Design  $V_{GS5}|_{I_5} = V_{GS3}|_{I_{b/2}} \Rightarrow \text{systematic offset} = 0$

May not need to do this if  $A_1$  is very large.