Basic differential amplifier: half-circuit analysis

\( (W/L)_{1,2} = 100 \)

By symmetry and driven by \( +v_{id}/2, -v_{id}/2 \)
Basic differential amplifier: half-circuit analysis

\[
\frac{v_{x2}}{v_{id}} = -g_{m2} \left( R \parallel R_{o2} \right)^{1/2}
\]

\[
\begin{align*}
\text{Transconductance portion of } M_2 & = g_{m2} \frac{v_{id}}{2} \\
\text{Transconductance portion of } M_1 & = g_{m1} = g_{m2}
\end{align*}
\]

\[
\frac{v_{x1}}{v_{id}} = g_{m2} \left( R \parallel R_{o2} \right)^{1/2}
\]

Common Source

\[
v_{x2} = -g_{m2} \frac{v_{id}}{2} \left( R + R_{o2} \right)
\]

\[
d_1 = \frac{-v_{id}}{2}
\]

\[
d_2 = \frac{g_{m2} v_{id}}{2}
\]
Open-loop differential-mode gain $A_o$: $A_1 = \frac{V_i}{V_{id}}$.

$+V_{DD} = 5\text{ V}$

$R_B = 8.8\text{ M}\Omega$

$M_3$  
$(W/L)_{3,4} = 20$

$M_4$  
$(W/L)_4 = 1$

$M_5$  
$(W/L)_{5} = 10$

$M_6$  
$(W/L)_6 = 400$

$M_7$  
$(W/L)_7 = 100$

$M_8$  
$(W/L)_8 = 1$

$V_{id} = \frac{q_{m1} V_{id}}{2}$

$V_{id} = \frac{q_{m2} V_{id}}{2}$

$I_{D1} = 5\text{ \mu A}$

$I_{D2} = 5\text{ \mu A}$

$I_{B1} = 10\text{ \mu A}$

$I_{B2} = 100\text{ \mu A}$

$-V_{SS} = -5\text{ V}$

$\frac{V_i}{V_{id}} = -g_{m1}(\frac{r_2}{r_4})$

$g_{m1}$
Open-loop differential-mode gain $A_o$: \[ A_o \]

\[ R_B = 8.8 \, \text{M}\Omega \]

\[ (W/L)_{3,4} = 20 \]

\[ (W/L)_{1,2} = 100 \]

\[ (W/L)_{5} = 10 \]

\[ (W/L)_{6} = 400 \]

\[ (W/L)_{7} = 100 \]

\[ I_{B1} = 10 \, \mu\text{A} \]

\[ v_{id}/2 \]

\[ v_{id}/2 \]

\[ M_5 \]

\[ M_7 \]

\[ M_8 \]

\[ (W/L)_8 = 1 \]

\[ v_{x1} = 2v_{id} \]

\[ v_{x2} = v_{1} \]

\[ v_{id} = v_{1} \]

\[ v_{x1} = \frac{1}{2} \]

\[ \frac{v_{x}}{-v_{id}/2} = -g_{m1}g_{m3} \]

\[ v_{x} = -g_{m1}(\frac{1}{\frac{1}{g_{m2}}}) \]

\[ v_{x} = -g_{m1}(\frac{1}{\frac{1}{g_{m2}}}) \]

\[ I_{test} = \frac{I_{test}}{I_{test}} \]

\[ I_{test} = \frac{v_{test}}{g_{m3}} + g_{m3}v_{test} \]

\[ \approx \frac{1}{g_{m3}} \]
Open-loop differential-mode gain $A_0$

$$ A_0 = \frac{v_o}{v_{id}} = \frac{v_0}{v_1} \cdot \frac{v_1}{v_{id}} = \left( -g_{m6}(r_{o6 \parallel r_{o7}}) \right) \left( -g_{m4}(r_{o2 \parallel r_{o4}}) \right) > 0 $$

$\sim 70 \quad \sim 100 \quad \sim 1000 \rightarrow 70$-80 dB.
Basic differential amplifier: CMRR
Basic differential amplifier: diff-mode gain

\[ \frac{v_{x2}}{v_{id}} = -\frac{g_{m1}}{2} (R1/R2) \]
Basic differential amplifier: common-mode gain

At this point, the tablet pen crashed, the rest of the lecture was done on white board – see the recorded lecture.