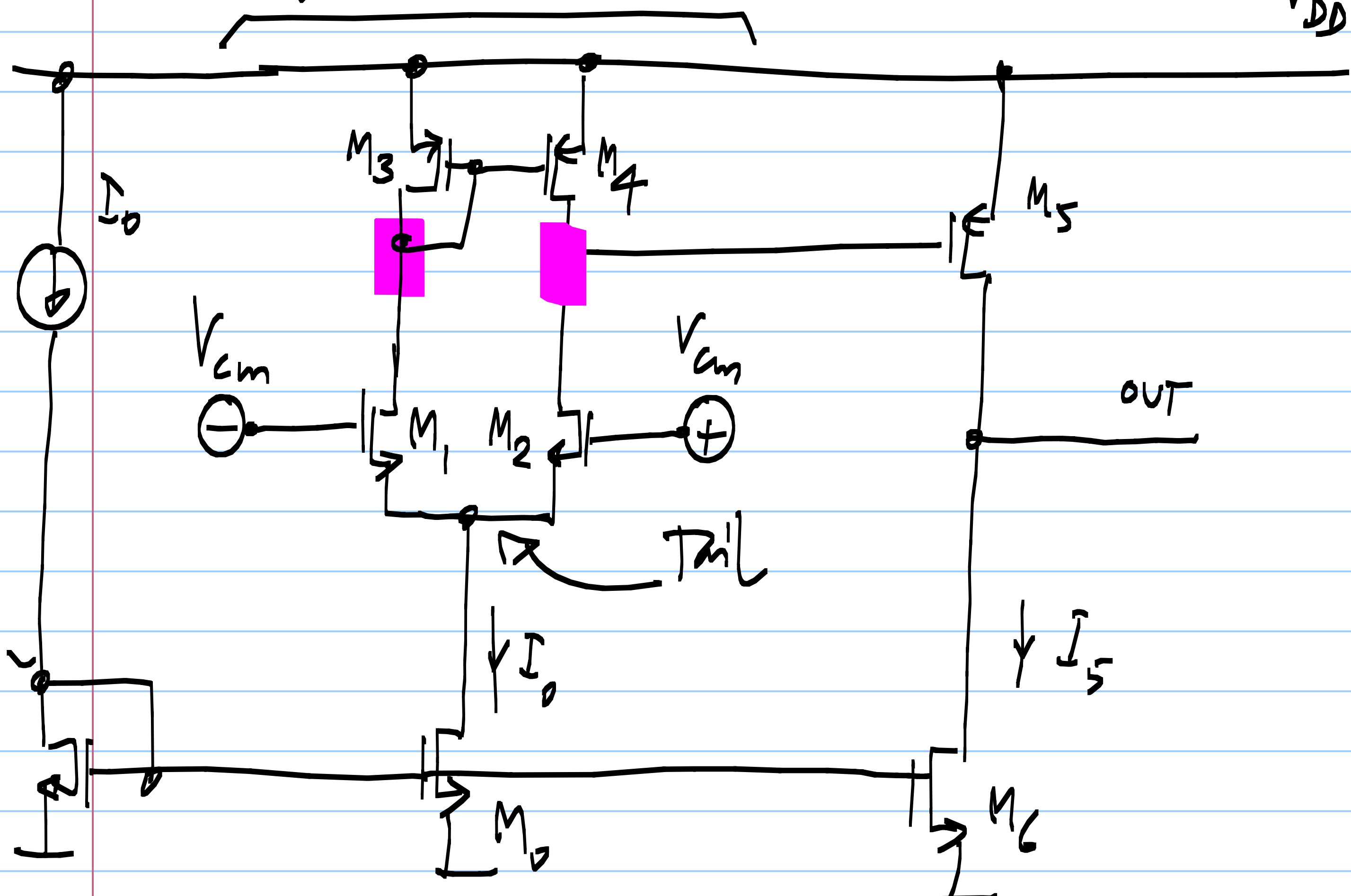
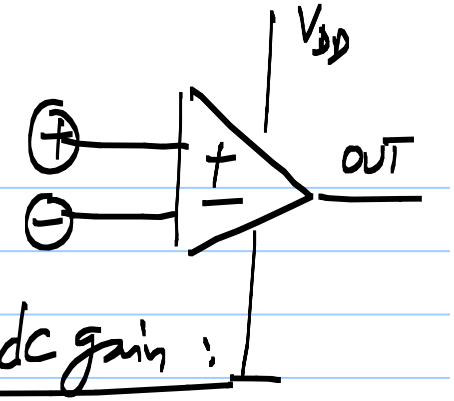
Two stage opamp:

Single stage opamp



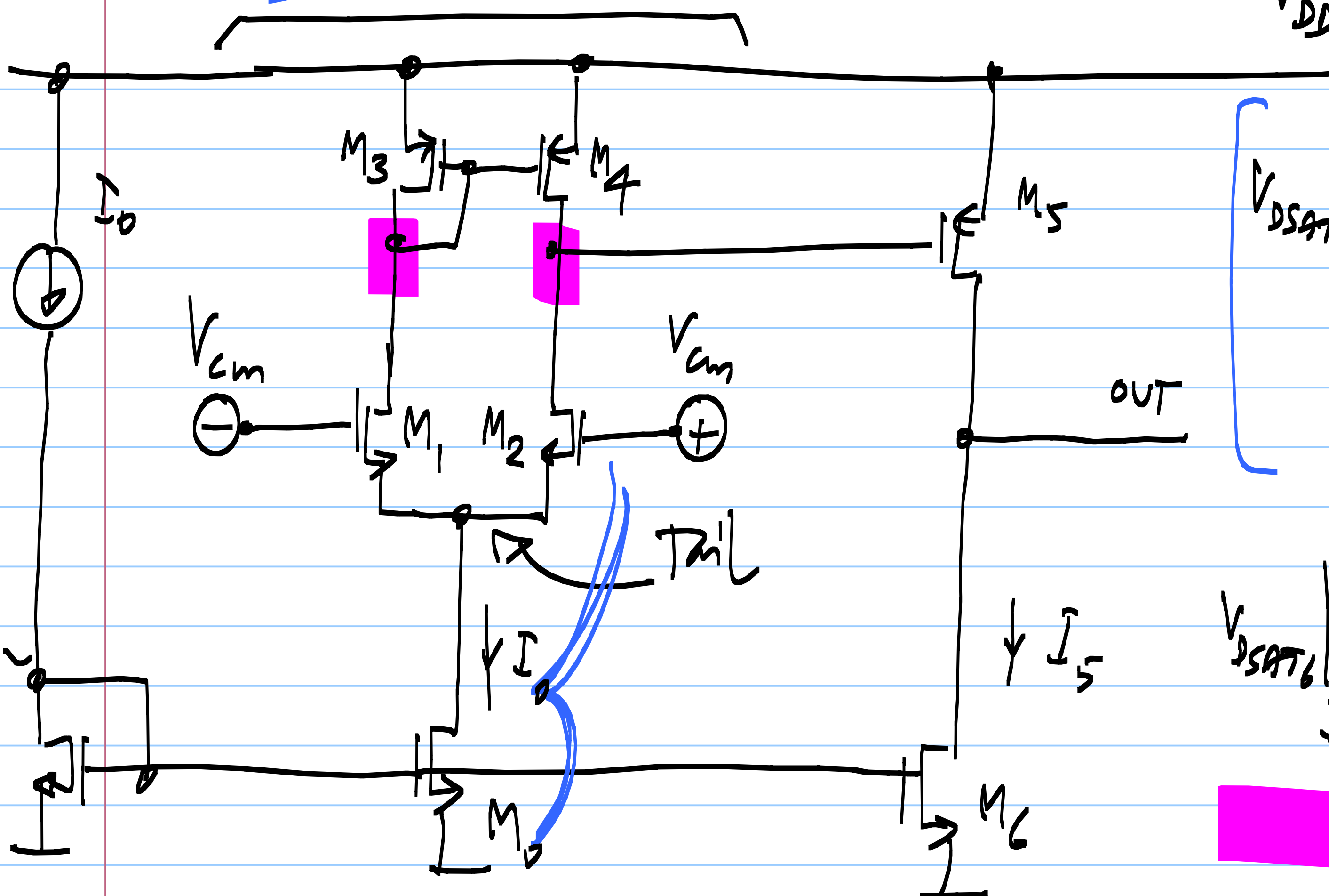


dc gain:

$$A_0 = \frac{g_{m_1}}{g_{ds_1} + g_{ds_3}} \cdot \frac{g_{m_5}}{(g_{ds_5} + g_{ds_6})}$$

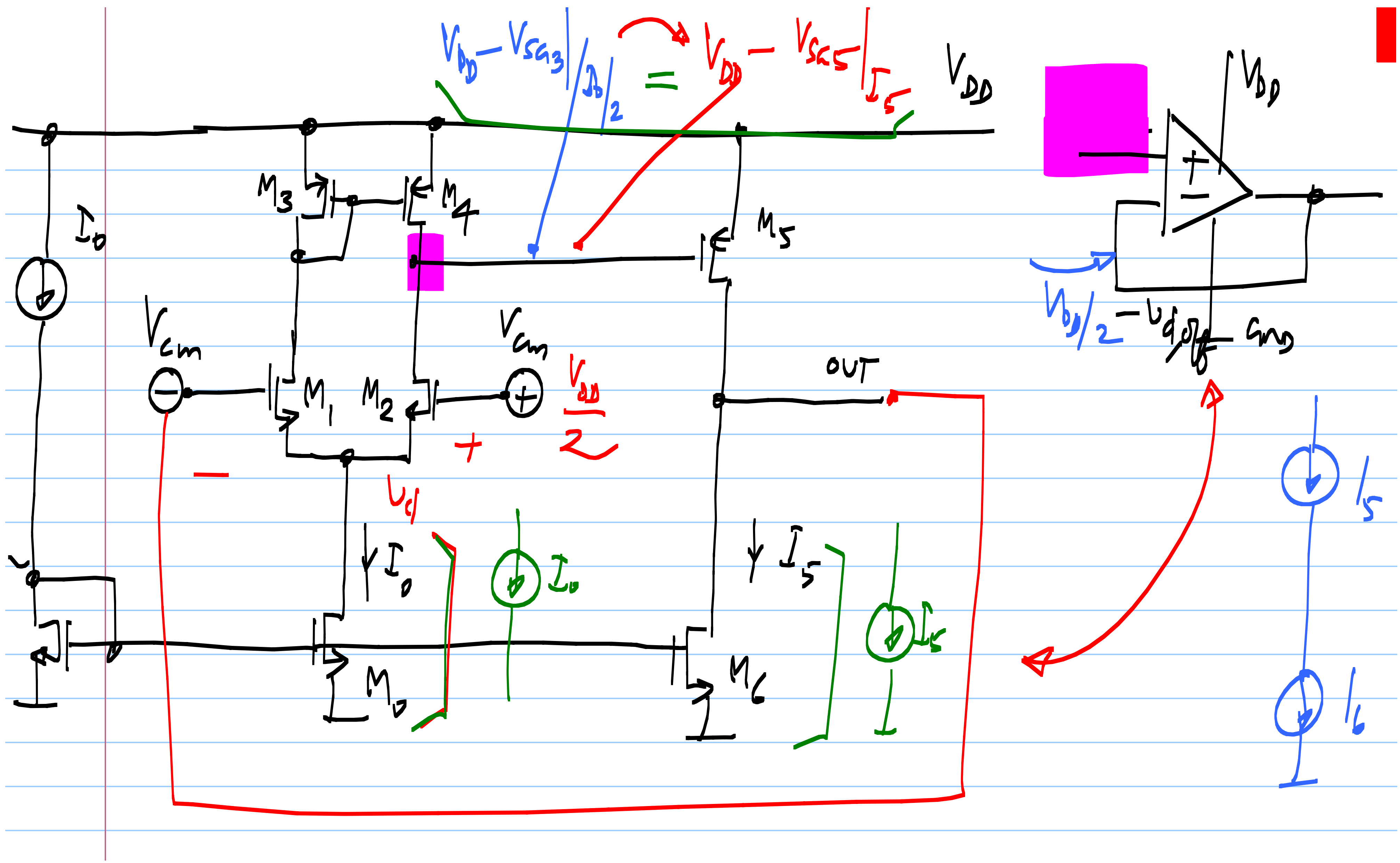
$$R_{out} = \frac{1}{g_{ds_5} + g_{ds_6}}$$

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

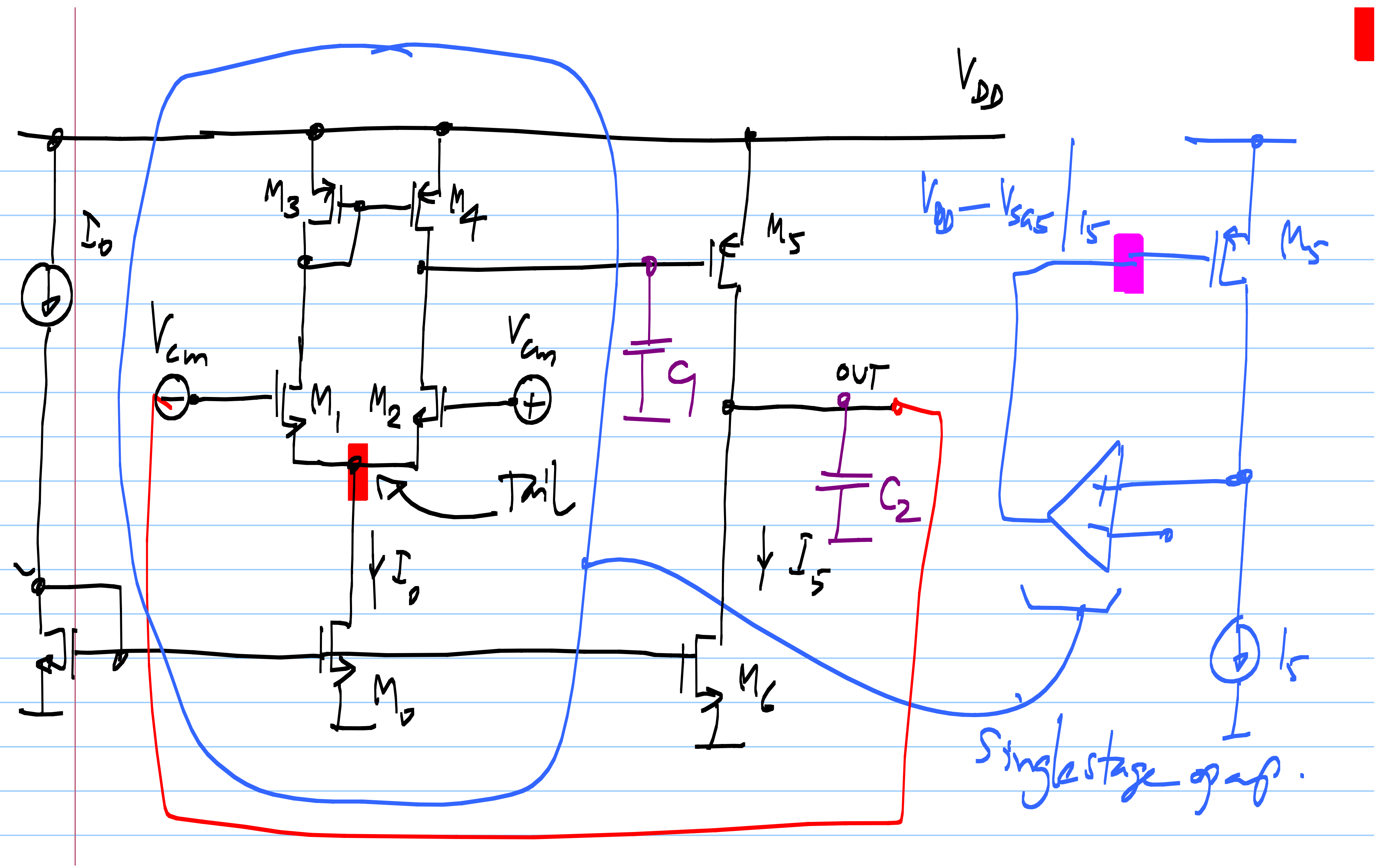


$$V_{DSAT_3}\Big|_{I_3} + V_{DSAT_1}\Big|_{I/2} + V_{TN} < V_{cm} < V_{DD} - V_{GS_3}\Big|_{I/2} + V_{TN}$$

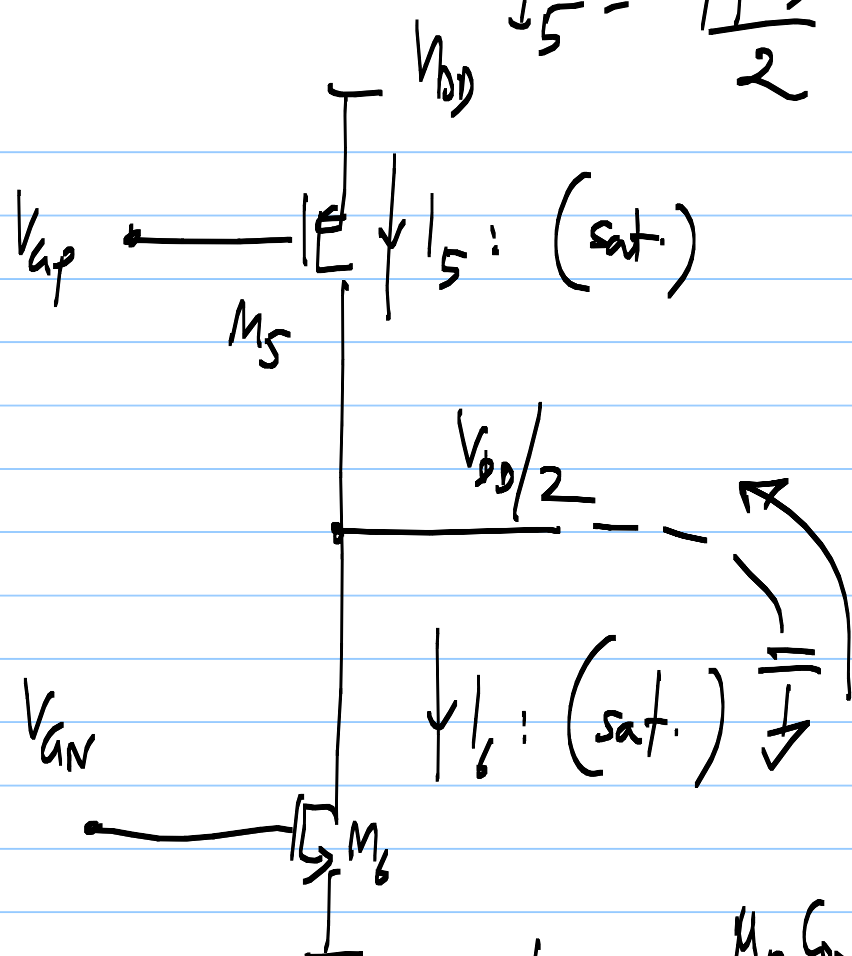
$$V_{DSAT_6}\Big|_{I_5} < V_{out} < V_{DD} - V_{DSAT_5}\Big|_{I_5}$$



$V_{DD} - V_{SG3}|_{I_D/2}$ = $V_{DD} - V_{SG5}|_{I_5}$
V_{DD}
I_0
M_3
M_4
M_5
V_{cm}
M_1
M_2
V_{cm}
$\frac{V_{DD}}{2}$
OUT
$V_{DD}/2 - V_{d,off}$
Gnd
V_{DD}
I_0
M_0
I_5
M_6
I_5
I_6



VDD
I0
M3
M4
M5
Vcm
M1
M2
Vcm
C1
OUT
C2
Tail
I0
I5
M0
M6
VDD − VSG5
I5
M5
I5
Single stage op-amp.



$$I_5 = \frac{\mu_p C_{ox}}{2} \frac{W_5}{L_5} (V_{SG5} - V_{TP})^2$$

$I_6 > I_5$:

I_5 flows through M_6

triode

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

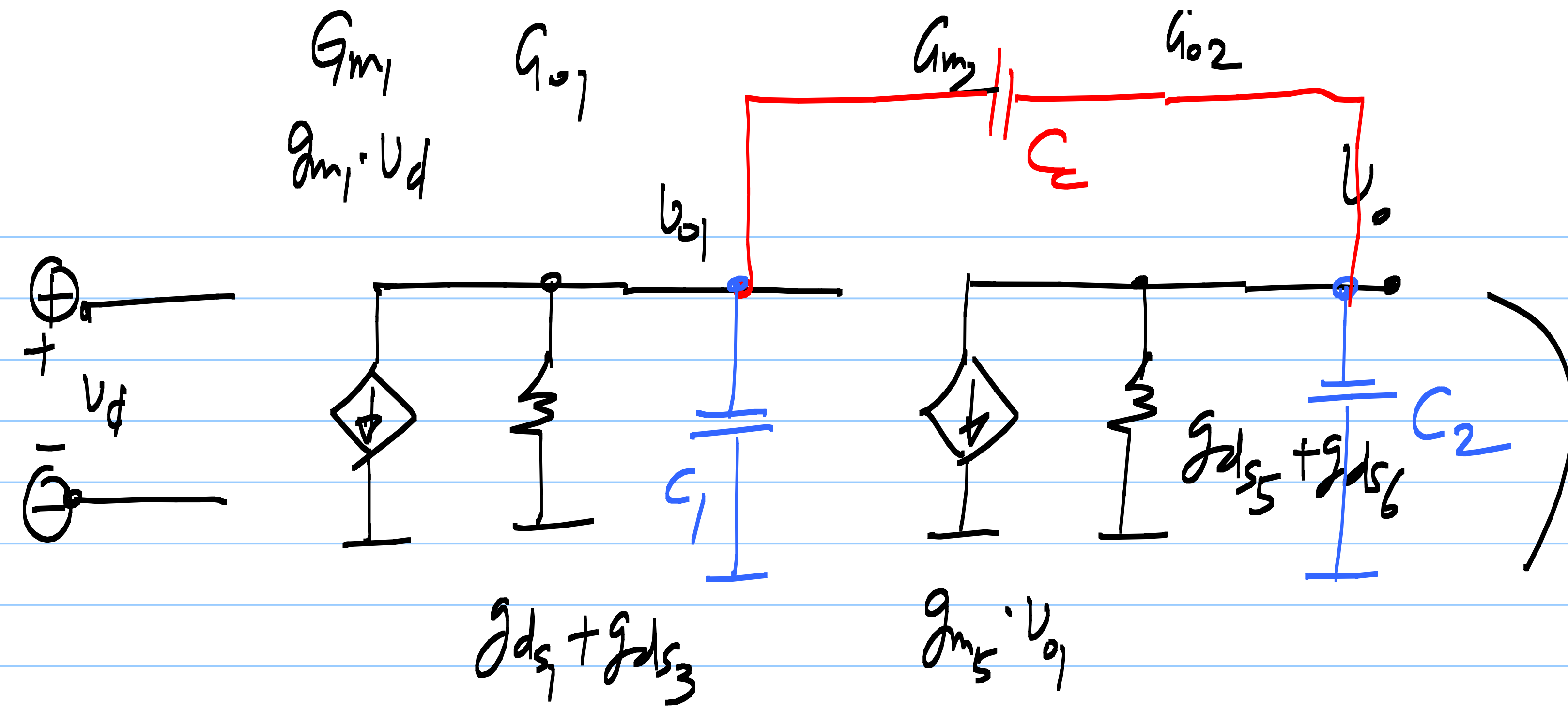
Systematic offset

In closed loop, the o/p of the first stage changes to $V_{DD} - V_{SG_5}\big|_{I_5}$ (from $V_{DD} - V_{SG_3}\big|_{I_0/2}$)

$$\Rightarrow \quad V_{off} = \frac{V_{SG_3}\big|_{I_0/2} - V_{SG_5}\big|_{I_5}}{A_1} \qquad A_1 = \frac{g_{m_1}}{g_{ds_1} + g_{ds_3}}$$

Fix: Design $V_{SG_5}\big|_{I_5} = V_{SG_3}\big|_{I_0/2} \Rightarrow$ systematic offset $= 0$

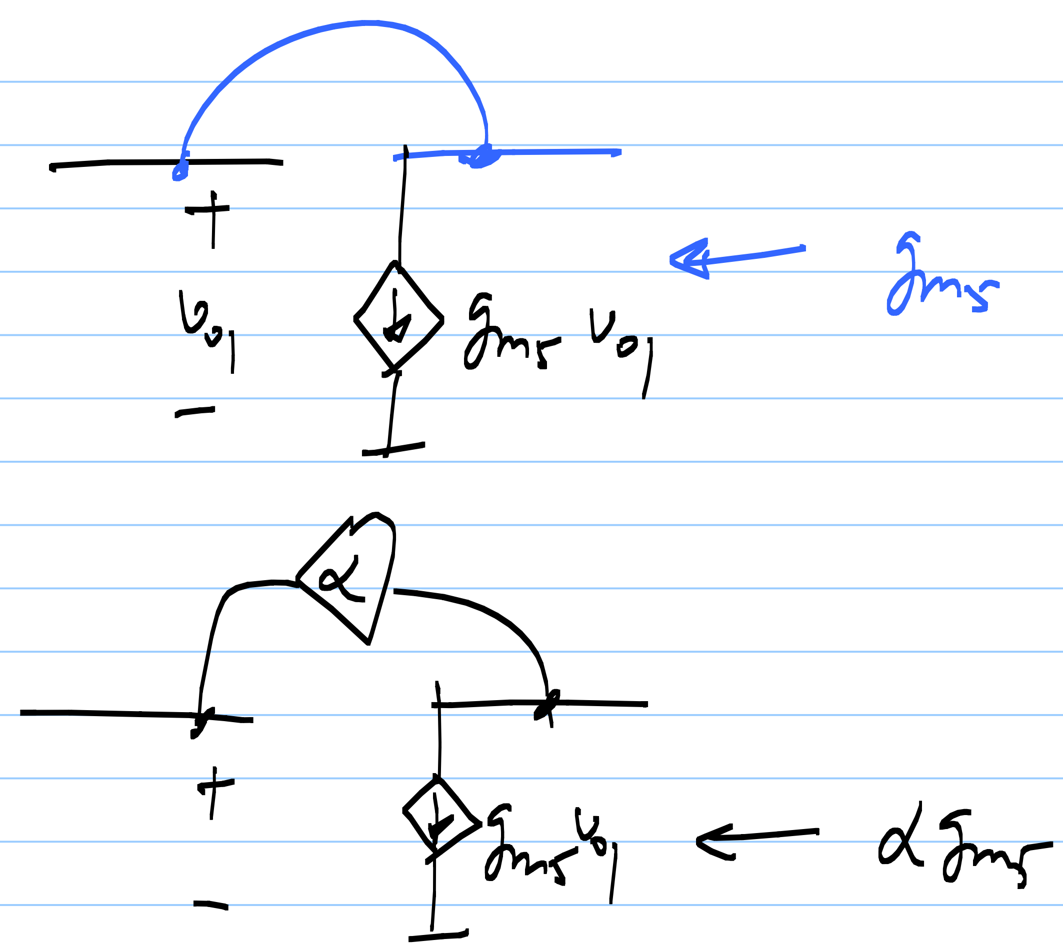
May not need to do this if A_1 is very large



$$A(s) = \frac{A_o\left(1 - \frac{s}{z_1}\right)}{\left(1 + \frac{s}{p_1}\right)\left(1 + \frac{s}{p_2}\right)}$$

$$z_1 = \frac{g_{m5}}{C_c}; \quad p_1 \simeq \frac{g_{ds_1} + g_{ds_3}}{C_1 + \left(1 + \frac{g_{m5}}{(\ )}\right) C_c}$$

$$p_2 = \frac{g_{m5} \cdot \frac{C_c}{C_c + C_1} + g_{ds5} + g_{ds_6}}{C_2 + C_c \| C_1}$$



+
v01
−
gm5 v01
gm5
α
+
−
gm5 v01
α gm5