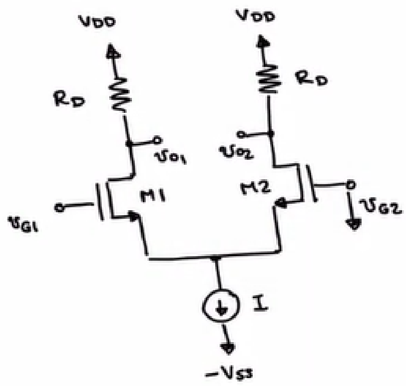
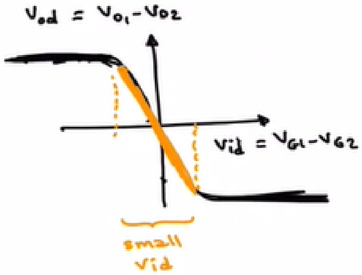
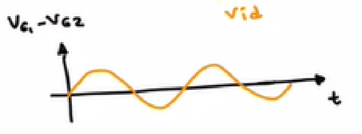
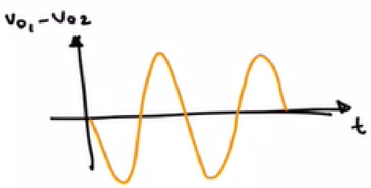
MOSFET Differential Pair: Qualitative Analysis









* Case 1: Common-Mode Signal ($v_{G1} = v_{G2} = v_{CM}$)

Assume M1, M2 matched

- $i_{D1} = i_{D2} = \frac{I}{2}$
- $v_S = v_{CM} - V_{GS}$
- $v_{O1} = v_{O2} = V_{DD} - \frac{I}{2} R_D \Rightarrow v_{O1} - v_{O2} = \emptyset$

$\Rightarrow A_{cm} = \emptyset$

* Case 2: Large Differential Signal (e.g. $v_{G2} = \emptyset$ and $|v_{G1}| \gg \emptyset$)

(a) $v_{G1} \gg \emptyset$

- $i_{D1} = I$, $i_{D2} = \emptyset$
- $v_{O1} = V_{DD} - IR_D$, $v_{O2} = V_{DD}$

(b) $v_{G1} \ll \emptyset$

- $i_{D1} = \emptyset$, $i_{D2} = I$
- $v_{O1} = V_{DD}$, $v_{O2} = V_{DD} - IR_D$

* Case 3: Small Differential signal (eg. $v_{G2} = \emptyset$)

- small increase in $v_{G1} \Rightarrow$ small increase in i_{D1} ($i_{D1} = \frac{I}{2} + \Delta I = \frac{I}{2} + i_{d1}$)
- Since $i_{D1} + i_{D2} = I \Rightarrow$ small decrease in i_{D2} ($i_{D2} = \frac{I}{2} - \Delta I = \frac{I}{2} - i_{d2}$)
- $\Delta v_{id} \Rightarrow \Delta I \Rightarrow \Delta v_o$

$$v_{O1} = V_{DD} - \frac{I}{2} R_D - i_{d1} R_D$$

$$v_{O2} = V_{DD} - \frac{I}{2} R_D + i_{d2} R_D$$

$$\Delta v_o = v_{O1} - v_{O2} = - i_{d1} R_D - i_{d2} R_D$$

$$v_{O1} - v_{O2} = - 2 i_d R_D$$

$\Rightarrow$ $\boxed{\text{differential amplifier}}$

What value of v_{id} cause the entire I to be steered towards one branch? (eg. M1)

This happens when v_{GS1} reaches a value corresponding to $i_{D1} = I$ and $v_{GS2} = V_t \Rightarrow v_S = -V_t$ (since $v_{G2} = \emptyset$)

$$i_{D1} = I = \frac{1}{2} (\mu_n C_{ox}) \left(\frac{W}{L}\right) (v_{GS1} - V_t)^2$$

$$\Rightarrow v_{GS1} = V_t + \sqrt{\frac{2I}{\mu_n C_{ox} W/L}} = V_t + \sqrt{2}\, V_{ov}$$

(where V_{ov} = overdrive voltage corresponding to a current of $I/2$)

$$\boxed{v_{id\,max} = v_{GS1} + v_S = V_t + \sqrt{2} V_{ov} - V_t = \sqrt{2} V_{ov}}$$

Condition for M1, M2 to remain in saturation.
For larger v_{id}, all the current is steered towards one branch.

Small differential signal: $\boxed{v_{id} \le \sqrt{2} V_{ov}}$