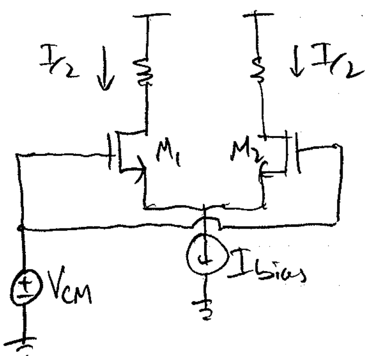
ECE 3110: Lecture #7 (insert prior to normal lecture)

Recap from last class: Differential Pair

Two parts to analysis: (1) Large Signal → common mode bias (a)
→ differential mode bias (b)

(2) Small Signal → differential signal gain (a)
→ common mode signal gain (b)

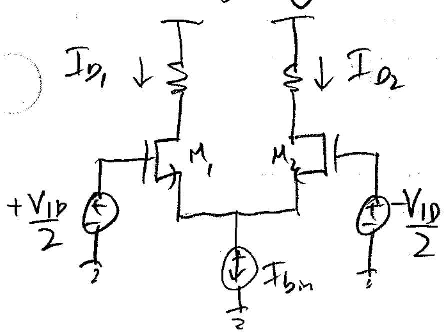
(1)(a) Large Signal Common Mode Bias



→ How low/high can the bias voltage on the gates of M_1, M_2 be before the diff. pair stops functioning?

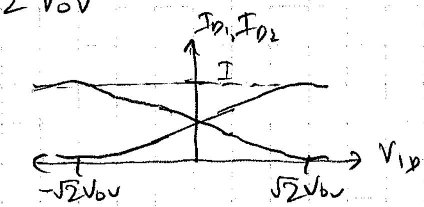
- High: M_1, M_2 pushed out of saturation into triode.
- Low: I_{bias} current source needs minimum output voltage.

(1)(b) Large Signal Differential Mode Bias



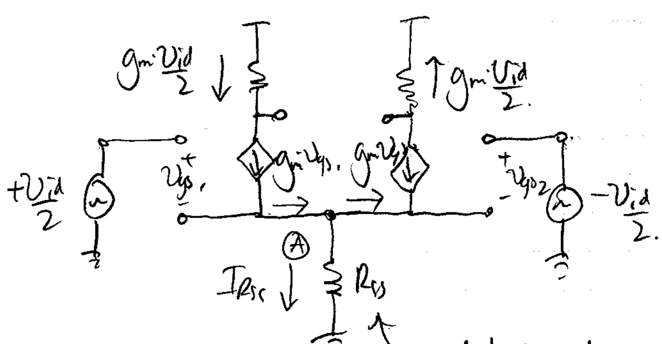
→ DC transfer function of I_{D1}, I_{D2} as we sweep V_{ID} from $-\sqrt{2}V_{ov}$ to $+\sqrt{2}V_{ov}$

- current switches from one side to the other



(2)(a) Small Signal Diff. Gain

- Calculate bias conditions, plug in S.S. models



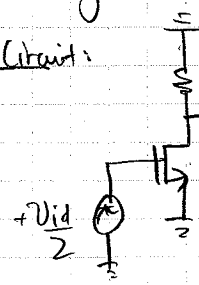
→ Why is node (A) a virtual ground?

KCL @ (A): $g_m \frac{v_{id}}{2} + \left(-g_m \frac{v_{id}}{2}\right) + \frac{V_A}{R_{SS}} = 0$

$\Rightarrow \frac{V_A}{R_{SS}} = 0 \rightarrow \boxed{V_A = 0}$

→ So, can split into two half circuits.
- analyze one half circuit, if output is taken differentially, gain will be 2× that of half circuit.

Half Circuit:

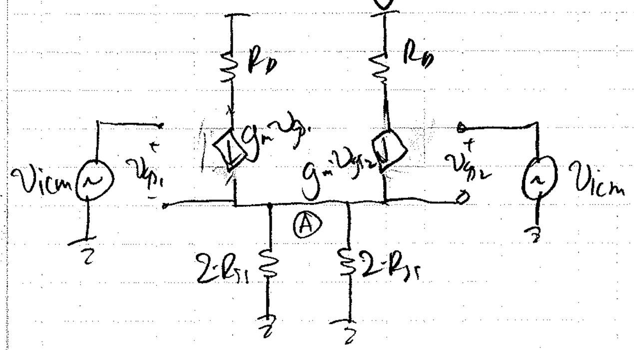


$v_o = -g_m \cdot \frac{v_{id}}{2} \cdot R_D$

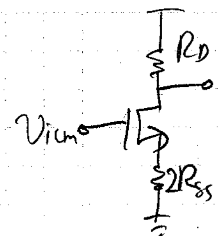
Single Ended Output: $A_d = \frac{v_{o2}}{v_{id}} = \frac{g_m \cdot R_D}{2}$

Diff. Output: $A_d = \frac{v_{o2} - v_{o1}}{v_{id}} = g_m \cdot R_D$

② (b) Small Signal Common Mode Gain



- Can no longer assume Ⓐ is a virtual ground since R_{SS} will have a net current flow through it.
- Split into half circuits:



$\frac{-g_m \cdot v_{icm} \cdot R_D}{1 + g_m \cdot 2 \cdot R_{SS}}$

Single-Ended Output: $A_{cm} = \frac{v_{o2}}{v_{icm}} \approx \frac{R_D}{2 \cdot R_{SS}}$ (assuming $\frac{1}{g_m} \ll 2 \cdot R_{SS}$)

Diff. Output: $A_{cm} = \frac{v_{o2} - v_{o1}}{v_{icm}} = 0$