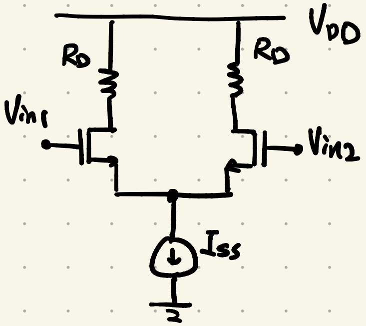
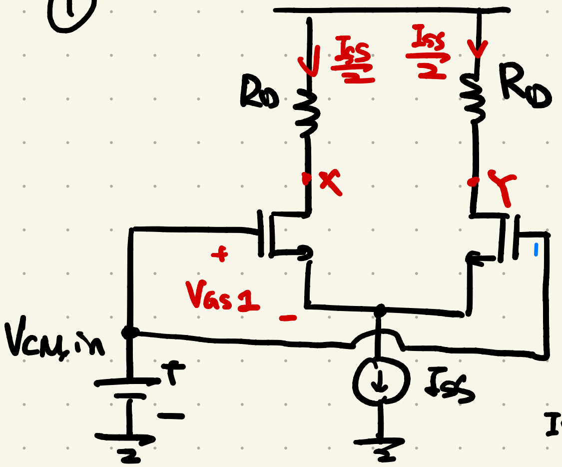
Lec 12

- MOS Differential Pair
  - General Properties
  - Large-Signal Behavior



• General Properties

①



$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{TH})^2$

overdrive voltage

(device on & sat.)

$V_X = V_Y = V_{DD} - R_D\frac{I_{SS}}{2}$

$V_{GS} = \sqrt{\dfrac{I_{SS}}{\mu_n C_{ox}\frac{W}{L}}} + V_{TH}$

If $V_{in1} = V_{in2}$, the diff pair is in "equilibrium"

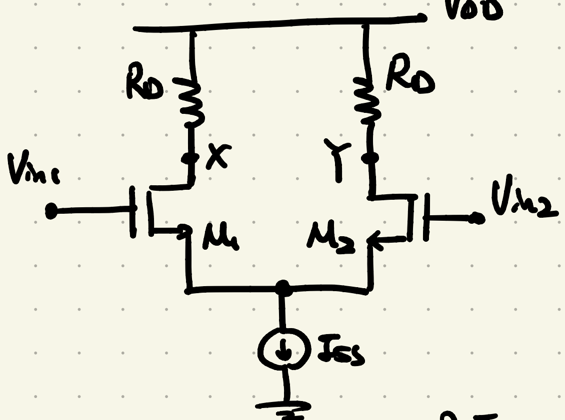
The equilibrium overdrive voltage:

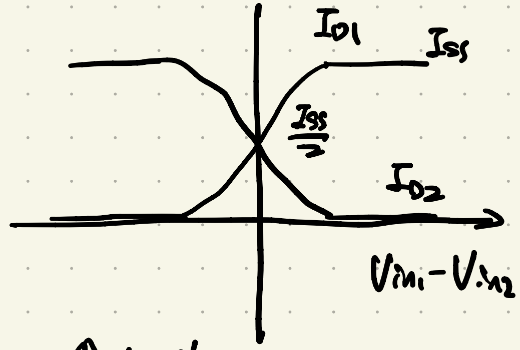
$$V_{GS1} - V_{TH} = \sqrt{\frac{I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$$

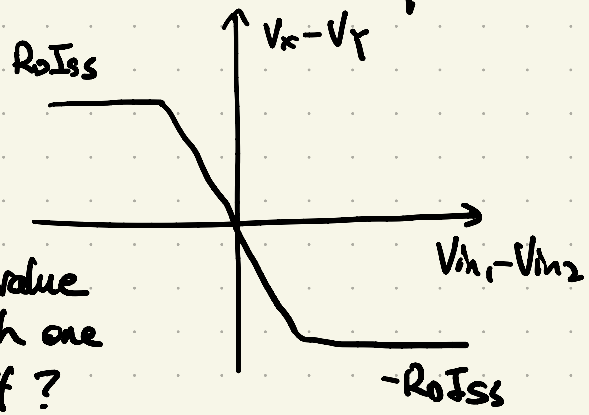
- If $V_{cm,in}$ changes, what quantities in the circuit change?

  Nothing changes

② Differential behavior

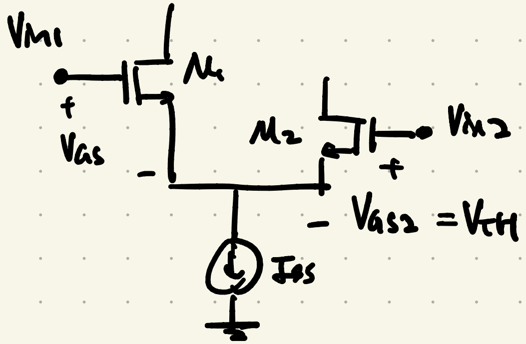






Example

What is the minimum value of $V_{in1}-V_{in2}$ at which one transistor turns off?

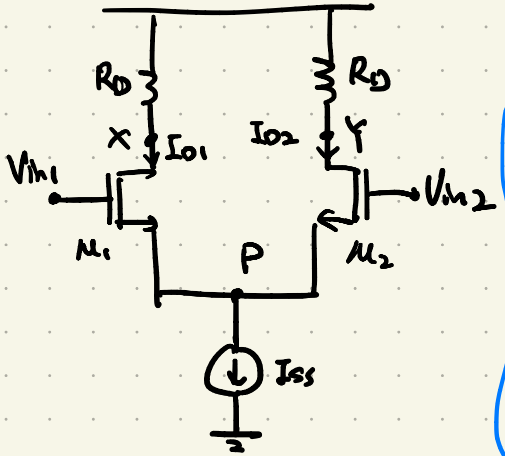


$V_{GS1} = \sqrt{\dfrac{2I_{SS}}{\mu_n C_{ox}\frac{W}{L}}} + V_{TH}$

$V_{in1} - V_{in2} = V_{GS1} - V_{GS2}$

$$= \sqrt{\frac{2I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$$

Large-Signal Analysis



$V_{in1}-V_{in2} = V_{GS1} - V_{GS2}$

$$V_{in1}-V_{in2} = \sqrt{\frac{2I_{D1}}{\mu_n C_{ox}\frac{W}{L}}} + V_{TH} - \left(\sqrt{\frac{2I_{D2}}{\mu_n C_{ox}\frac{W}{L}}} + V_{TH}\right)$$

$$I_{D1}+I_{D2} = I_{SS}$$

$$V_X - V_Y = -R_D(I_{D1}-I_{D2})$$

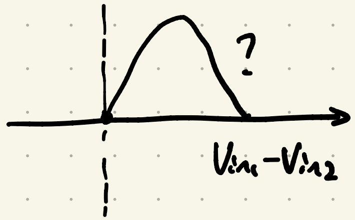
$$(V_{in1}-V_{in2})^2 = \frac{2I_{D1}}{\mu_n C_{ox}\frac{W}{L}} + \frac{2I_{D2}}{\mu_n C_{ox}\frac{W}{L}} - \frac{2\sqrt{4I_{D1}I_{D2}}}{\mu_n C_{ox}\frac{W}{L}}$$

$$(V_{in1}-V_{in2})^2 - \frac{2I_{SS}}{\mu_n C_{ox}\frac{W}{L}} = -4\sqrt{\frac{I_{D1}(I_{SS}-I_{D1})}{\mu_n C_{ox}\frac{W}{L}}}$$

$$I_{D1}-I_{D2} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in1}-V_{in2})\sqrt{\frac{4I_{SS}}{\mu_n C_{ox}\frac{W}{L}} - (V_{in1}-V_{in2})^2}$$

Observations

① $I_{D1}-I_{D2}=0$ if $V_{in1}=V_{in2}$



② Equation Ⓐ is valid only if M_1 and M_2 are on or at the edge of turning off; up to

$$|V_{in1}-V_{in2}| = \sqrt{\frac{2I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$$