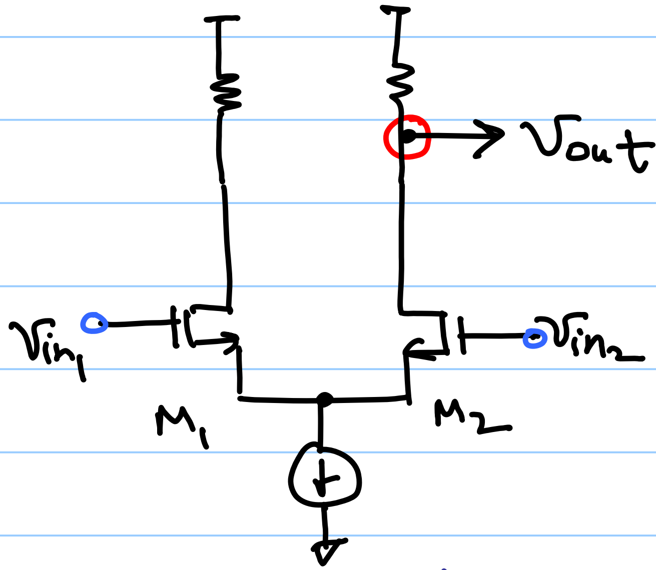
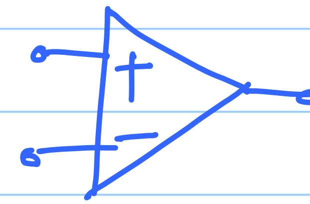
ECE 511 - Lecture 22

Note Title 4/9/2015

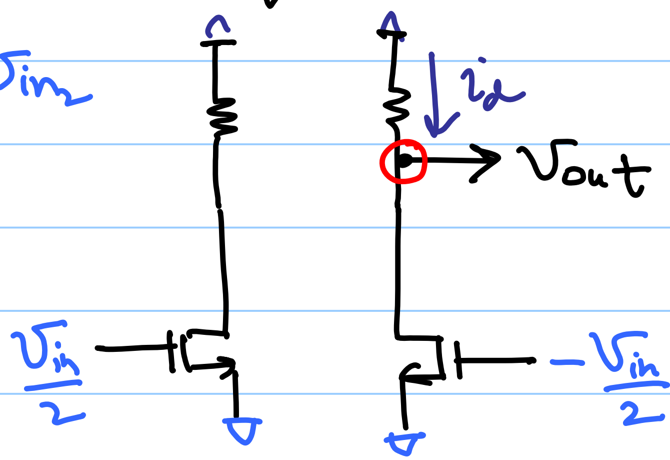
Single-ended Diffamp





$A_{v,DM} =$

$V_{in} = V_{in_1} - V_{in_2}$



Half DM circuit

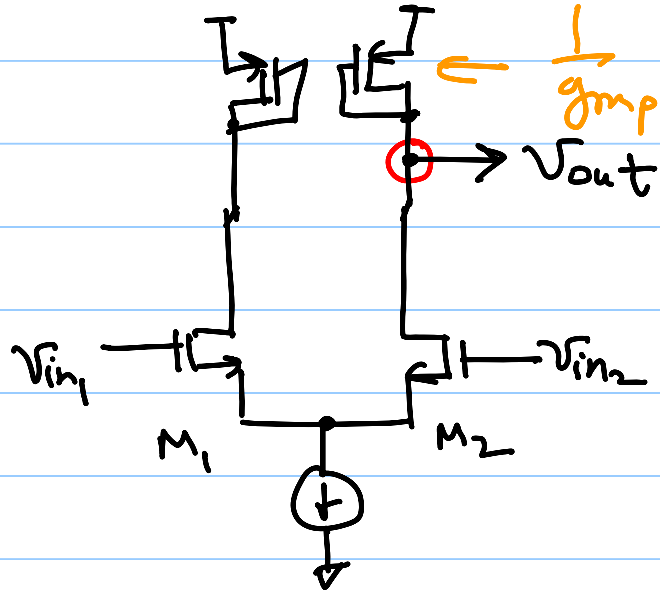
$$V_{out} = -i_d (R_D \| r_o)$$

$$= -\left(-g_m \frac{V_{in}}{2}\right) R_D \| r_o$$

$$A_{v,DM} = + \frac{g_m R_D \| r_o}{2}$$

$$\simeq \frac{1}{2} g_m R_D$$

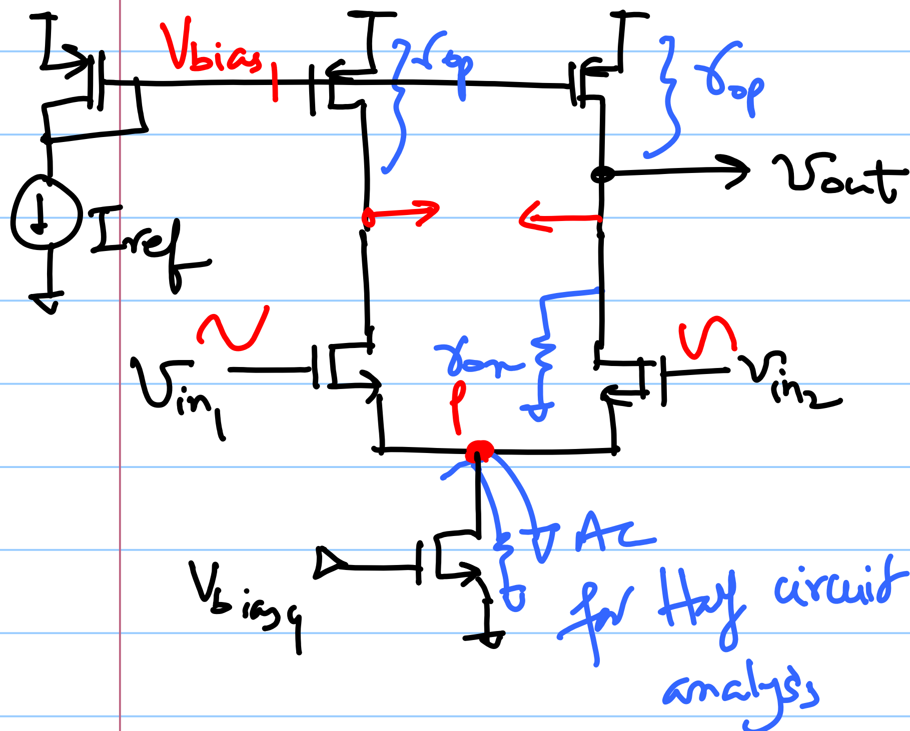
Diode-connected load → low-gain



$$A_v = + \frac{g_{mn}}{2} \cdot \frac{1}{g_{mp}}$$

↳ low-gain

③ Current Source load



Single ended output

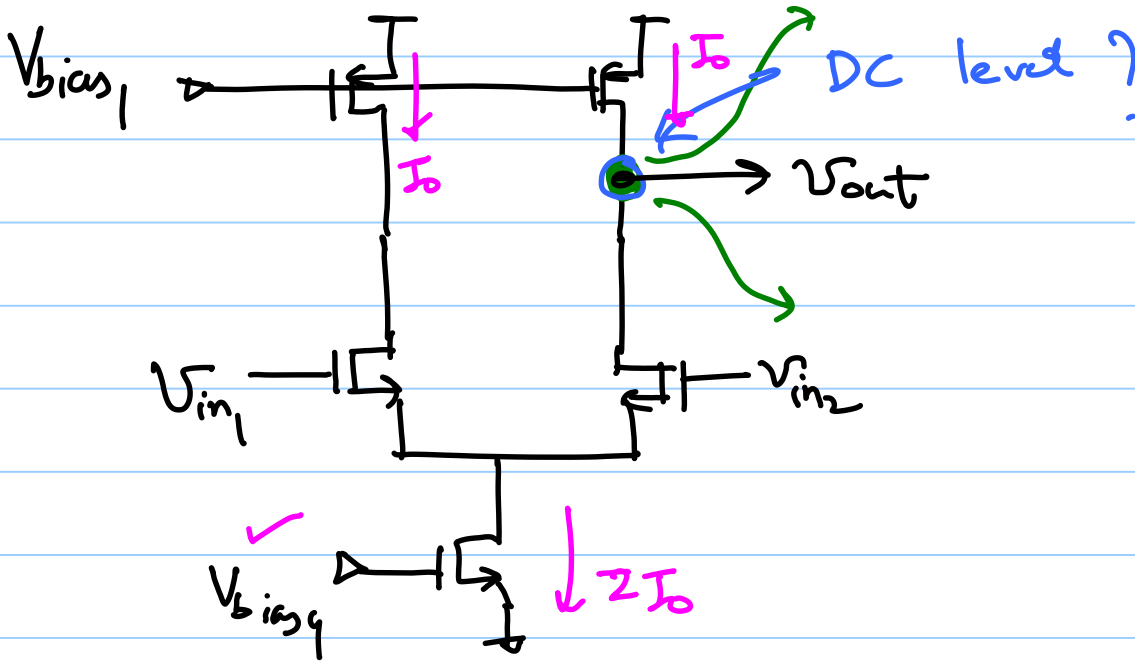
$$A_{v,DM} = \frac{1}{2} g_{m_n} (r_{on} \| r_{op})$$

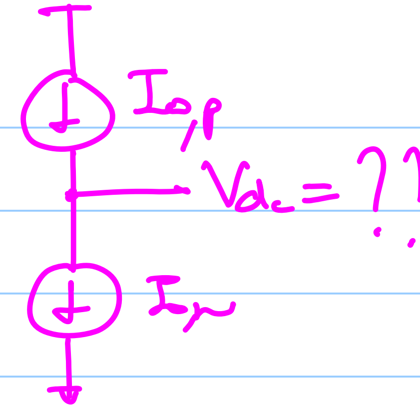
$$\simeq \frac{1}{4} g_m r_o$$

if $r_{op} = r_{on} = r_o$

differential gain $\Rightarrow g_{m_n} (r_{op} \| r_{on})$

"higher gain"

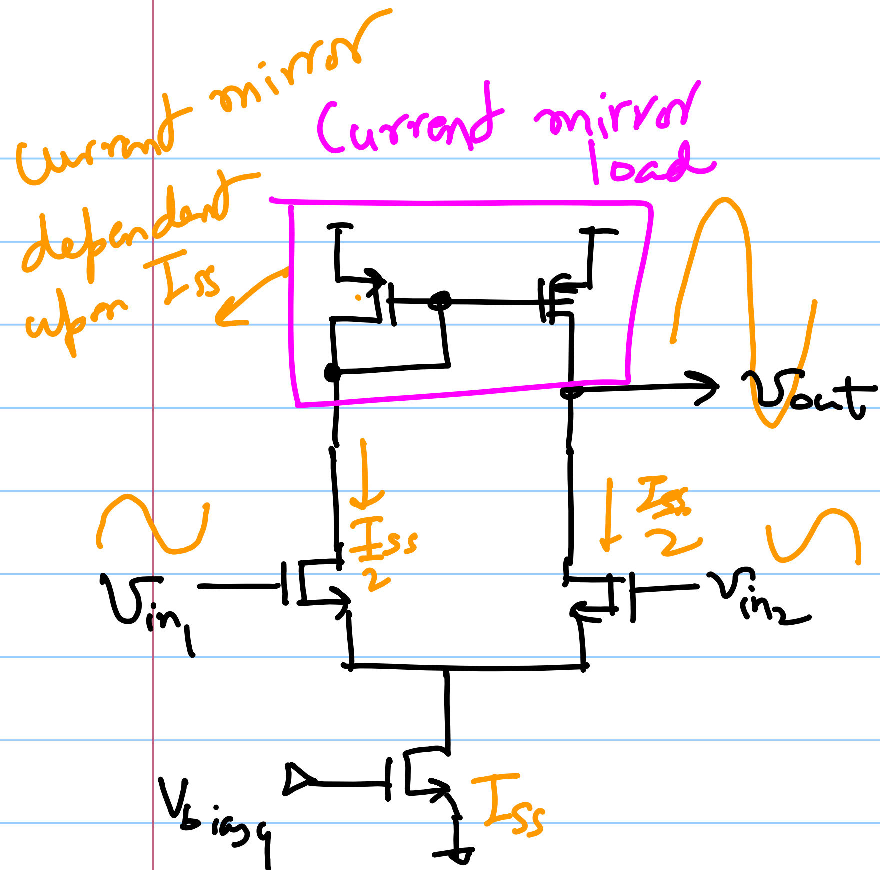




Not biased properly
↳ 2 independent current sources fighting

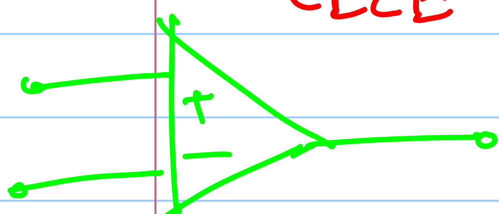
Solution: Make one of the current sources dependent on another

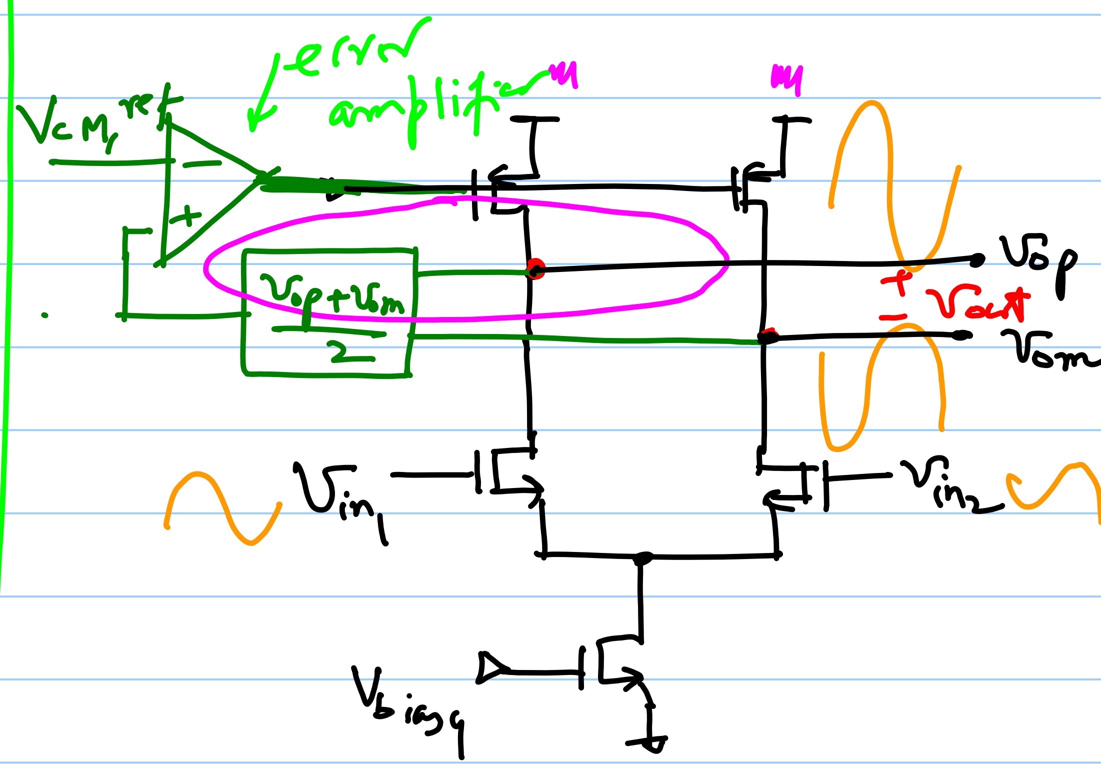
fully-different amplifier



Single-ended o/p

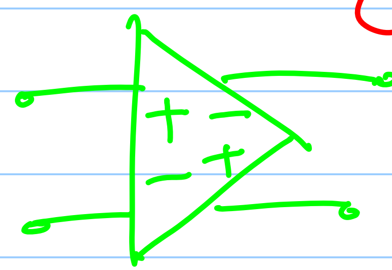
(ECE 5/411)





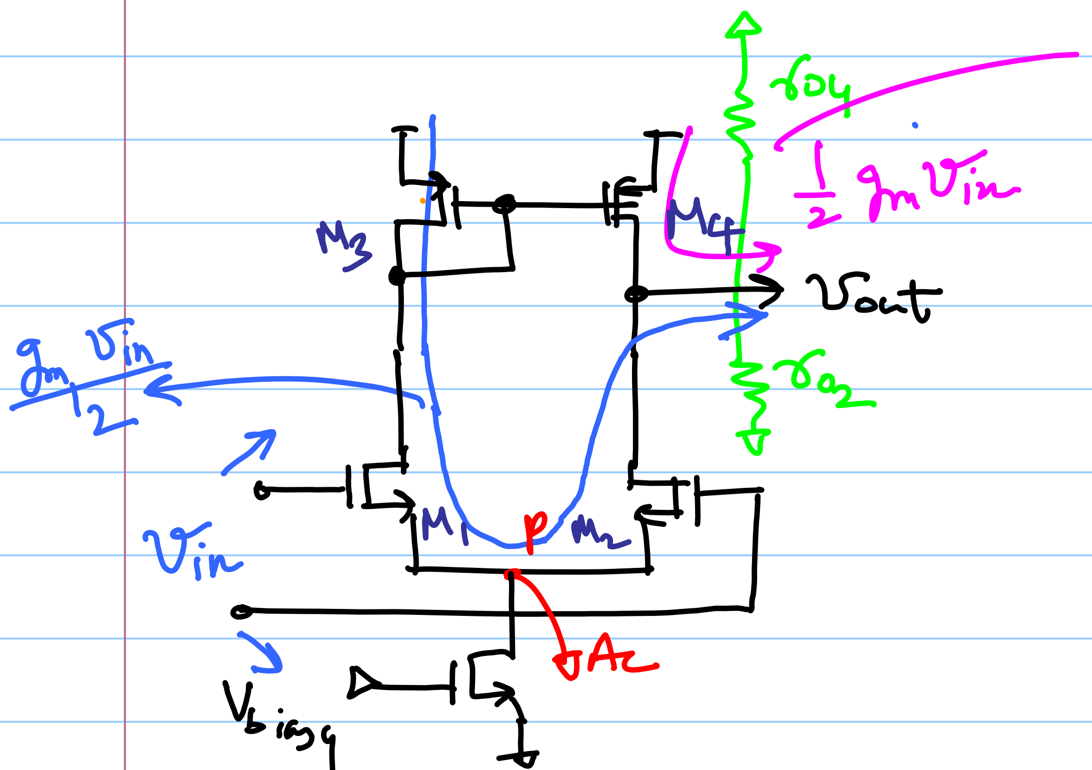
Common-mode feedback loop

(ECE 614)



Opamp

Current Mirror load

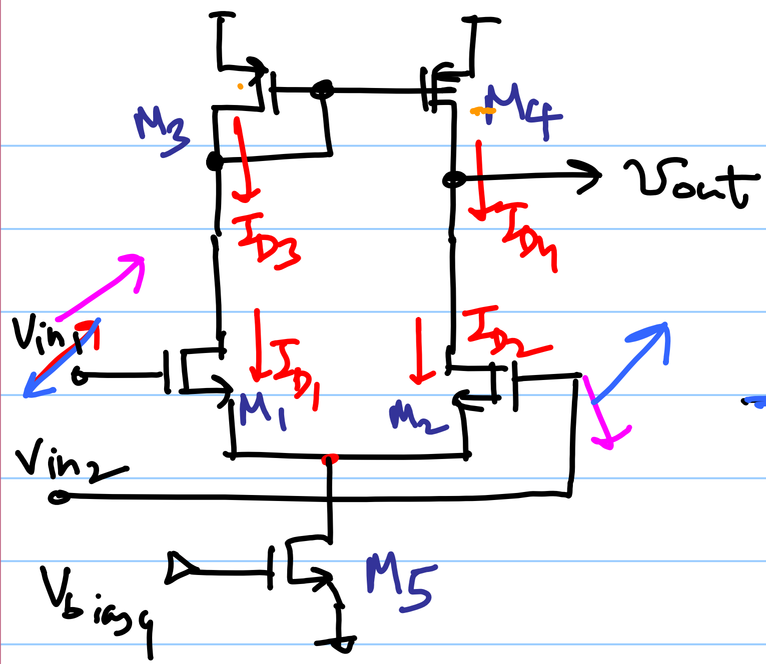


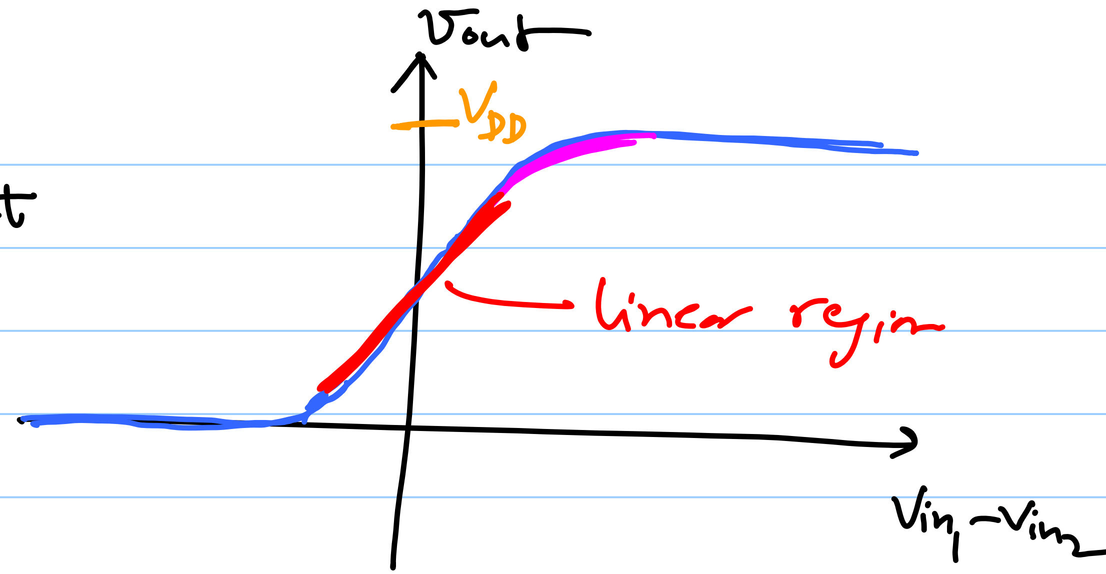
current mirror also contributes to the output.

total current flowing into v_{out} $= g_{m1} v_{in}$

$$v_{out} = g_{m1} v_{in} (r_{o2} \| r_{o4})$$

$$A_{v,DM} = + g_{m1} (r_{o2} \| r_{o4})$$





① V_{in_1} is more negative than V_{in_2}

M_1 off, M_3 & M_4 are off too

M_2 & M_5 are in deep triode ⇒ $V_{out} = 0$

② as V_{in_1} approaches V_{in_2}, M_1 turns ON, drawing part of I_{SS}, M_3 & M_4 turn on

③ as V_{in_1} gets more positive than V_{in_2},

I_{D_1}, I_{D_3} & I_{D_4} increase

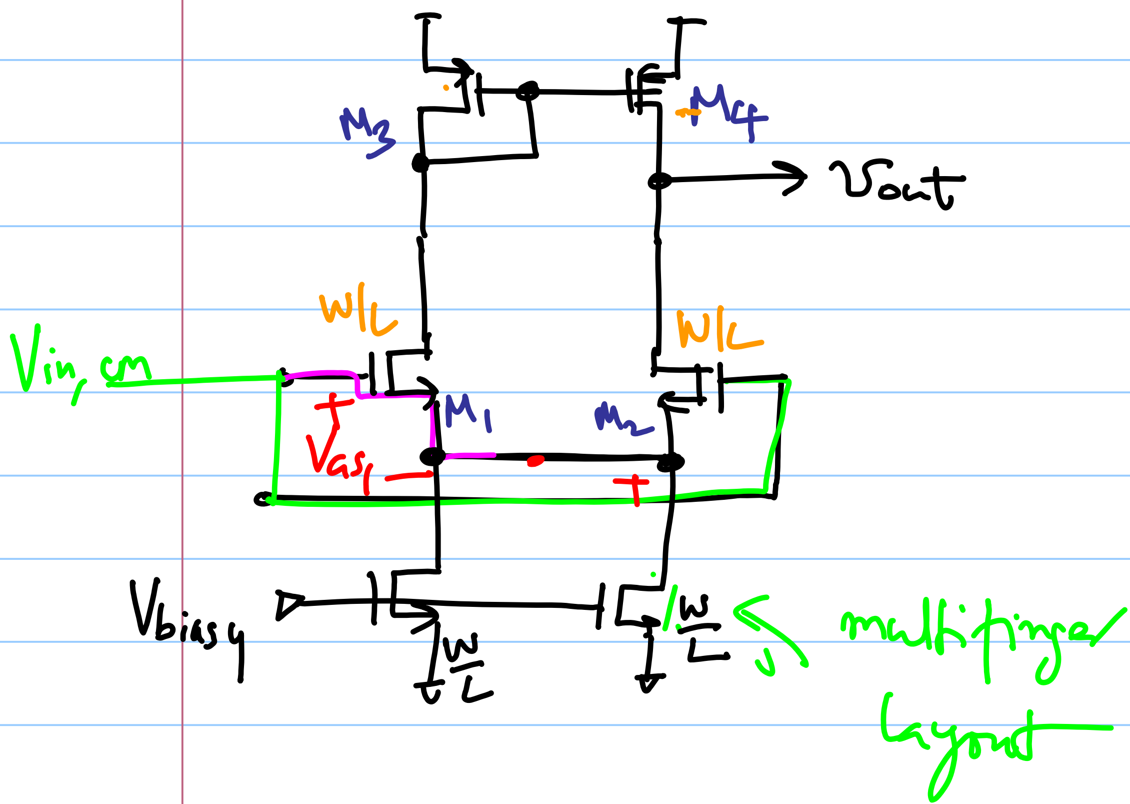
$I_{D_2} \downarrow$

→ drives M_4 into triode

↳ finally M_2 shuts off & M_4 operates in deep triode with

$V_{out} = V_{DD}$

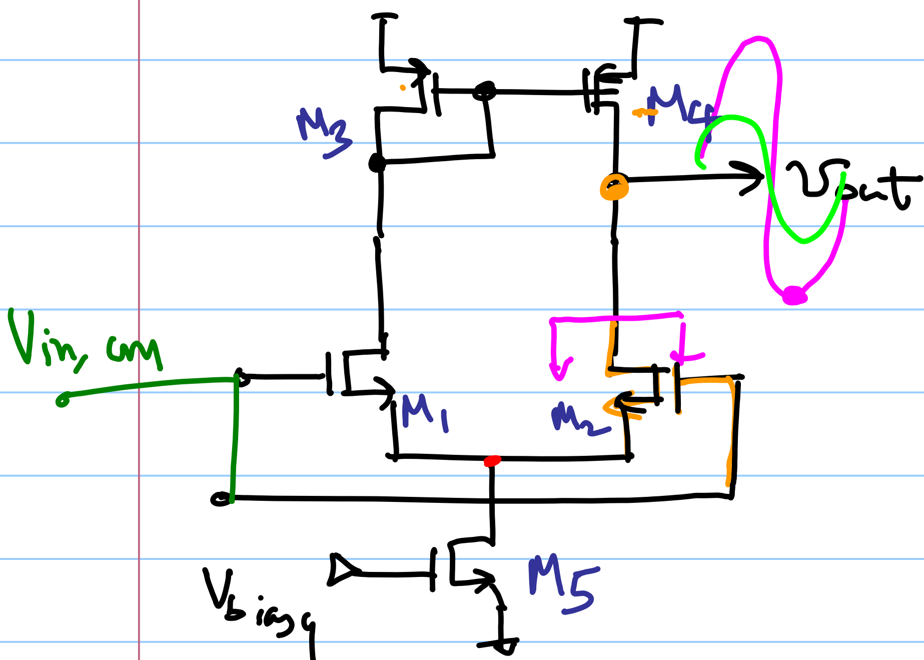
Input common-mode range



$V_{in,cm} \geq V_{GS_{1,2}} + V_{DS,sat_5}$

to keep $M_{1,2}$ & M_3 in SAT.

What about the output



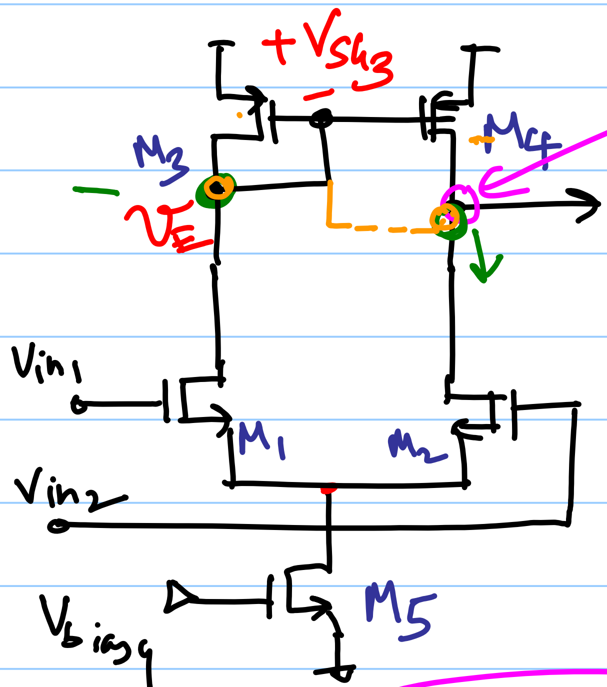
to keep M_2 in SAT

$$V_{DS} \geq V_{GS} - V_{THN}$$

$$V_D - \cancel{V_S} \geq V_G - \cancel{V_S} - V_{THN}$$

$$v_{out} \geq V_{in,cm} - V_{THN}$$

$$\boxed{V_{in,cm} \leq v_{out} + V_{THN}}$$



what is the DC level here ?? ($\simeq V_{bias_1}$??)

With perfect symmetry

$$V_{out} = V_E = V_{DD} - V_{SG_3}$$

Let $V_{out} < V_E$

then M_1 must carry higher current than M_2 $\Rightarrow$ $(I_{D_1} > I_{D_2})$ → ①

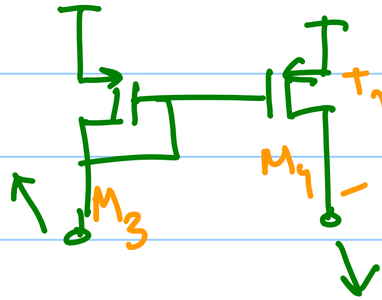
Should also be true that $(I_{D_4} > I_{D_3})$ → ②

But $I_{D_1} > \frac{I_{ss}}{2}$ $\Rightarrow$ $I_{D_3} > \frac{I_{ss}}{2}$

$\Rightarrow$ $I_{D_4} < \frac{I_{ss}}{2}$ → Contradicts with ②

Contradiction

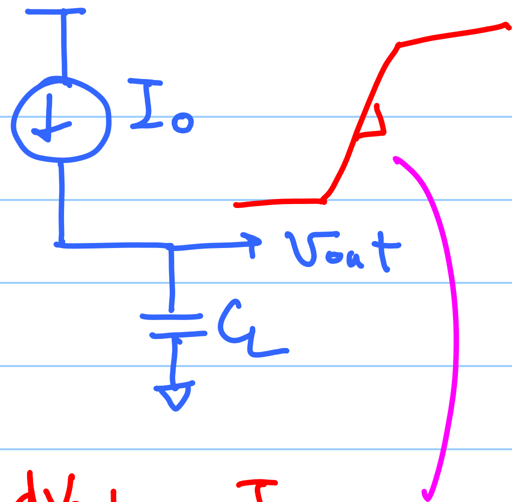
$I_{D_1} = I_{D_2}$ & $V_{out} = V_E = V_{DD} - V_{SG_3}$

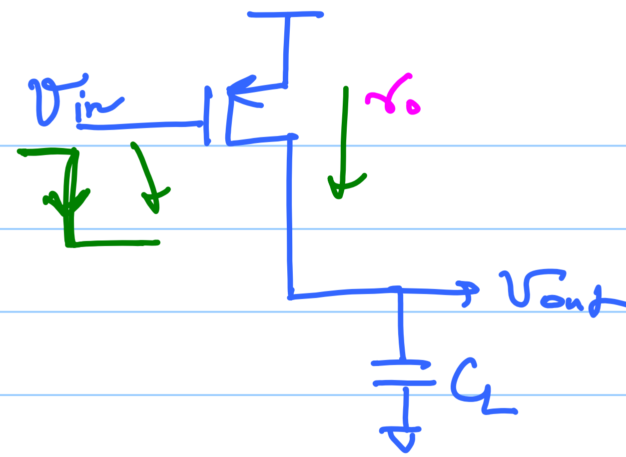


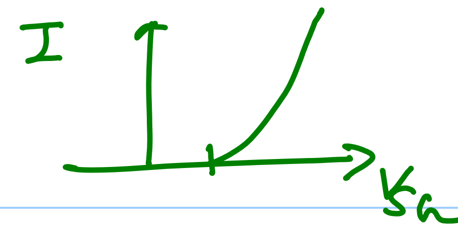
$V_{SD_4} > V_{SD_3}$

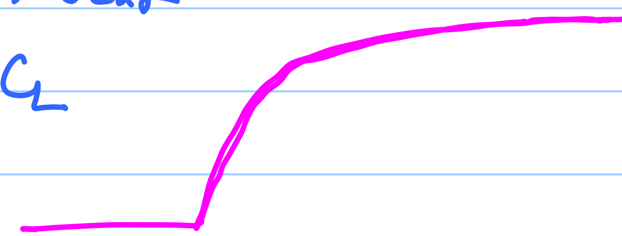
$\Rightarrow I_{D_4} > I_{D_3}$

$\Rightarrow$





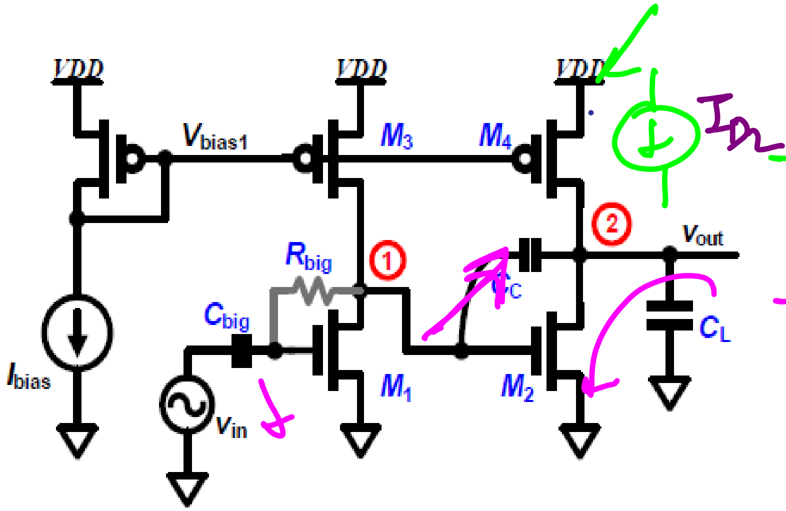


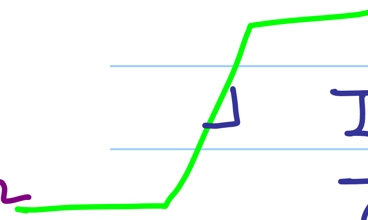


$$\frac{dV_{out}}{dt} = \frac{I_o}{C_L}$$

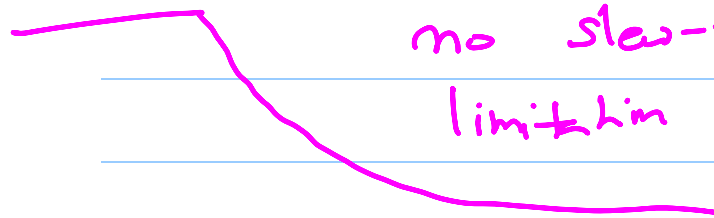
"slewing"

Charging
Slew rate limited by
M_4 current
source



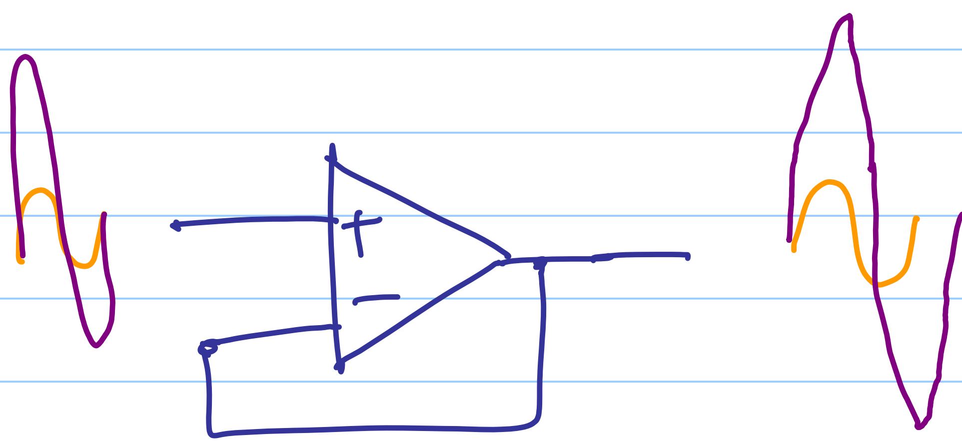


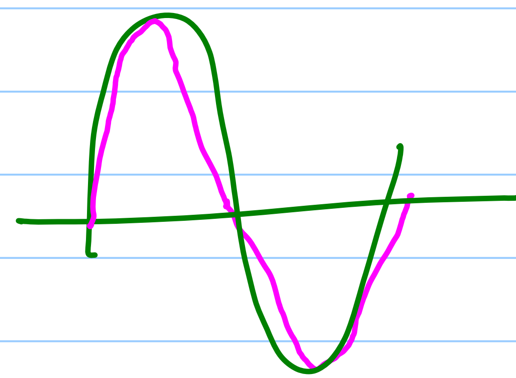
$$\frac{I_{D4}}{C_L}$$

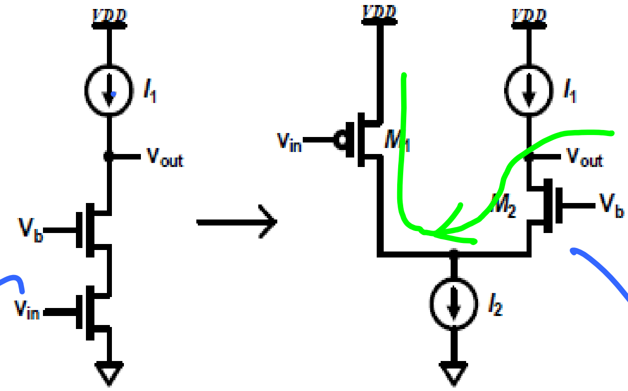


no slew-rate
limitation while
discharging.

$$\frac{dV_{out}}{dt} > I_{D2}$$







(a) Cascode Amplifier

(b) Folded Cascode Amplifier

(a) (10 points) Find the small-signal gain of the folded-cascode amplifier (b) shown above, and compare it with the gain of the cascode amplifier (a). Assume that the current sources are ideal.

$G_m = g_{m1}$

$R_{out} = g_{m2} r_{o2} r_{o1}$

$= -g_{m1}(g_{m2} r_{o2} r_{o1})$

$A_v = -g_{m1}(g_{m2} r_{o2} r_{o1})$