→ Later when we examine stability we will be concerned with the non-dominant poles
- remember each pole also causes a 90° phase shift in output

→ Breadboard capacitances?

ECE 3110: Lecture #10

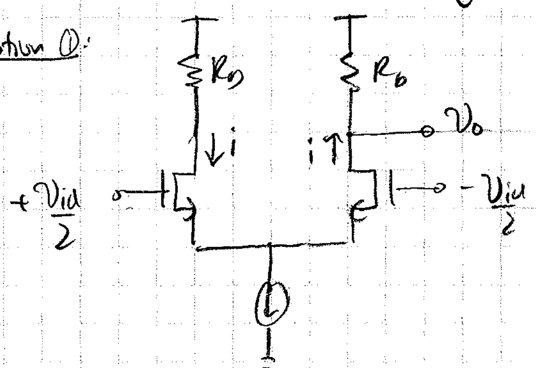
4 - (Late on faulty RMI Road).
1) - Long labs
2) - Quiz
3) - homework correct.

→ Back to differential pairs...

→ we saw that it is better to take a differential output signal from the pair
- better CMRR
- more gain (x2)

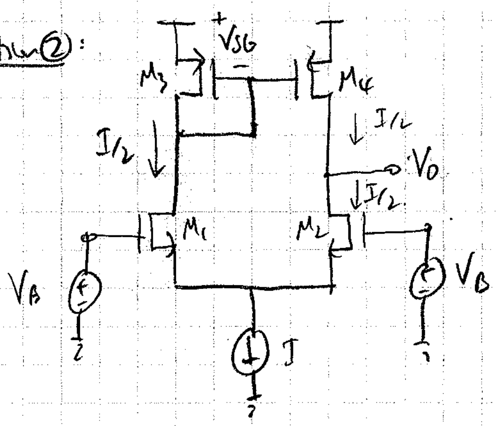
→ at some point the signal must be converted to single-ended

Option ①:



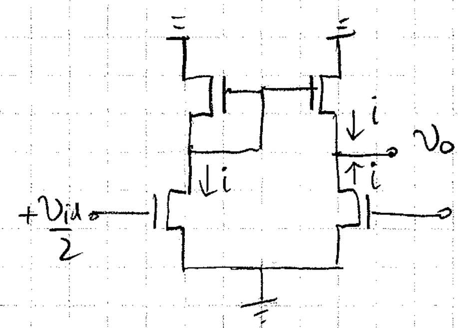
- just discard one output
  - bad CMRR
  - wasting gain
- We can do better, what about using an active load?

Option ②:



→ large signal: $V_O = V_{DD} - V_{SG3}$

→ small signal:



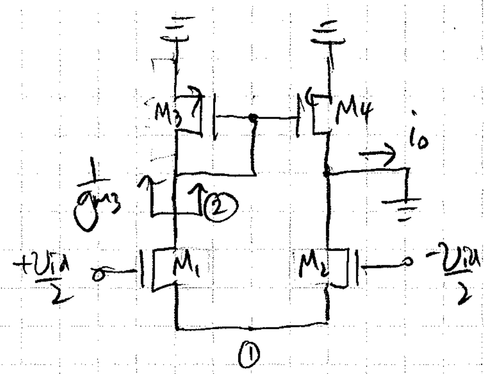
- total current driven to the output is $2i$, nothing is wasted!

→ Analysis is a little more complicated than for resistive loads, since asymmetry prevents us from using the half circuit approach.

→ BUT... we will employ a "quick and dirty" shortcut from the book that simplifies things.

Differential Gain
- Find in two steps: ① find the short-circuit transconductance
  ② find the output resistance
  → then multiply them together

① Short circuit transconductance: – ground output

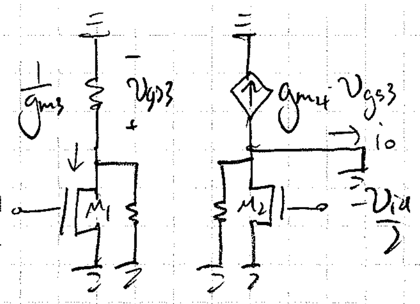


– technically we can't make the half circuit separated of a virtual ground at ①

– since at ② we see $1/g_m$ to ground, if $1/g_m$ is small, ② is "almost" grounded

– then assume symmetry and ① is a virtual gnd.

redraw:



∴ in M_1: induces a current of $g_{m_1} \cdot \frac{v_{id}}{2}$

$\rightarrow v_{gs_3} = -g_{m_1} \frac{v_{id}}{2} \cdot \frac{1}{g_{m3}}$

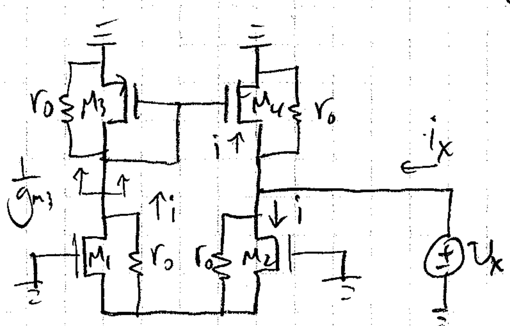
$\rightarrow i_o = \frac{v_{id}}{2} \cdot g_{m2} + g_{m4} \cdot v_{gs3}$

$= \frac{v_{id}}{2} \cdot g_{m2} + g_{m4} \cdot \frac{v_{id}}{2} \cdot \frac{g_{m1}}{g_{m3}}$

If $M_1 = M_2$, $M_3 = M_4$: $= \frac{v_{id}}{2} \cdot g_m + \frac{v_{id}}{2} \cdot g_m$

$= g_m \cdot v_{id}$

② Now, to find output voltage we need to know the output resistance.
– ground inputs, put test source at output.



→ current flowing into M_2 sees $\sim 2r_{o2}$ (neglect $1/g_{m3}$)

∴ $i = \frac{v_x}{2 \cdot r_o}$

→ total $i_x = 2 \cdot i + \frac{v_x}{r_{o4}}$

$= \frac{2 \cdot v_x}{2 \cdot r_{o2}} + \frac{v_x}{r_{o4}}$

$= \frac{v_x}{r_{o2}} + \frac{v_x}{r_{o4}} \Rightarrow v_x = i_x \cdot R_o$

$\rightarrow R_o = (r_{o2} \parallel r_{o4})$

∴ **Differential Gain: $A_d = g_m (r_{o2} \parallel r_{o4})$**