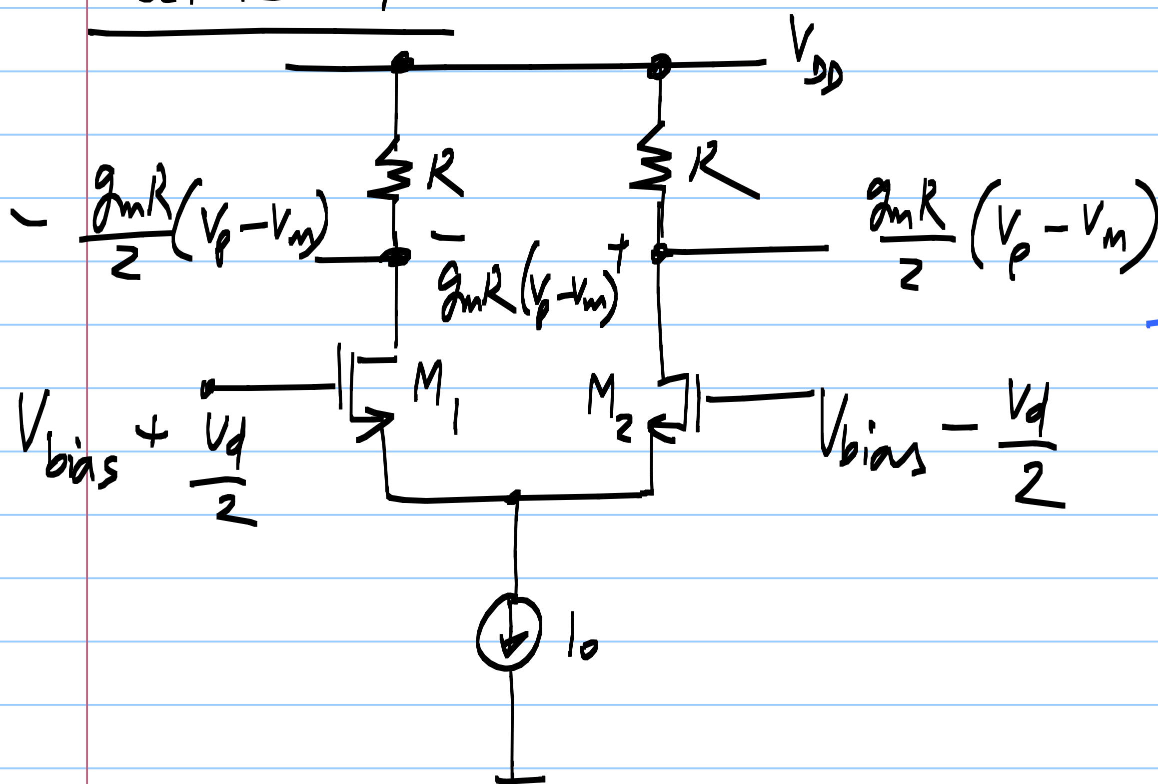
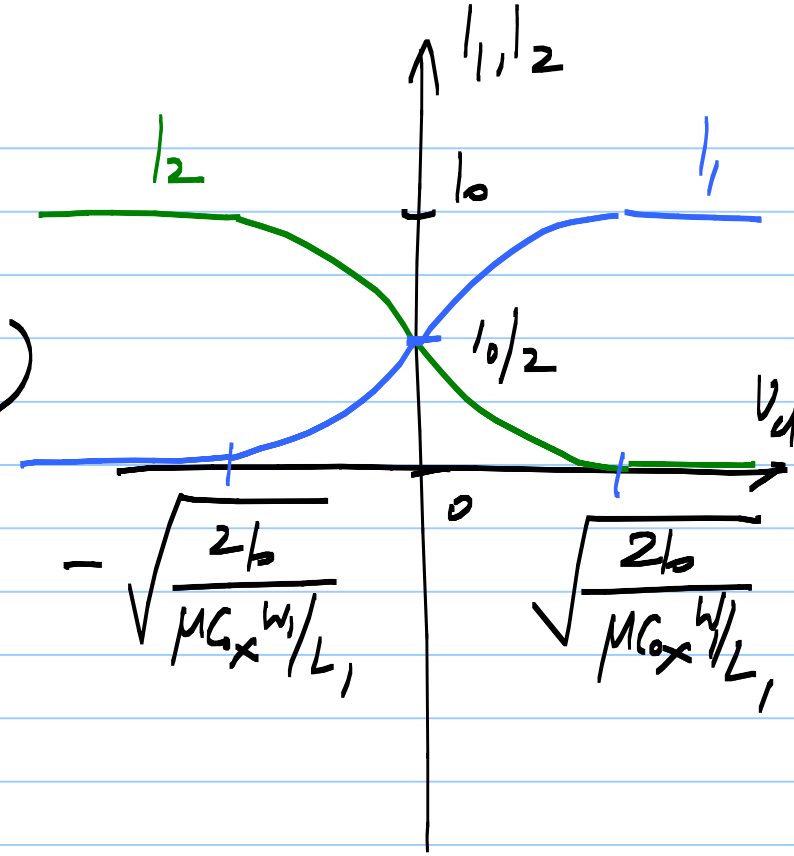
Lecture 29

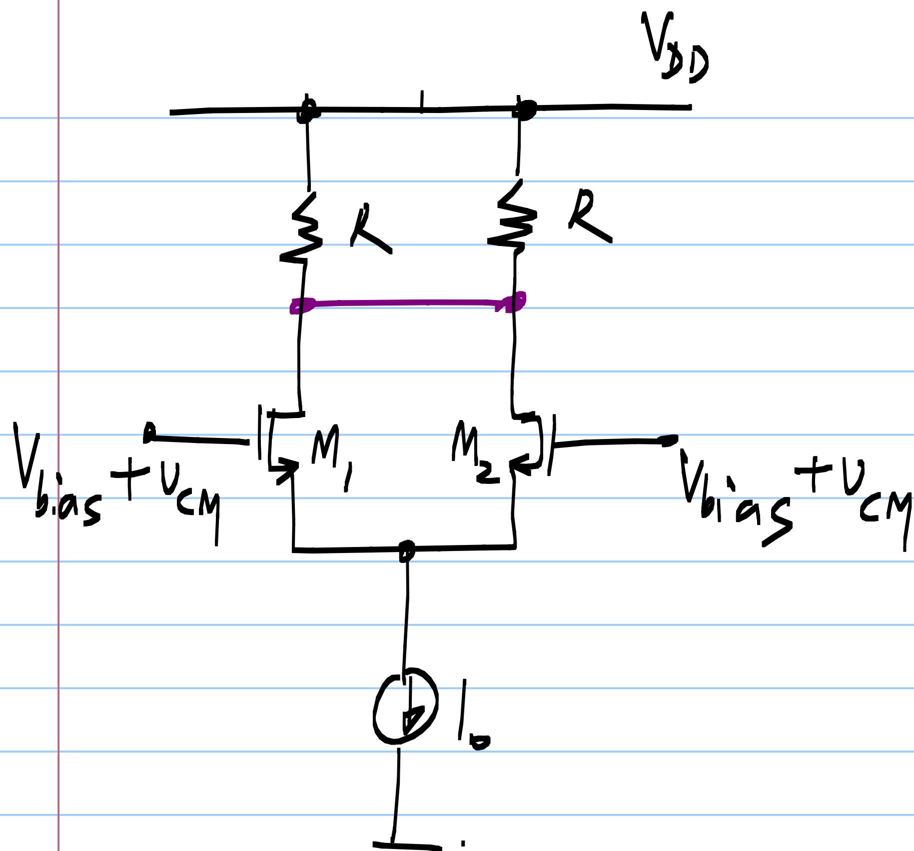


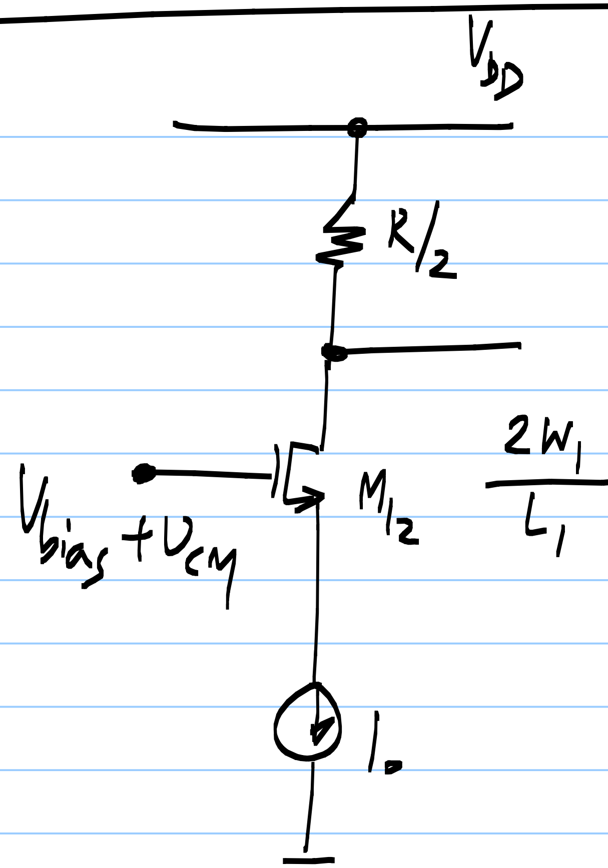
V_{DD}
R
R
$-\frac{g_mR}{2}(V_p - V_m)$
$\frac{g_mR}{2}(V_p - V_m)$
$-$
$+$
$g_mR(V_p - V_m)$
M_1
M_2
$V_{bias} + \frac{V_d}{2}$
$V_{bias} - \frac{V_d}{2}$
I_0



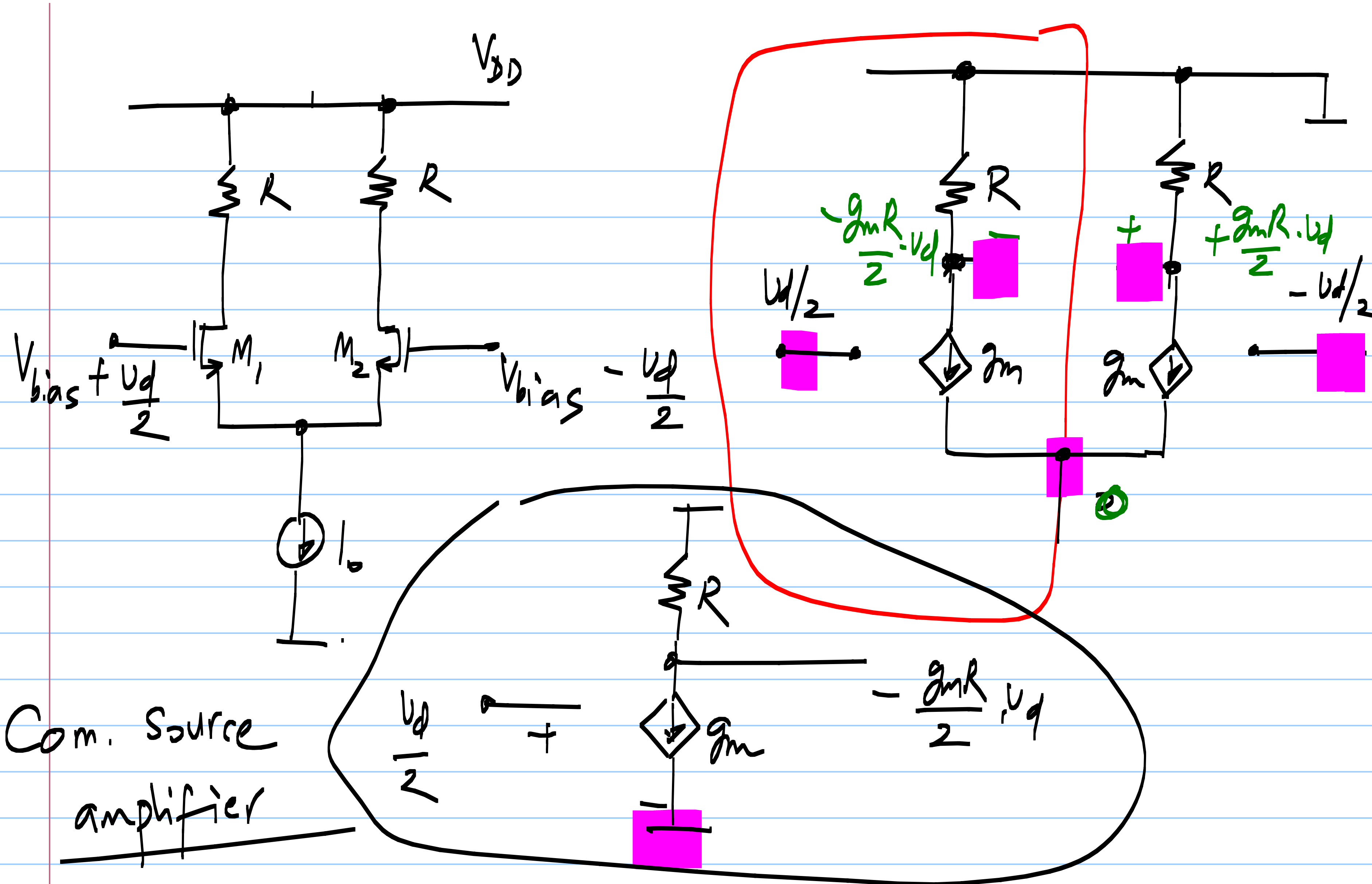
I_1, I_2
I_2
I_1
I_0
$I_0/2$
V_d
0
$-\sqrt{\frac{2I_0}{\mu C_{ox} W_1/L_1}}$
$\sqrt{\frac{2I_0}{\mu C_{ox} W_1/L_1}}$

COMMON MODE EQ. CIRCUIT

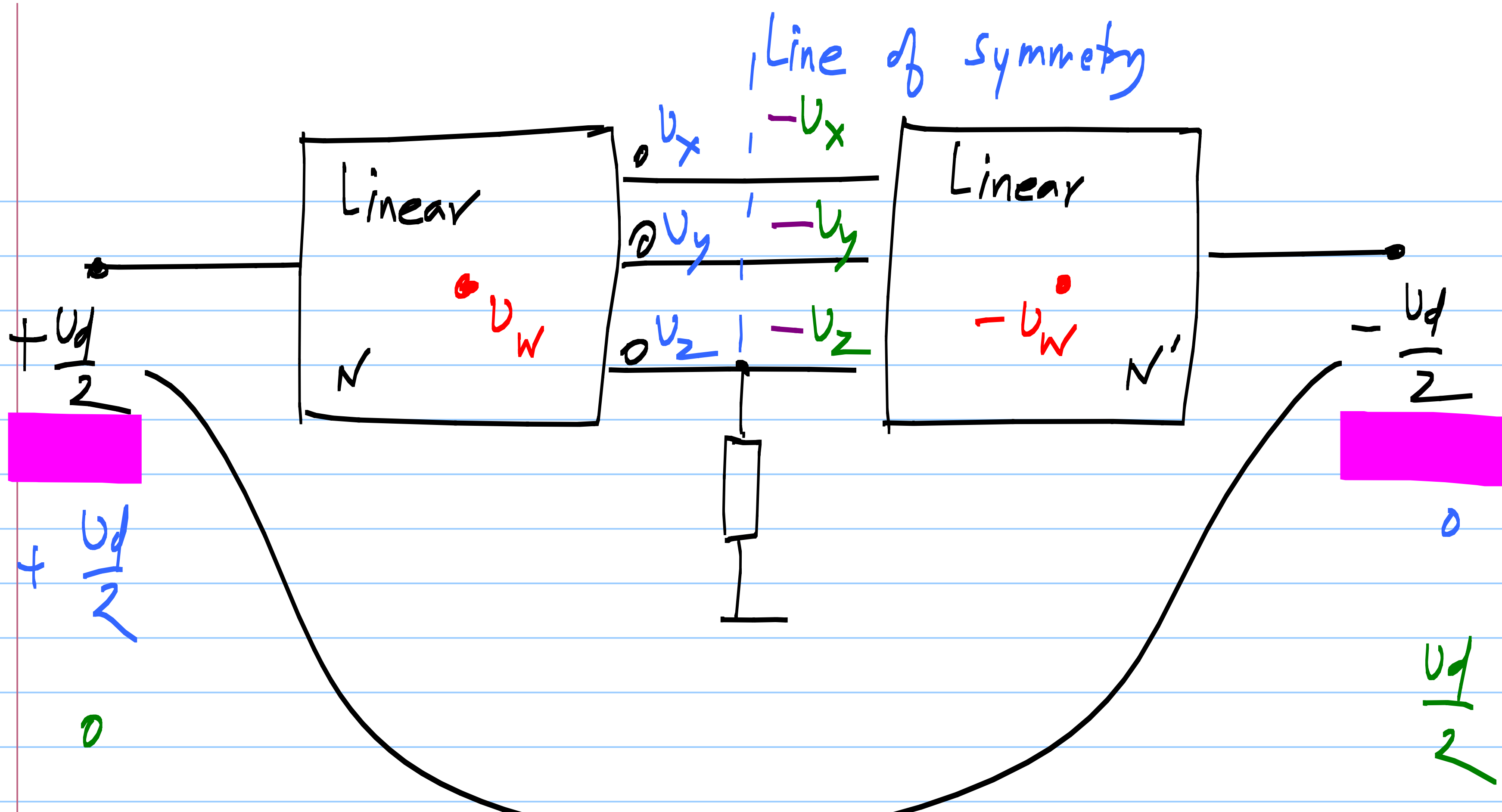




$M_1 = M_2 \quad \frac{W_1}{L_1}$

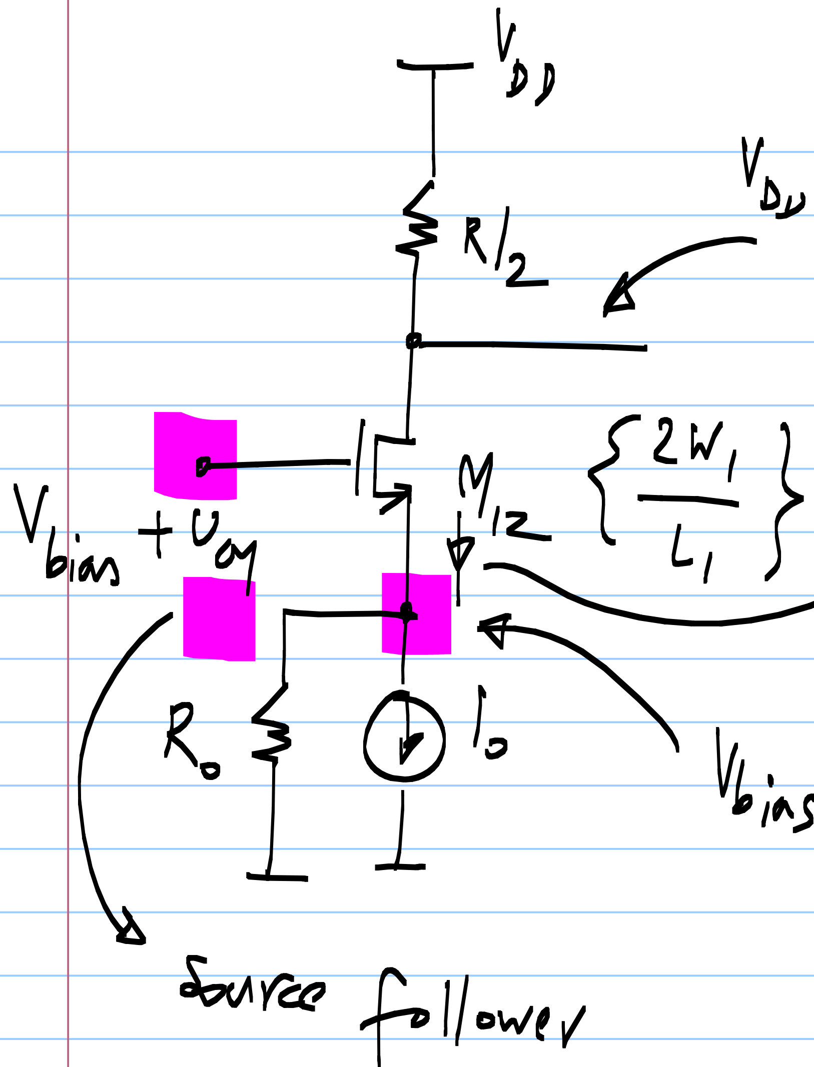


Com. Source amplifier



Voltages along the line of symmetry = 0

* The circuit does not respond to common mode inputs



$V_{DD} - \frac{I_o R}{2} + \frac{v_{CM}}{R_o} \cdot \frac{R}{2}$

$I_o + \frac{v_{CM}}{R_o}$

$V_{bias} - V_T - \sqrt{\frac{2 \cdot I_o/2}{\mu C_{ox} \cdot W_1/L_1}} + v_{CM}$

CM output

$= v_{CM} \cdot \frac{R}{2R_o}$

CM gain:

$= \frac{R}{2R_o}$

Differential pair:

* Differential gain: $\frac{V_{op} - V_{oM}}{V_p - V_M} = g_m R = A_d$
(differential input)

* CM gain $= \frac{(V_{op} + V_{oM})/2}{(V_p + V_M)/2} = \frac{R}{2R_o} = A_{cm}$
(CM input)

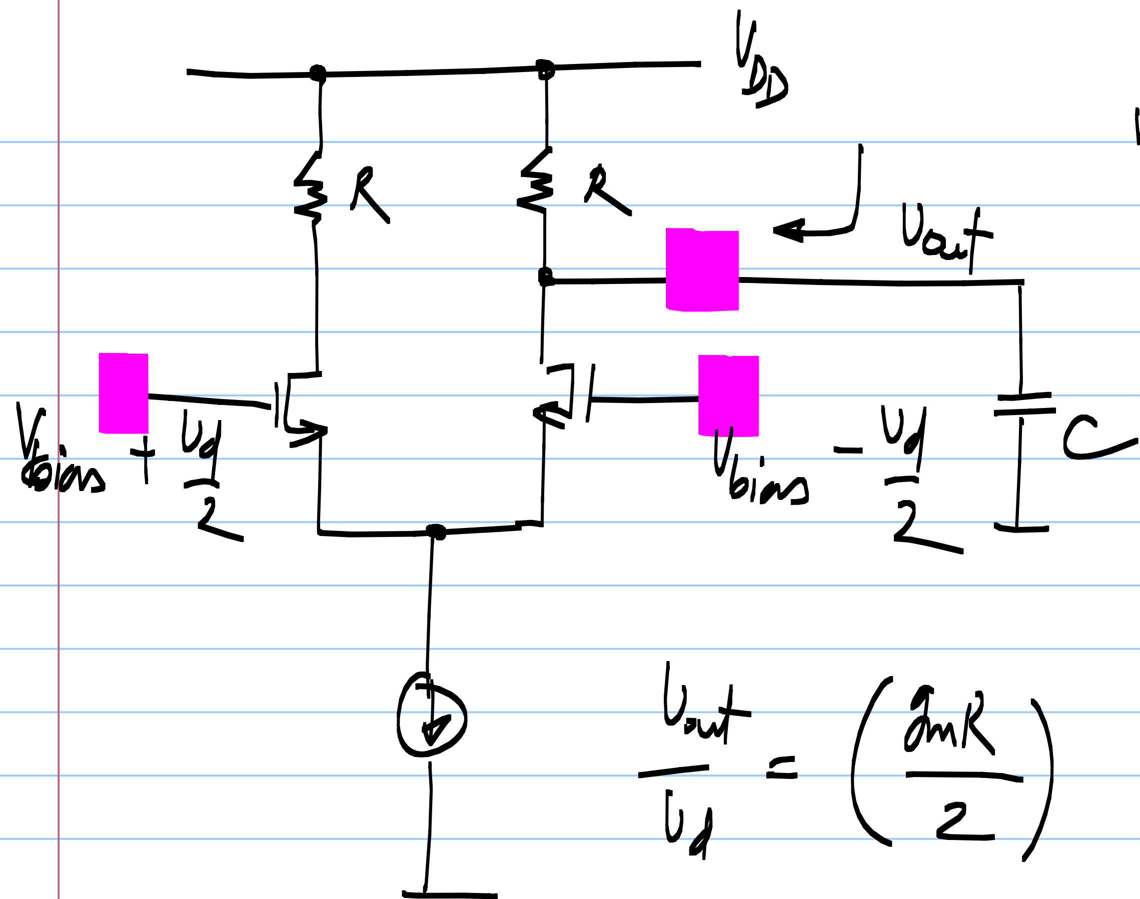
* CMRR $= \frac{A_d}{A_{cm}} = \frac{g_m R}{R/2R_o} = 2 \cdot g_m \cdot R_o$

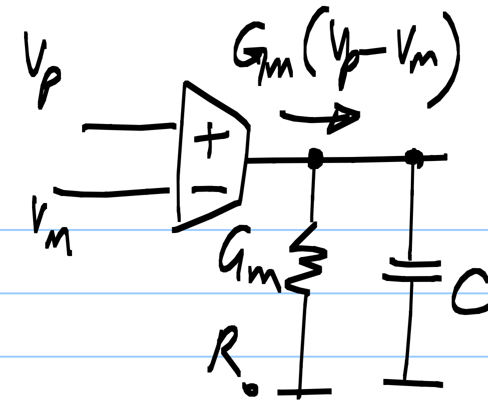
$$v_p = \frac{v_p + v_m}{2} + \frac{v_p - v_m}{2}$$

$$v_m = \frac{v_p + v_m}{2} - \frac{v_p - v_m}{2}$$

$$\frac{v_p + v_m}{2} = v_{cm}$$

$$v_p - v_m = v_d$$

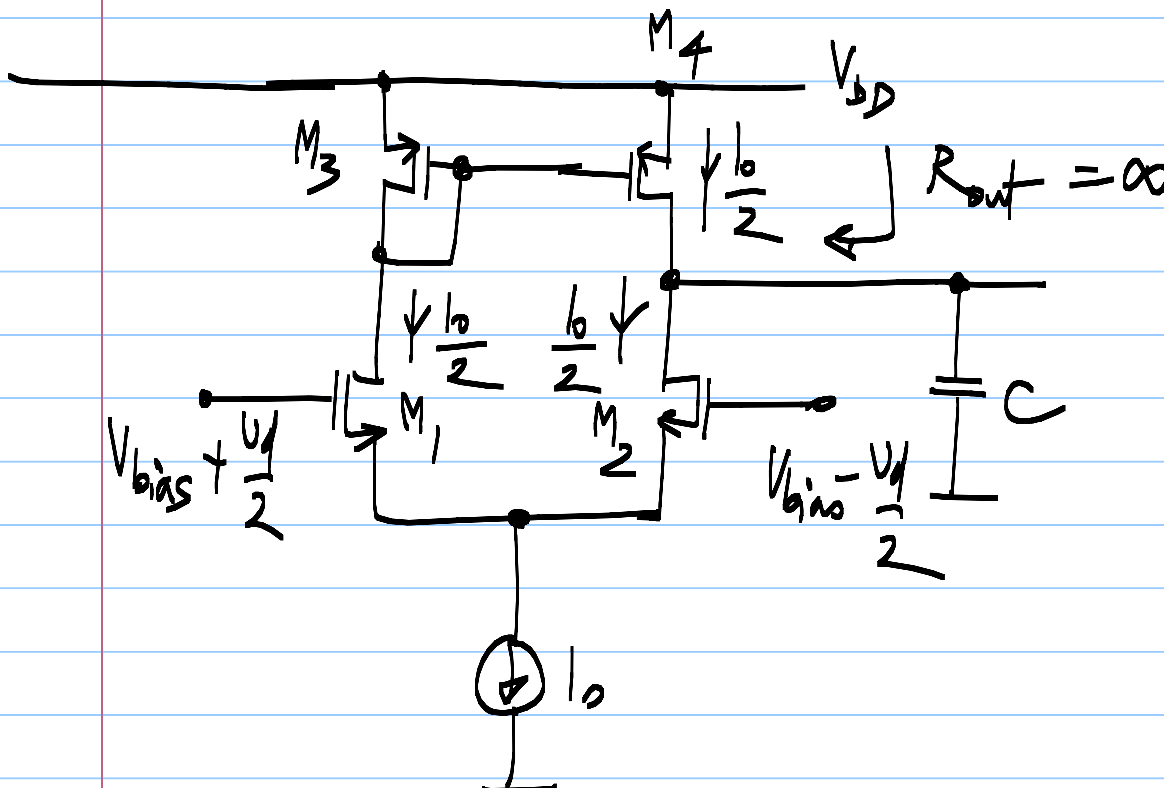




$$\frac{V_{out}}{v_d} = \left(\frac{g_m R}{2}\right)$$

$G_m R_o$

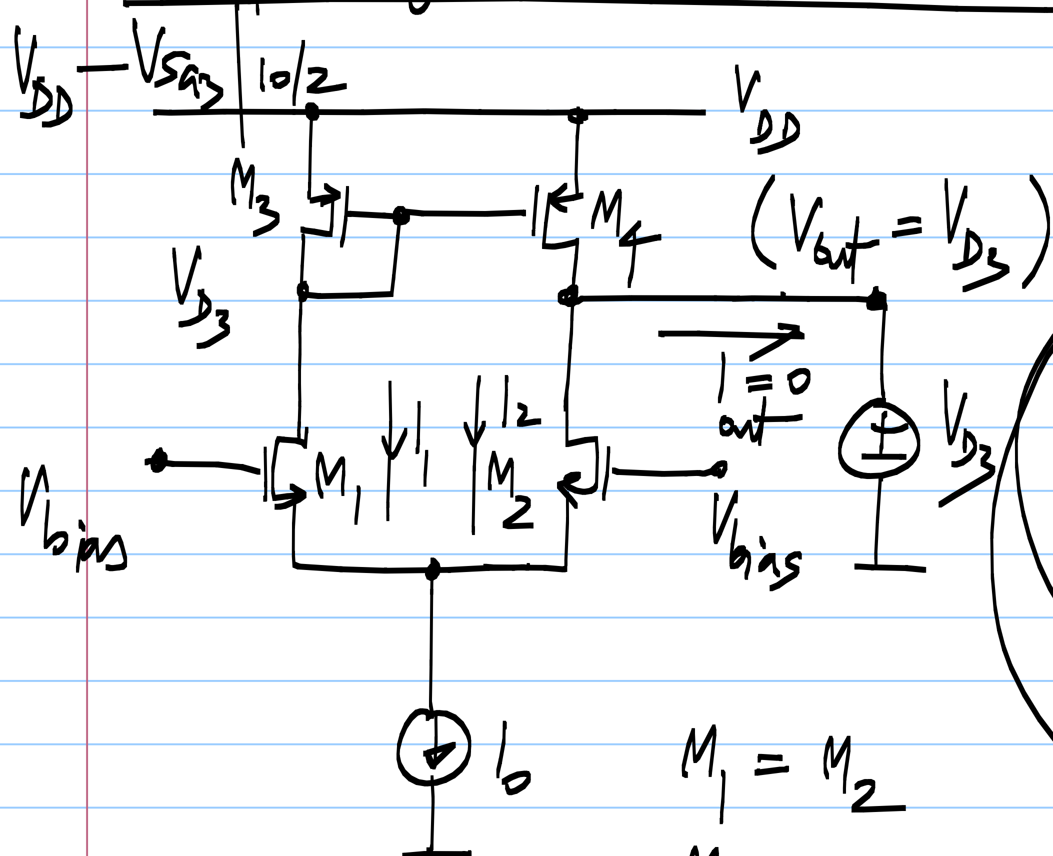
Differential pair with an active load



$R_{out} = \infty$ when

$r_{ds1,2,3,4} = \infty$

Analysis of the differential pair with active load:



$M_1 = M_2$

$M_3 = M_4$

$V_{out} = V_{D3}$ $\qquad V_{SG3}|_{I_0/2}$

$V_{out} > V_{D3}$

$V_{GS1} = V_{GS2}$; $V_{GS3} = V_{GS4}$

$\Rightarrow V_{DS2} > V_{DS1} \Rightarrow I_2 > I_1$

$\Rightarrow V_{SD3} > V_{SD4} \Rightarrow I_1 > I_2$

CM half circuit

Symmetric circuit w/ symmetric excitation:

* Identical voltages in the two halves of the circuit
* The two halves can be folded on top of each other
* $G \rightarrow 2G$; $W \rightarrow 2W$; $C \rightarrow 2C$
  $L \rightarrow L/2$; $R \rightarrow R/2$ [two halves]
* Components along the line of symmetry — not changed

Symmetric circuit w/ anti-symmetric excitation

* (Linear circuit) Voltages along the line of symmetry = 0
* Voltages in each half are antisymmetric

Differential half ckt