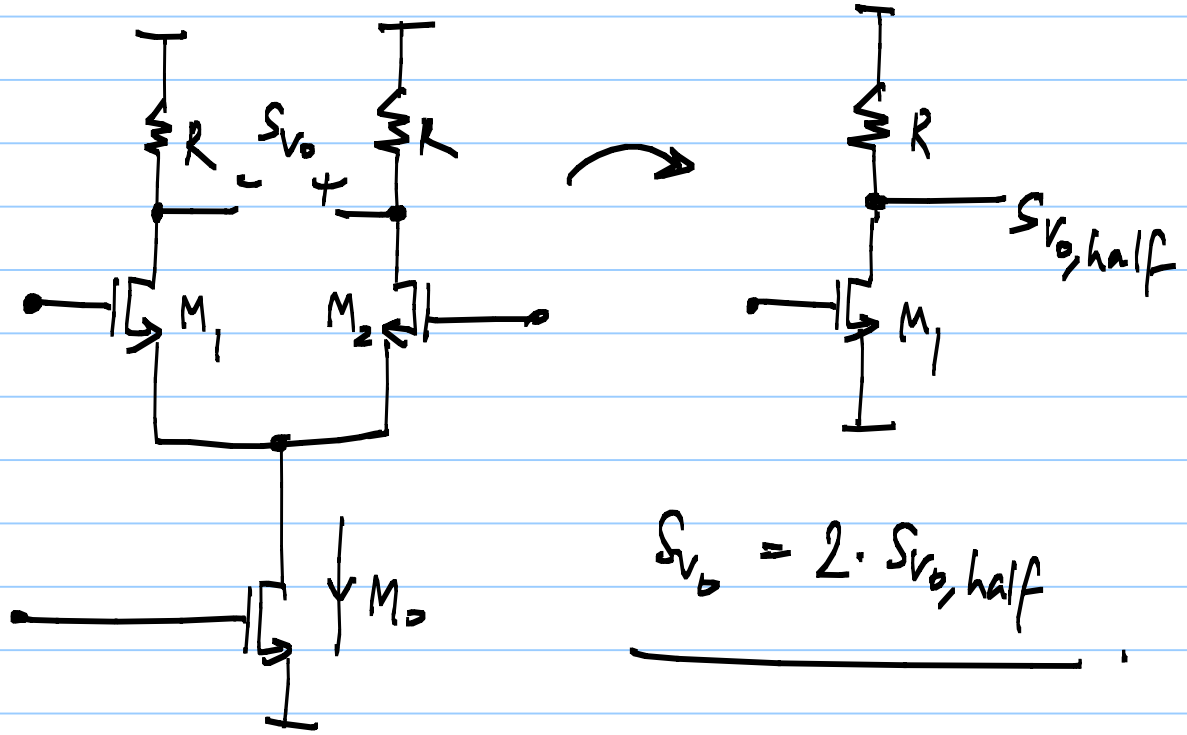
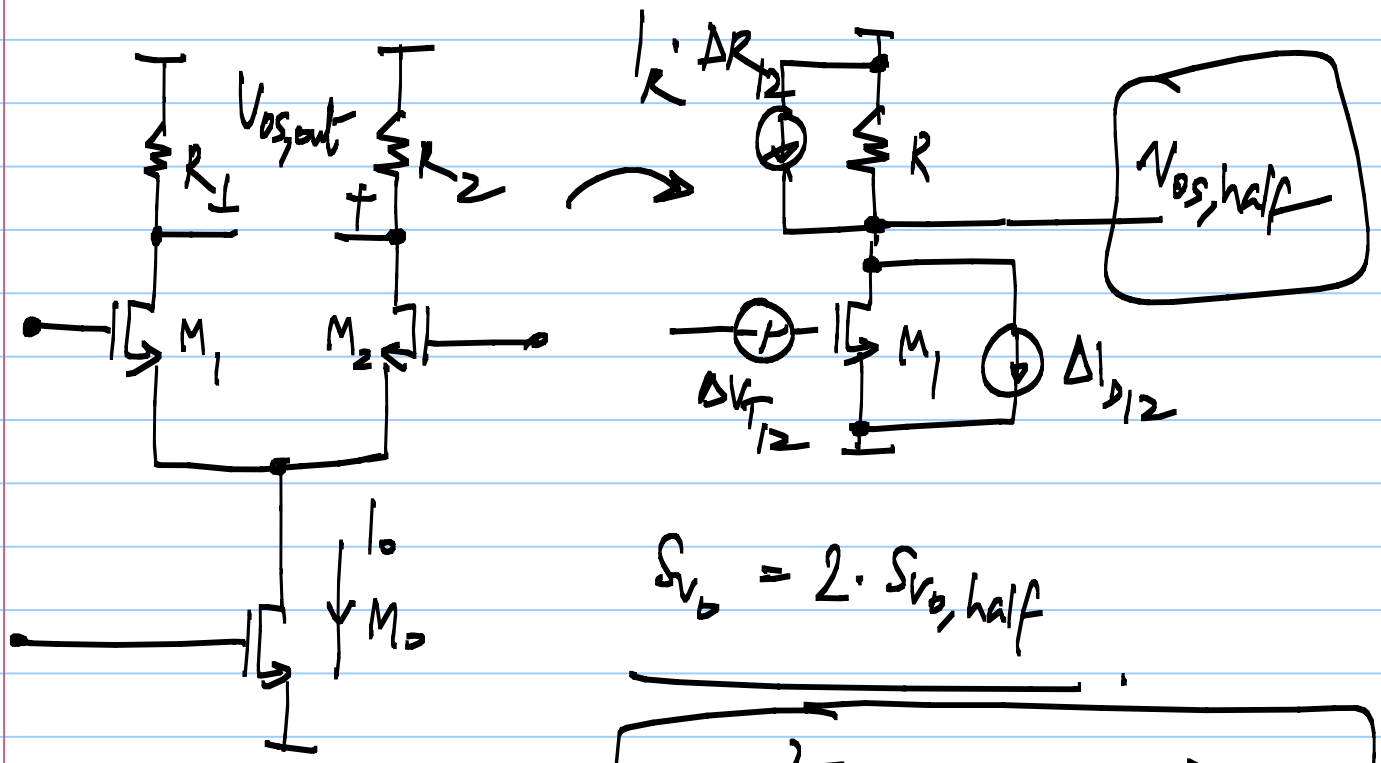
# Lecture 40

## offset in fully differential circuits:




$$S_{V_0} = 2 \cdot S_{V_0,half}$$

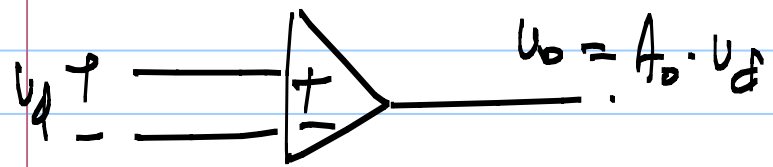
$$\Delta I_{D12} = \frac{I_o}{2} \cdot \Delta\beta \qquad \frac{\Delta\beta}{\beta};\ \frac{\Delta R}{R}$$

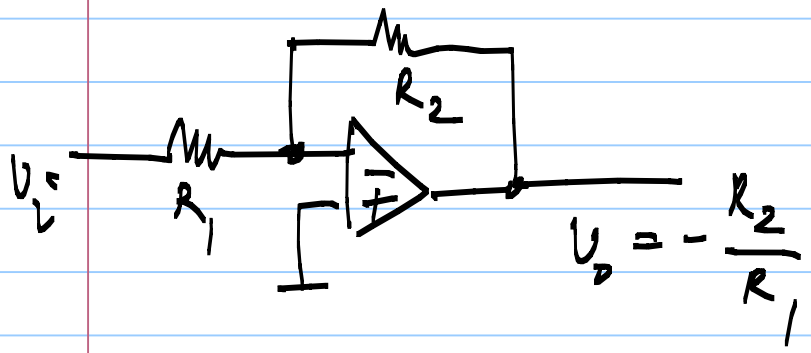



$$S_{V_o} = 2 \cdot S_{V_o,half}$$

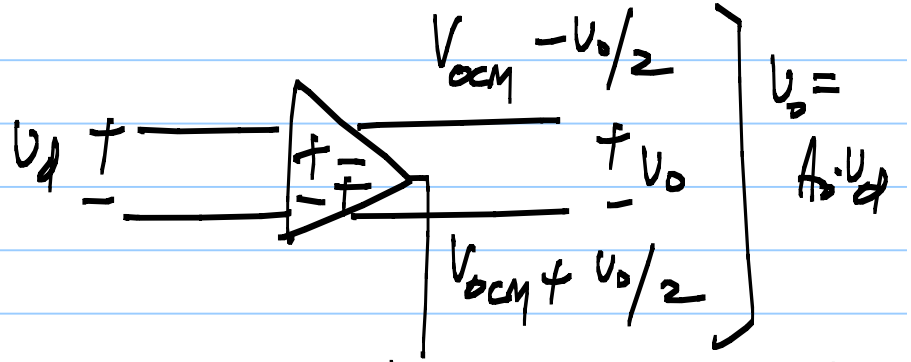
$$\sigma^2_{V_{OS,out}} = \sigma^2_{V_{OS,half}}$$

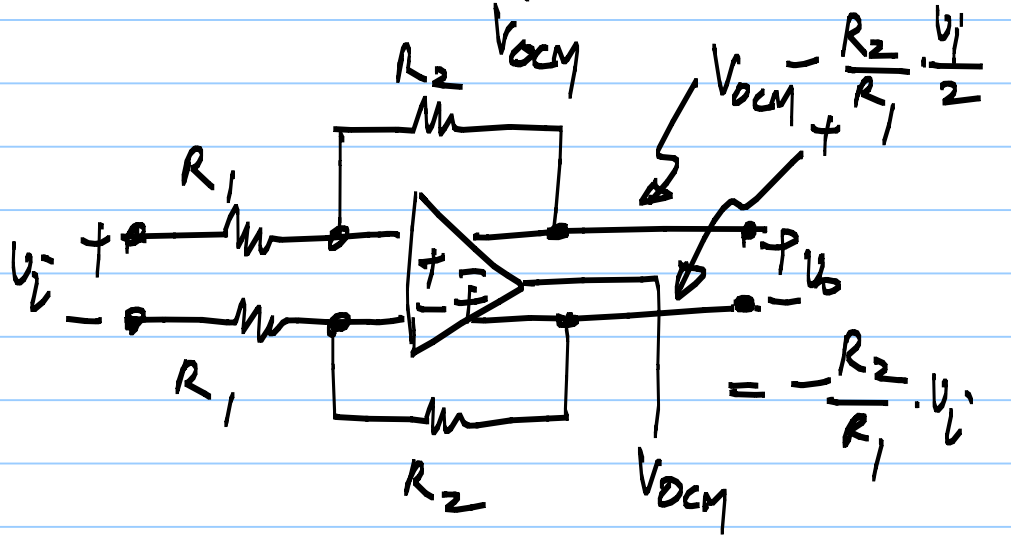
# Single ended opamp.

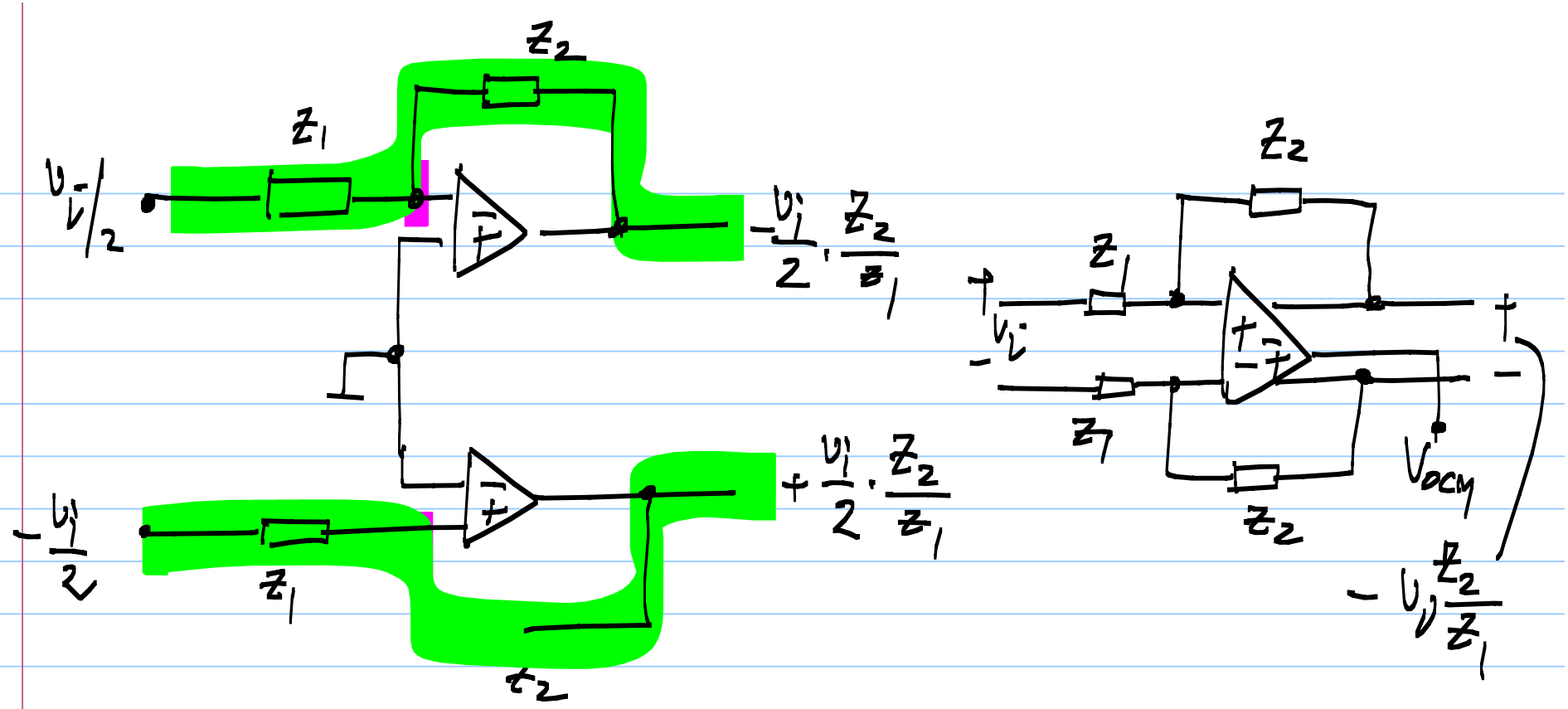


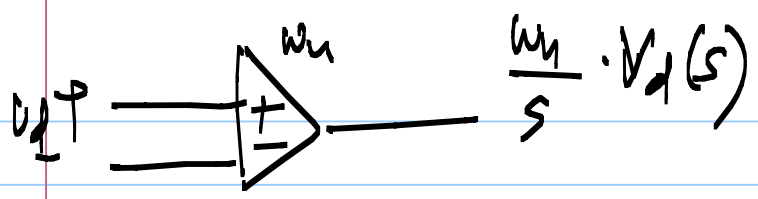



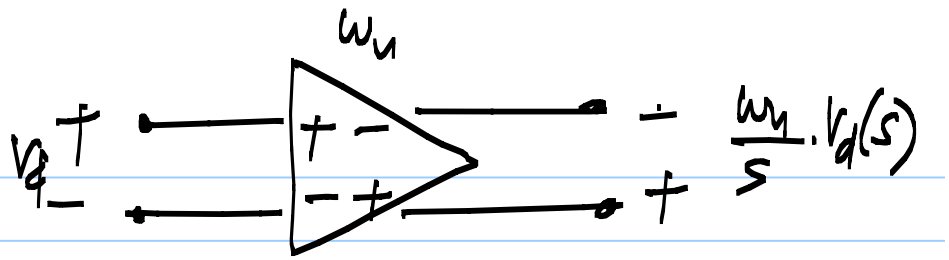

# Fully differential opamp

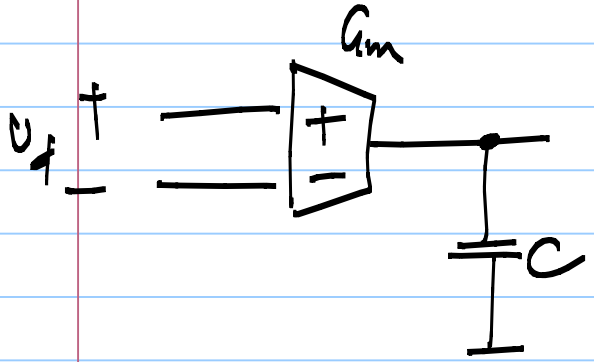


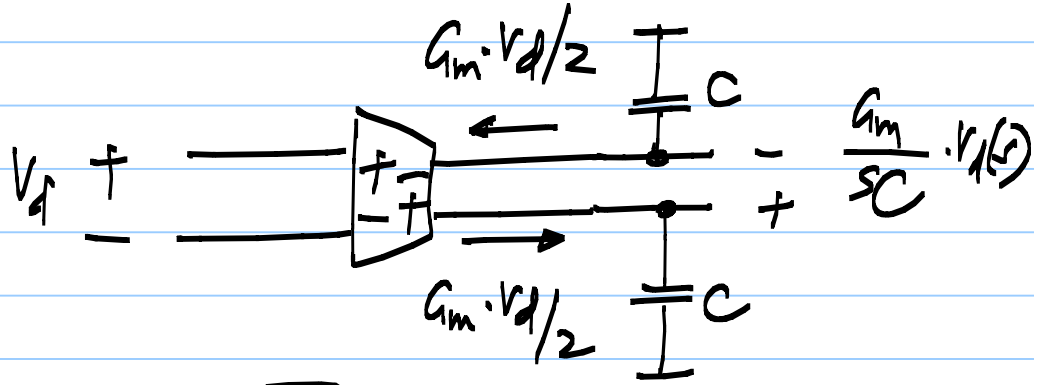




$Z_2$
$Z_1$
$v_i/2$
$-\frac{v_i}{2}\cdot\frac{Z_2}{Z_1}$
$-\frac{v_i}{2}$
$+\frac{v_i}{2}\cdot\frac{Z_2}{Z_1}$
$Z_1$
$Z_2$
$Z_2$
$Z_1$
$+$
$v_i$
$-$
$Z_1$
$V_{OCM}$
$-v_i\frac{Z_2}{Z_1}$



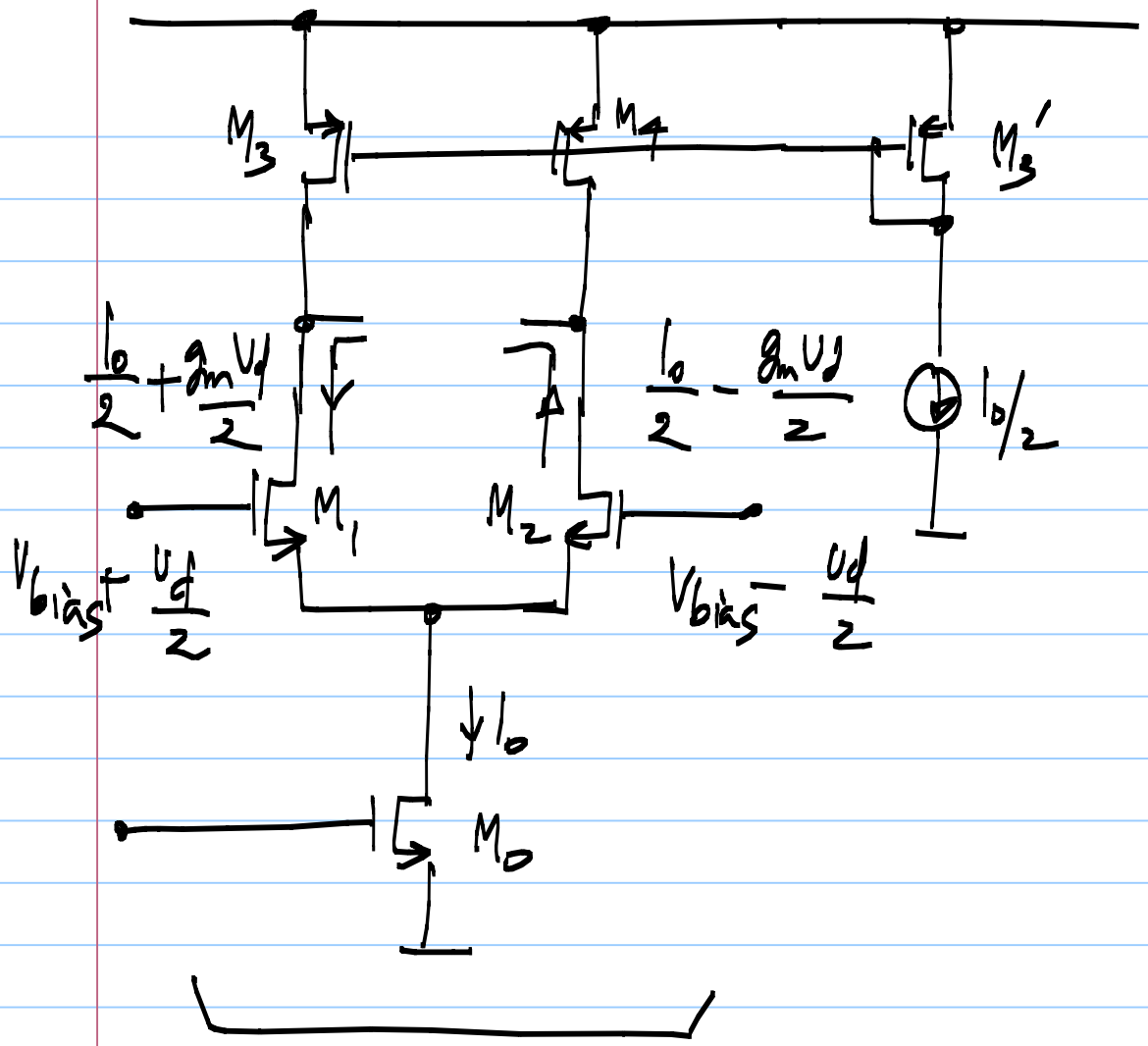



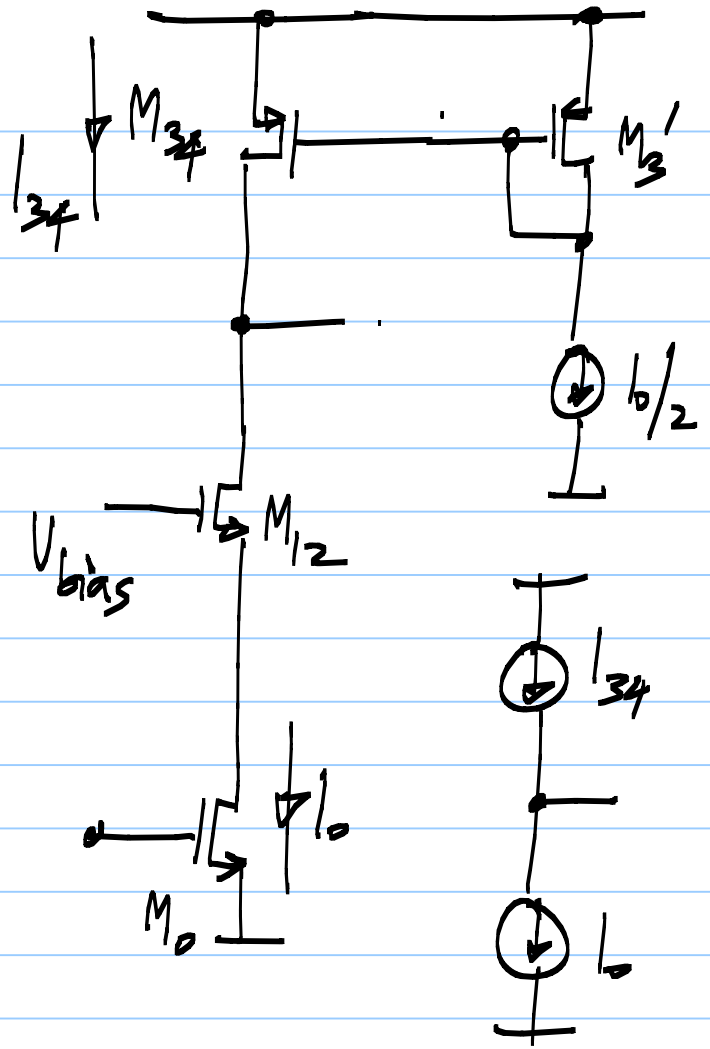



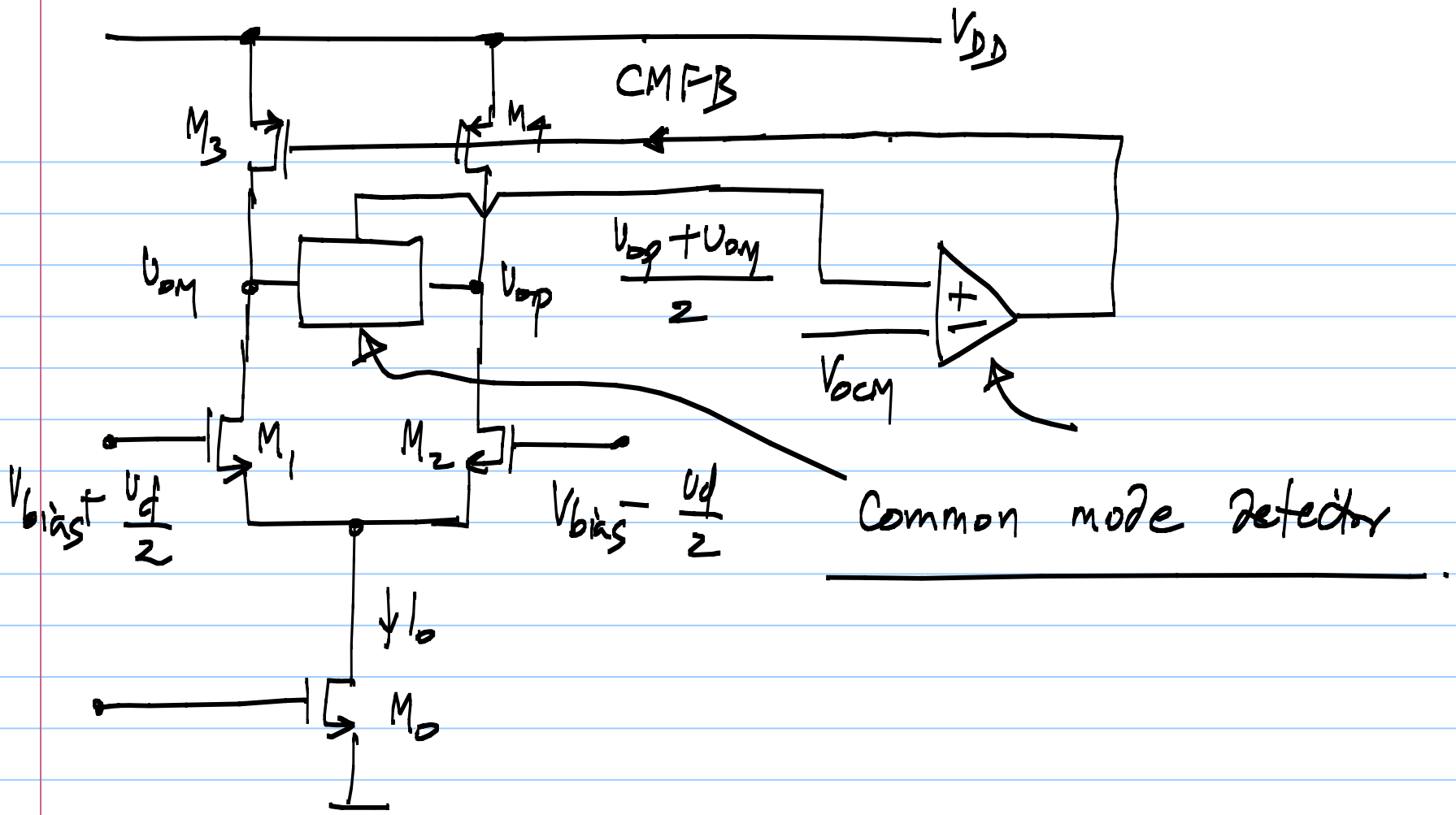



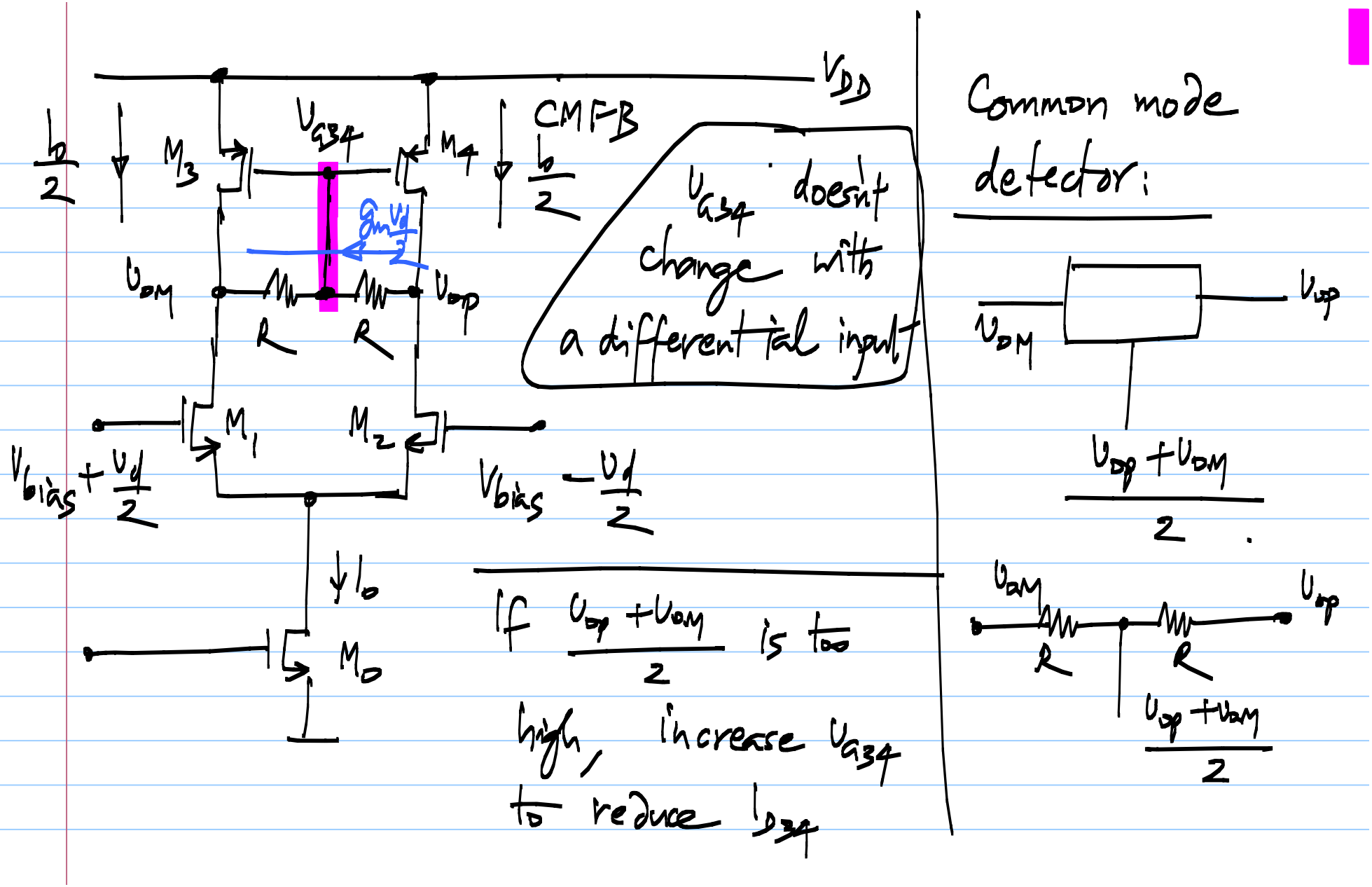

$$\omega_u = \frac{G_m}{C}$$

- Fully differential $G_m$
- Two capacitors C


M3
M4
M3'
Io/2 + gmVd/2
Io/2 - gmVd/2
Io/2
M1
M2
Vbias + Vd/2
Vbias - Vd/2
Io
M0

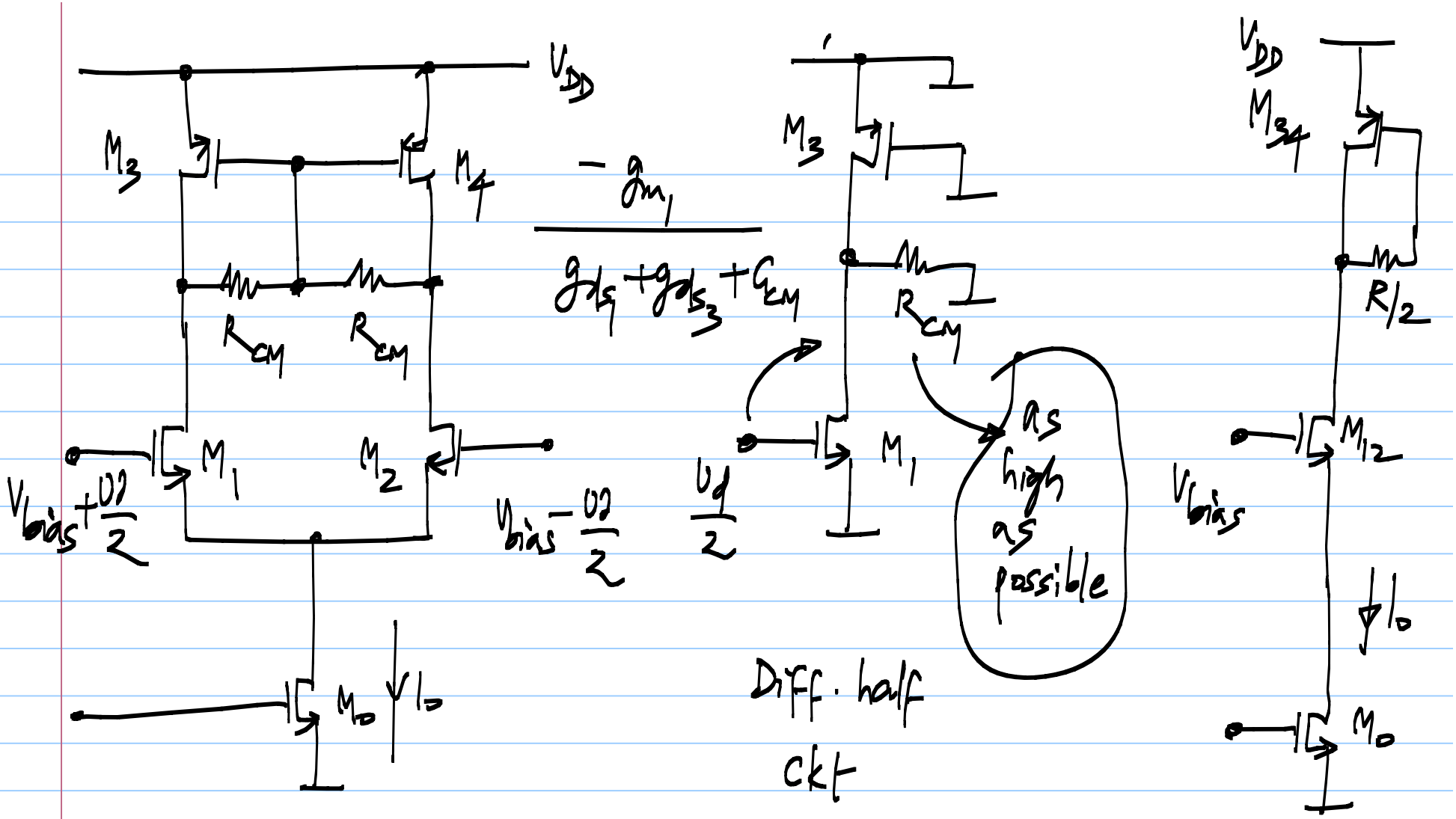

I34
M34
M3'
Io/2
M12
Vbias
I34
Io
M0
Io

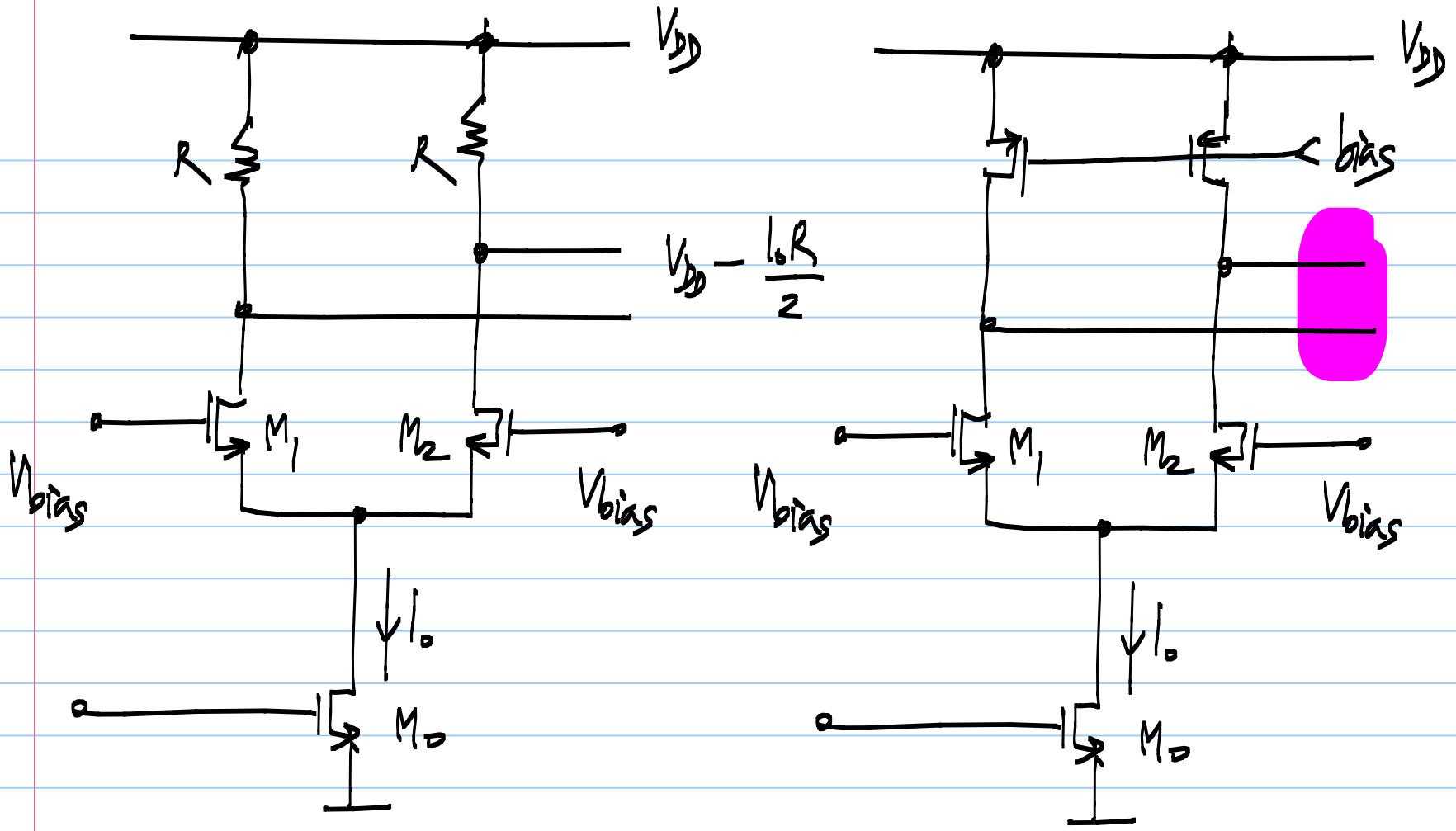

$V_{DD}$
CMFB
$M_3$
$M_4$
$V_{op} + V_{om}$
2
$V_{om}$
$V_{op}$
$V_{ocm}$
$M_1$
$M_2$
$V_{bias} + \frac{V_d}{2}$
$V_{bias} - \frac{V_d}{2}$
Common mode detector
$I_0$
$M_0$


$V_{DD}$
$\frac{I_b}{2}$
$M_3$
$V_{GS4}$
$M_4$
CMFB
$\frac{I_b}{2}$
$g_m \frac{V_d}{2}$
$V_{OM}$
$V_{op}$
R
R
$M_1$
$M_2$
$V_{bias} + \frac{V_d}{2}$
$V_{bias} - \frac{V_d}{2}$
$I_b$
$M_0$
$V_{GS4}$ doesn't change with a differential input
If $\frac{V_{op} + V_{OM}}{2}$ is too high, increase $V_{GS4}$ to reduce $I_{D4}$
Common mode detector:
$V_{OM}$
$V_{op}$
$\frac{V_{op} + V_{OM}}{2}$
$V_{OM}$
$V_{op}$
R
R
$\frac{V_{op} + V_{OM}}{2}$

Output CM voltage $= V_{DD} - V_{SG3}\Big|_{I_D/2} = V_{OCM}$

$$V_{DD} - V_{Tp} - \sqrt{\frac{2 \cdot I_D/2}{\mu_p C_{ox} W_3/L_3}}$$


$V_{DD}$
$M_3$
$M_4$
$R_{CM}$
$R_{CM}$
$M_1$
$M_2$
$V_{bias} + \frac{V_d}{2}$
$V_{bias} - \frac{V_d}{2}$
$M_0$
$I_0$
$-g_{m_1}$
$g_{ds_4} + g_{ds_3} + G_{CM}$
$\frac{V_d}{2}$
as high as possible
Diff. half ckt
$R/2$


$V_{DD}$
R
R
$V_{DD} - \frac{I_0 R}{2}$
$M_1$
$M_2$
$V_{bias}$
$V_{bias}$
$I_0$
$M_0$
$V_{DD}$
bias
$M_1$
$M_2$
$V_{bias}$
$V_{bias}$
$I_0$
$M_0$