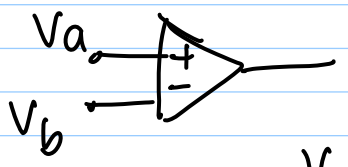
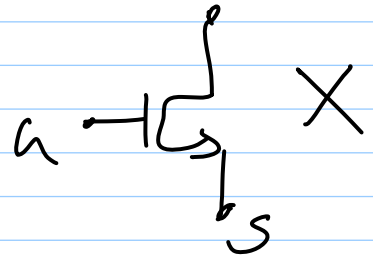
17-10-12

Lec 33



$V_o = A(V_a - V_b)$

$V_a \approx V_b \Rightarrow (V_a - V_b)$ small

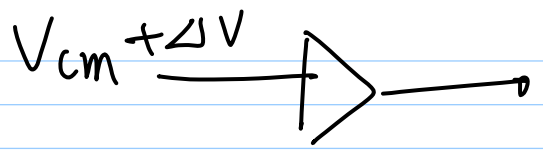


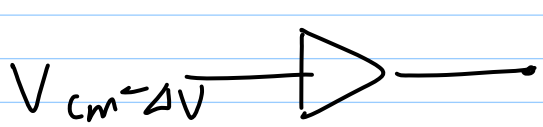
avg. (CM voltage)

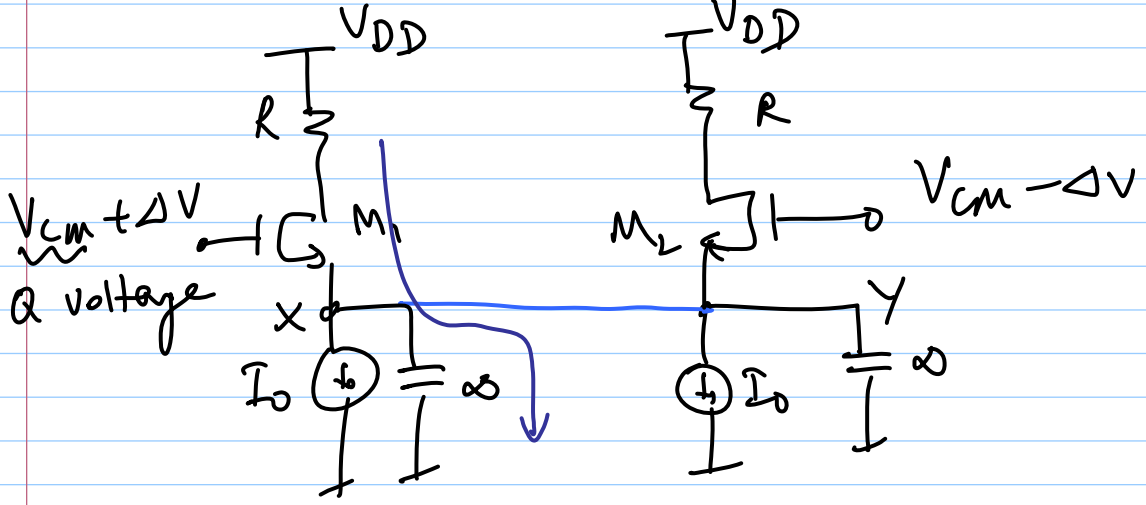
diff. (DM voltage)

$$V_a = \frac{V_a + V_b}{2} + \frac{V_a - V_b}{2}$$

$$V_b = \frac{V_a + V_b}{2} - \frac{V_a - V_b}{2}$$

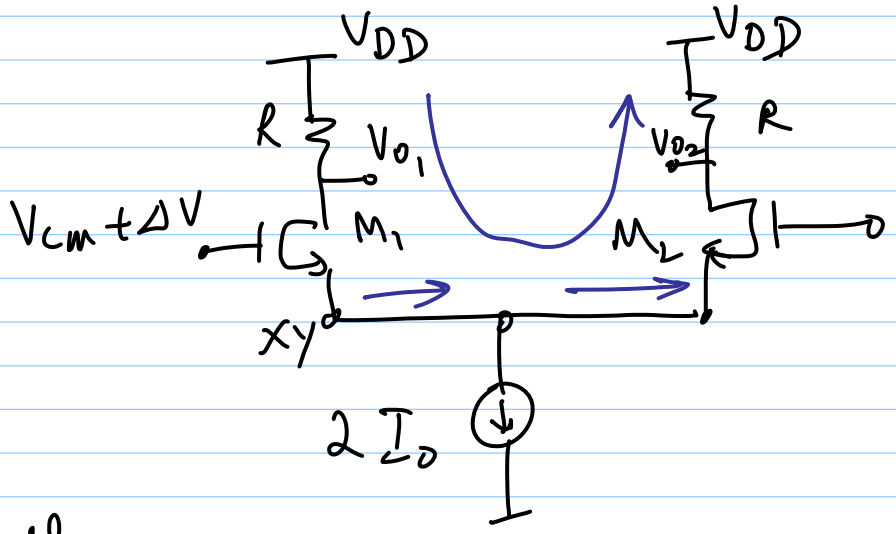






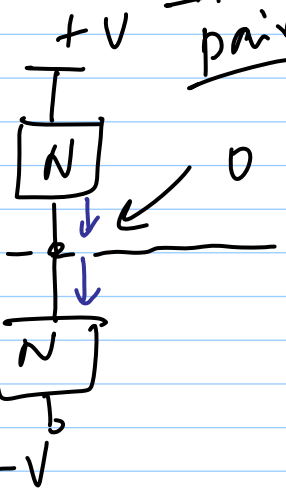
$V_x = V_{cm} - V_{GS_1}$; $V_y = V_{cm} - V_{GS_2} = V_x$

Differential Amplifier



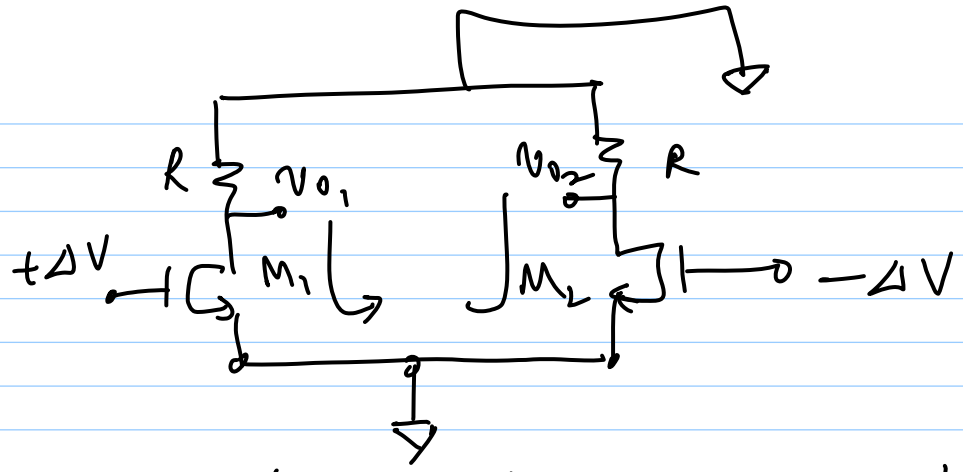
or

Diff. pair



Small signal $v_{xy} = 0$ (symmetry)

$V_{xy} = V_{cm} - V_{as_1}$ (total voltage)

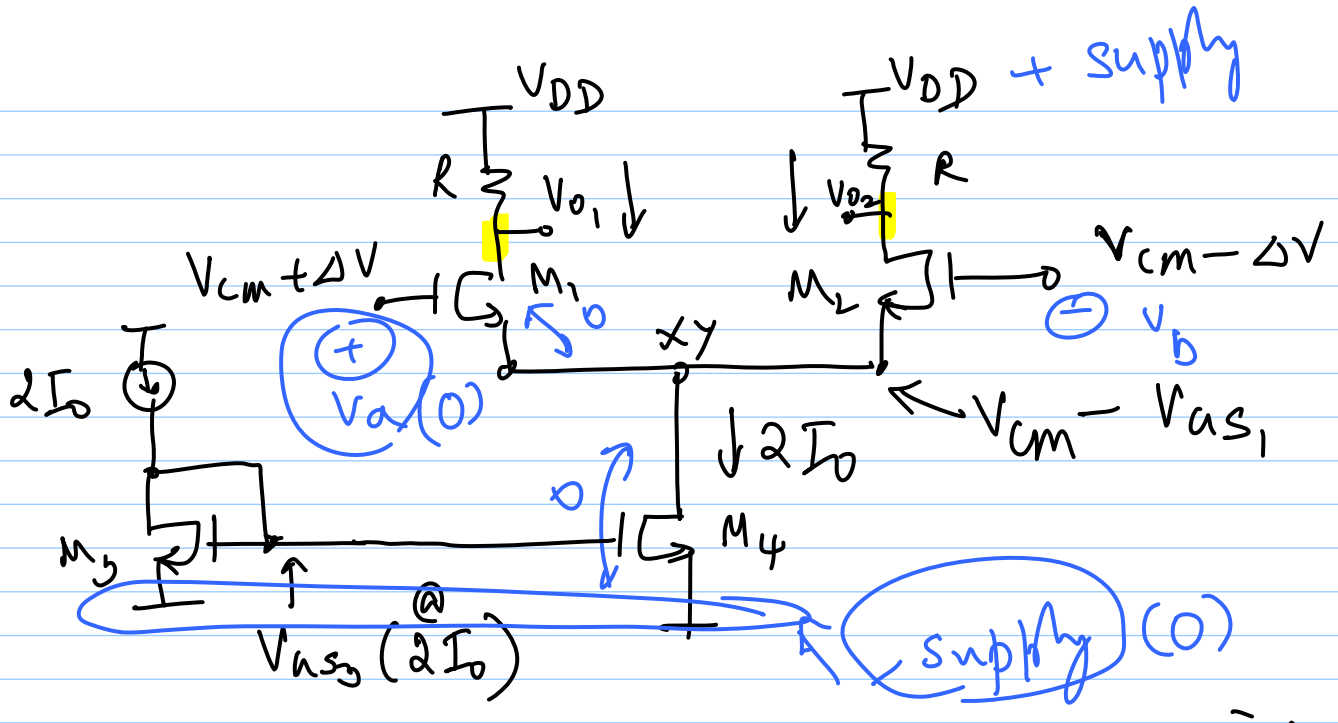


$i_{d_1} = g_m \Delta V$; $i_{d_2} = -g_m \Delta V$

$v_{o_1} = -g_m R \Delta V$; $v_{o_2} = g_m R \Delta V$

$V_{o_1} = V_{DD} - I_o R - g_m R \Delta V$

$V_{o_2} = V_{DD} - I_o R + g_m R \Delta V$



* $V_{cm} \downarrow \Rightarrow V_{xy} \downarrow \Rightarrow$ M_4 goes into triode

$\Rightarrow V_{cm} - V_{as1} \geq V_{D,sat4}$

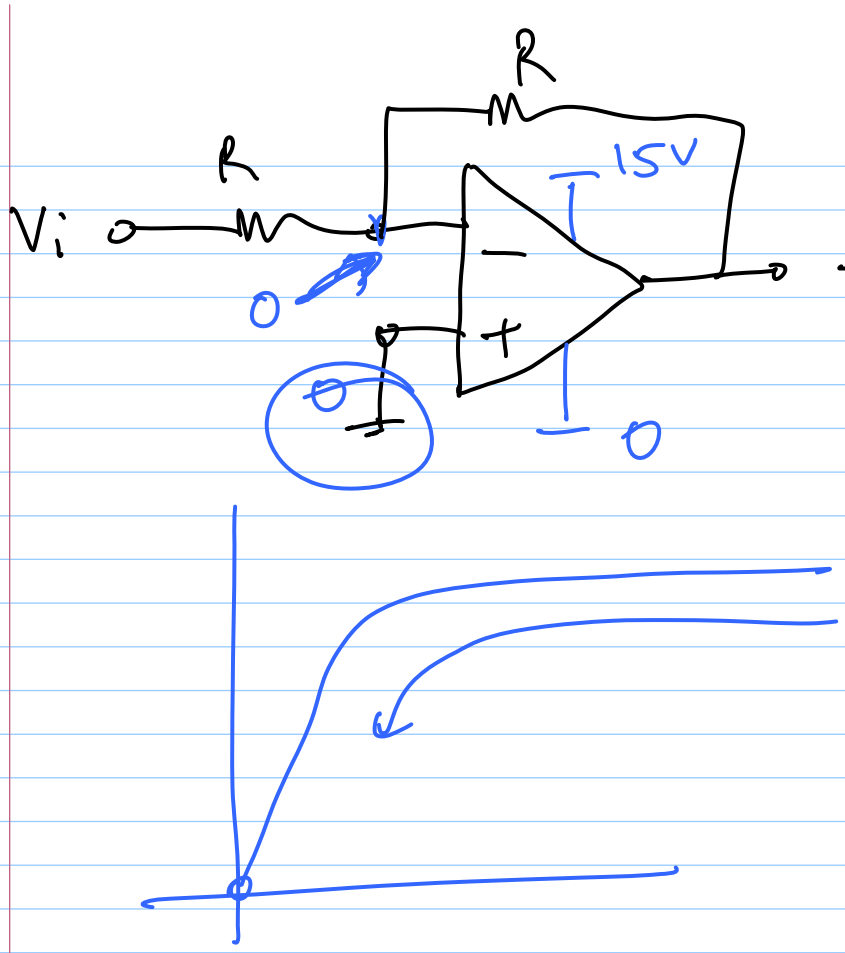
$\Rightarrow V_{cm,min} = V_{as1} + V_{D\,sat4}$

* $V_{cm} \uparrow \Rightarrow M_{1,2}$ approach triode

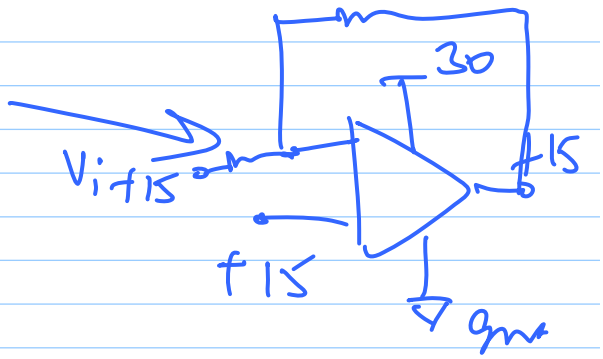
$V_{cm} - V_T \leq V_{DD} - I_0 R$

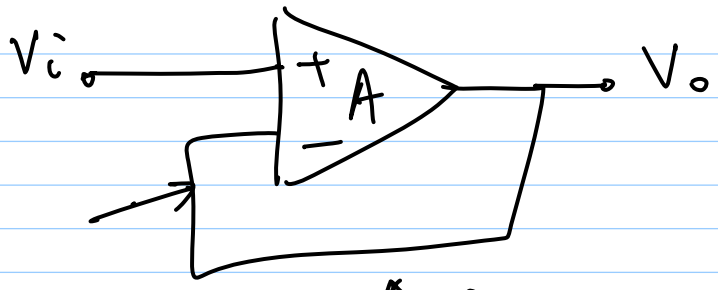
$\Rightarrow V_{cm,max.} = V_{DD} - I_0 R + V_T$

$\{ V_{cm,min}, V_{cm,max} \}$ Input common-mode range



✗ not possible





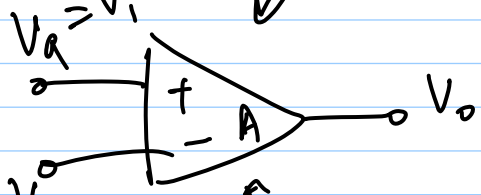
$\frac{V_o}{V_i} = ?$

$(V_i - V_o) A = V_o$

$V_o = \frac{A}{A+1} V_i$

$V_a = V_i$

$V_b = \frac{A}{A+1} V_i$



$= \frac{A}{A+1} \cdot V_i$ (diff amp @ input)

$$V_{cm} = \frac{V_i + \frac{A}{A+1} V_i}{2}$$

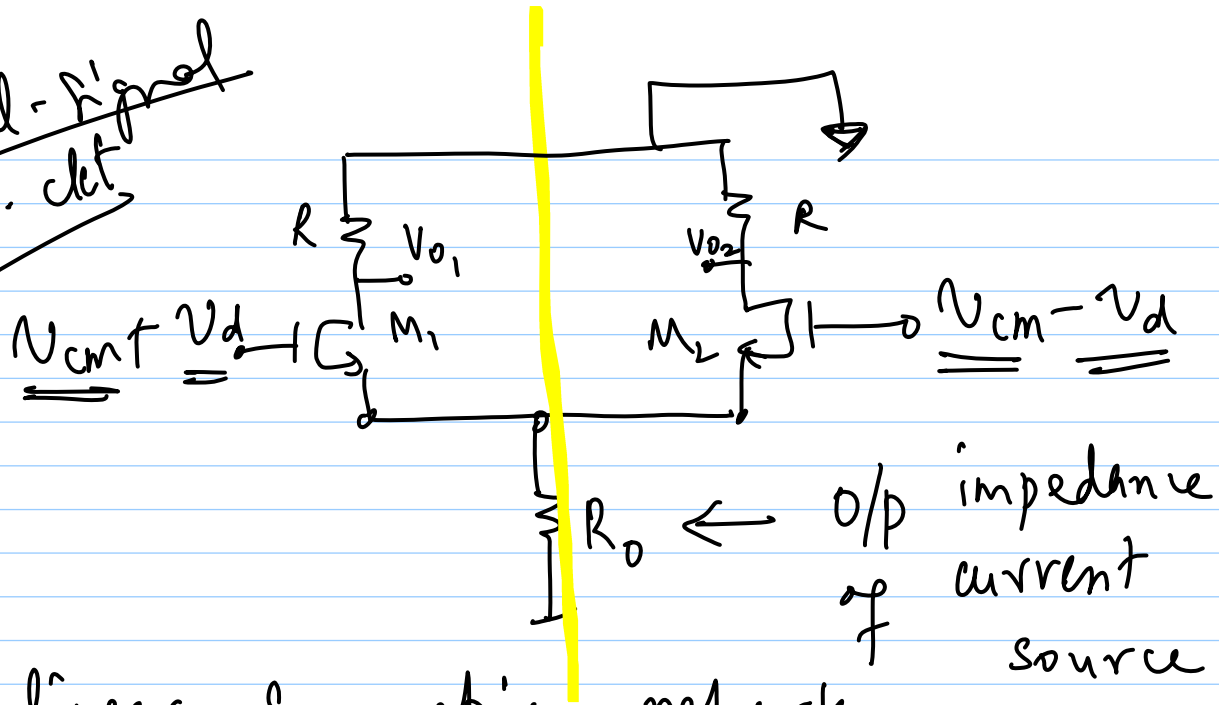
$$= \frac{2A+1}{2(A+1)} V_i \simeq V_i$$

"CM mode" $= f(V_i)$

$$V_{dm} = \frac{V_i - \frac{A}{A+1} V_i}{2} = \frac{V_i}{2(A+1)}$$

"dm signal"

Small-signal eqv. ckt

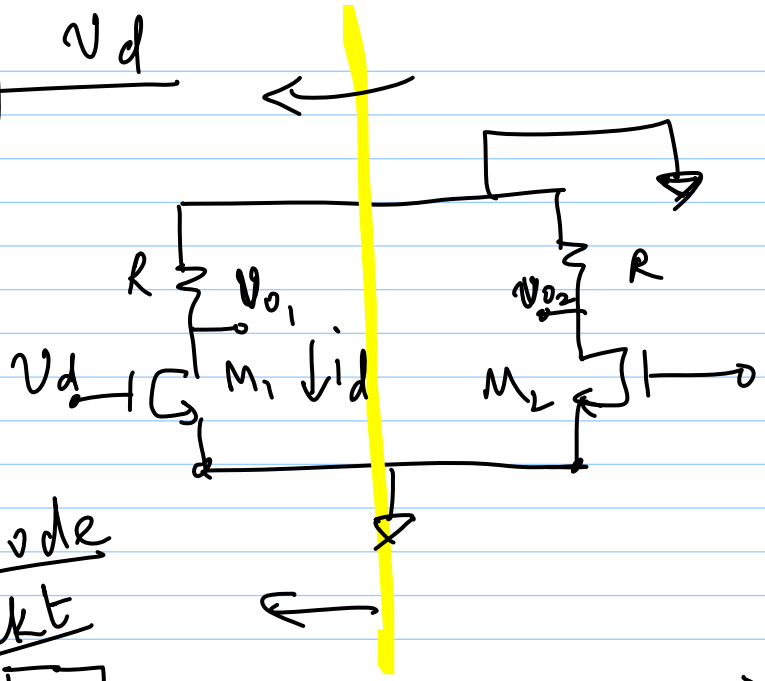


R_o ← o/p impedance of current source

* linear, symmetric network

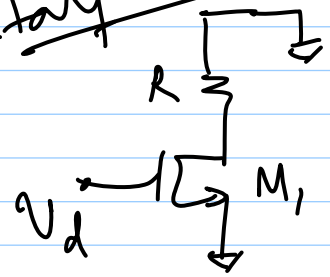
* V_{cm} = inc. CM component

Only v_d



v_d

Diff. mode Half ckt



$i_{d_1} = g_m v_d$

$v_{o_1} = -g_m R v_d$

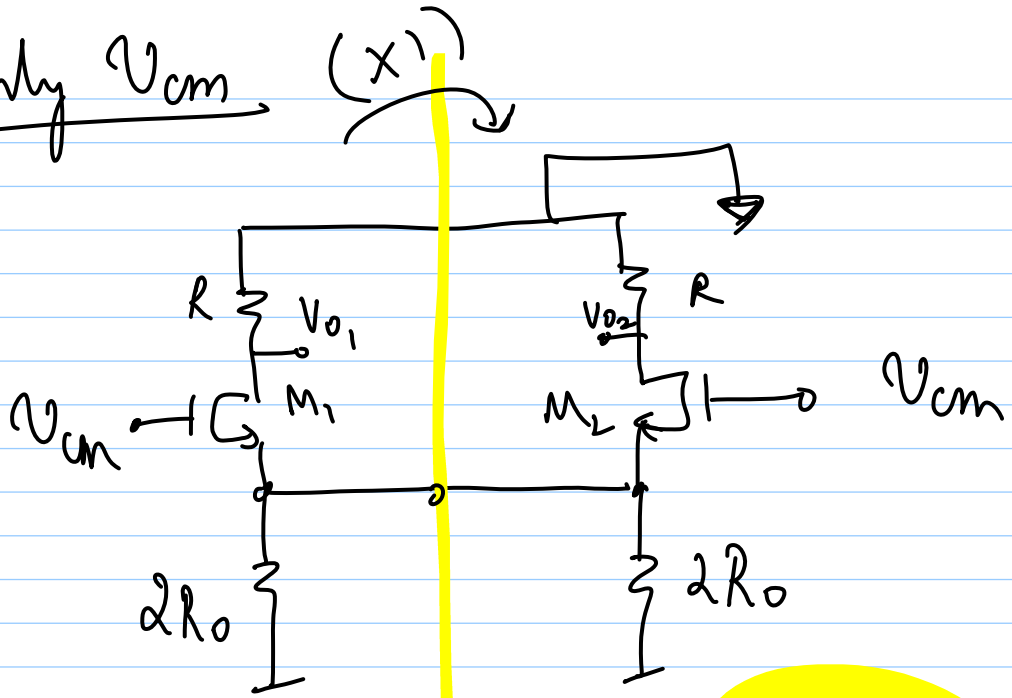
other half

$i_{d_2} = -g_m v_d$

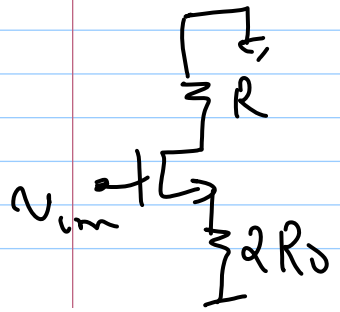
$v_{o_2} = +g_m R v_d$

$\{\times(-1)\}$

Only v_{cm} $(\times 1)$



CM Half ckt



$$i_{d_1} = \frac{g_m}{1+2g_m R_o} \cdot v_{cm}$$

$$v_{o_{cm}} = -i_{d_1} R$$