

ECE 523/421 – Analog Electronics

Lecture 11: Differential Amplifiers: MOS Differential Pair

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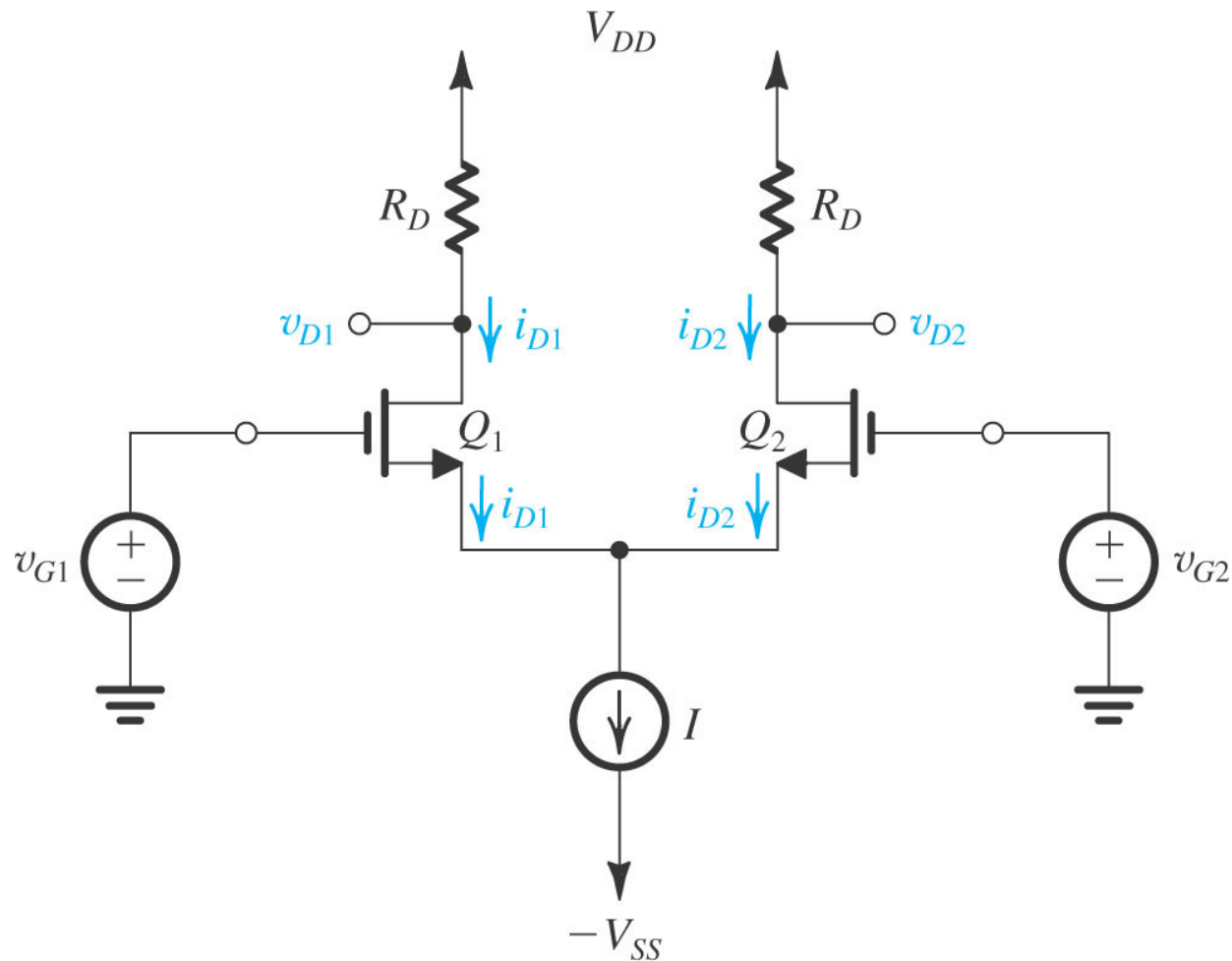
Review of Last Lecture

- ☐ **CC-CE, CD-CS, and CD-CE Configurations**
- ☐ **Darlington Configuration**
- ☐ **CC-CB and CD-CG Configurations**

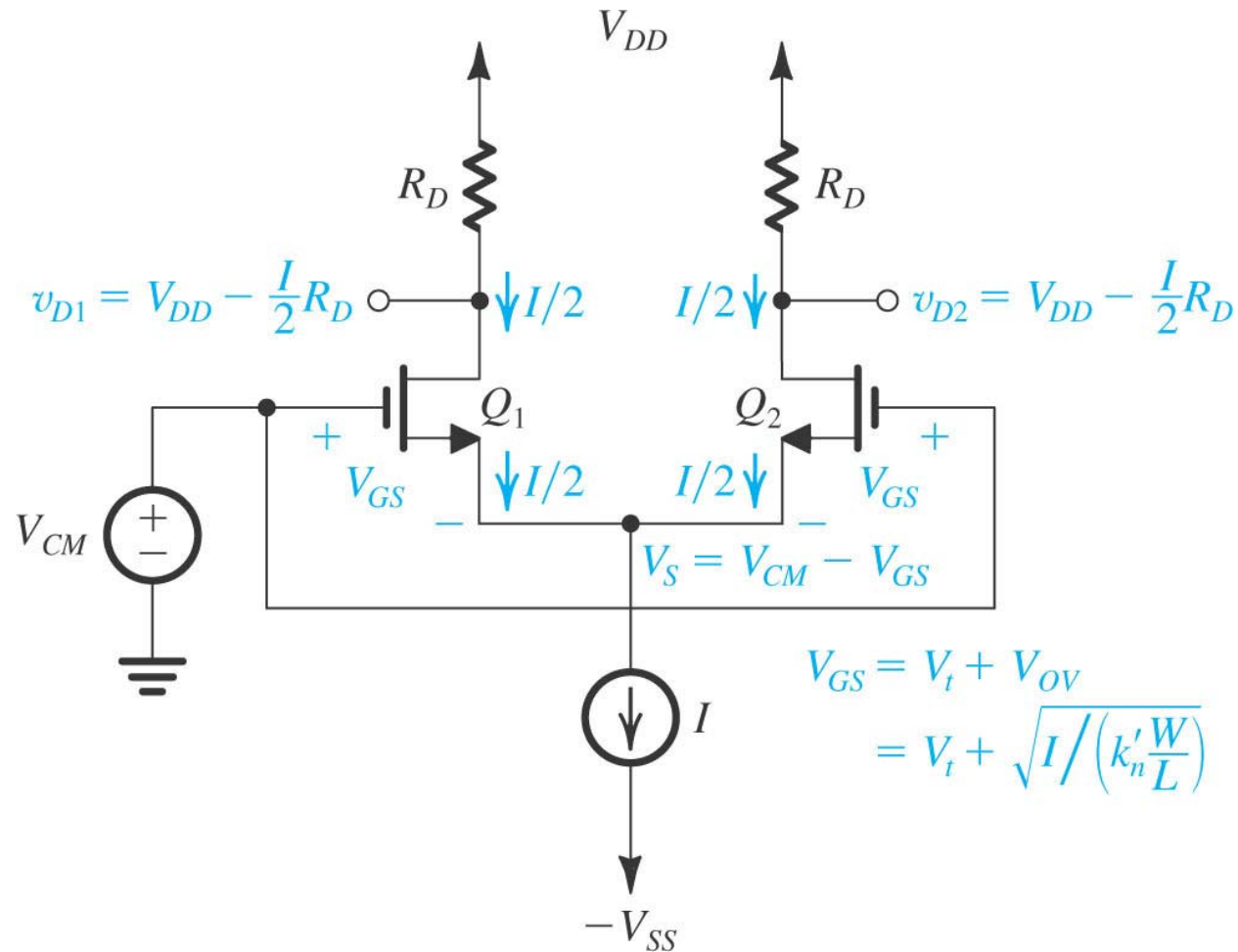
Today's Lecture

- ☐ **MOS Differential Amplifier**
- ☐ **Common Mode Input**
- ☐ **Differential Model Input**
- ☐ **Large Signal Operation**

MOS Differential Pair

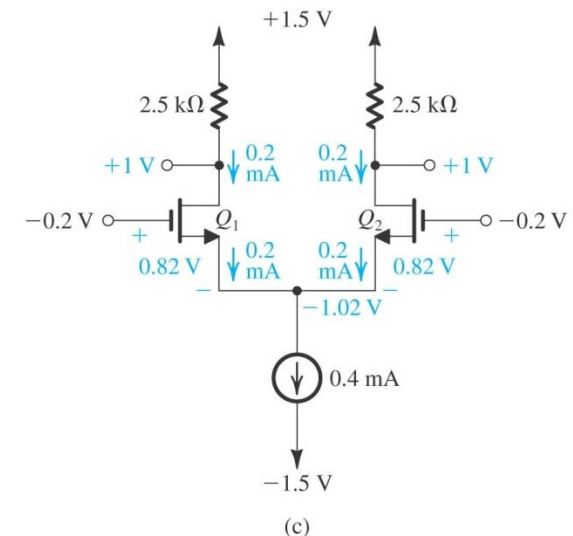
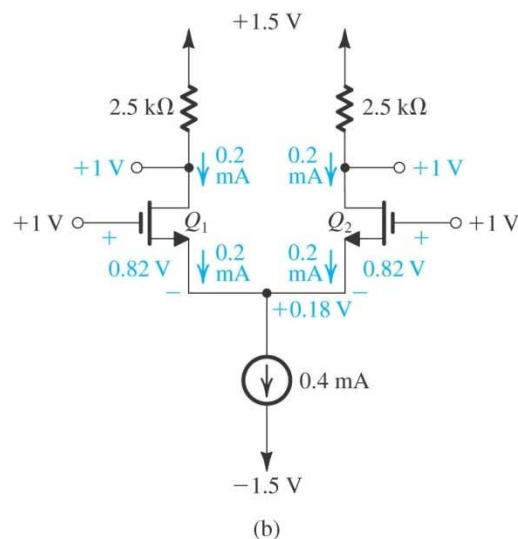
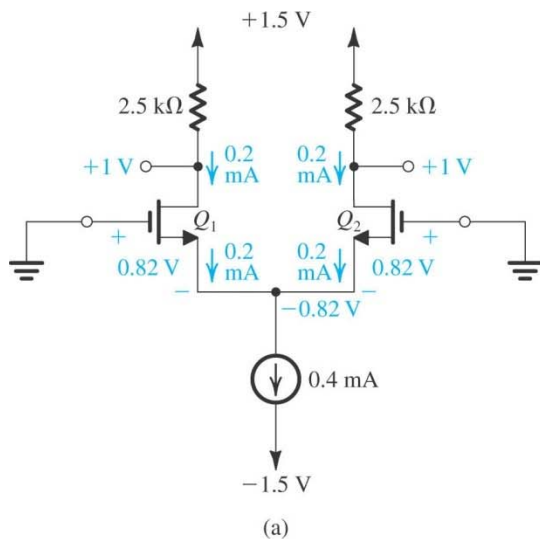


Operation With Common Mode Input

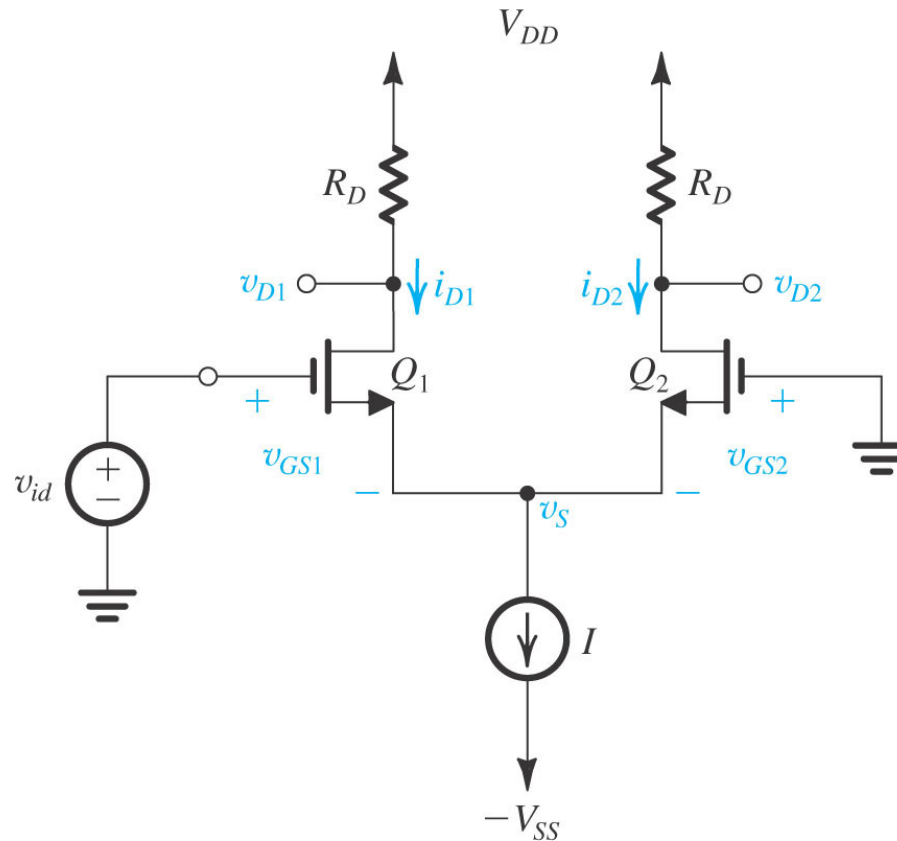


Example: Common Mode Input

- 1) Let $V_{DD}=V_{SS}=1.5\text{V}$, $K'_n(W/L)=4\text{mA/V}^2$, $V_t=0.5\text{V}$, $I=0.4\text{mA}$, and $R_D=2.5\text{k}\Omega$. Analyze the circuit for $V_{CM}=0\text{V}$, 1V , and -0.2V . If the current source requires 0.4V to operate properly, what is the maximum range for V_{CM} ?

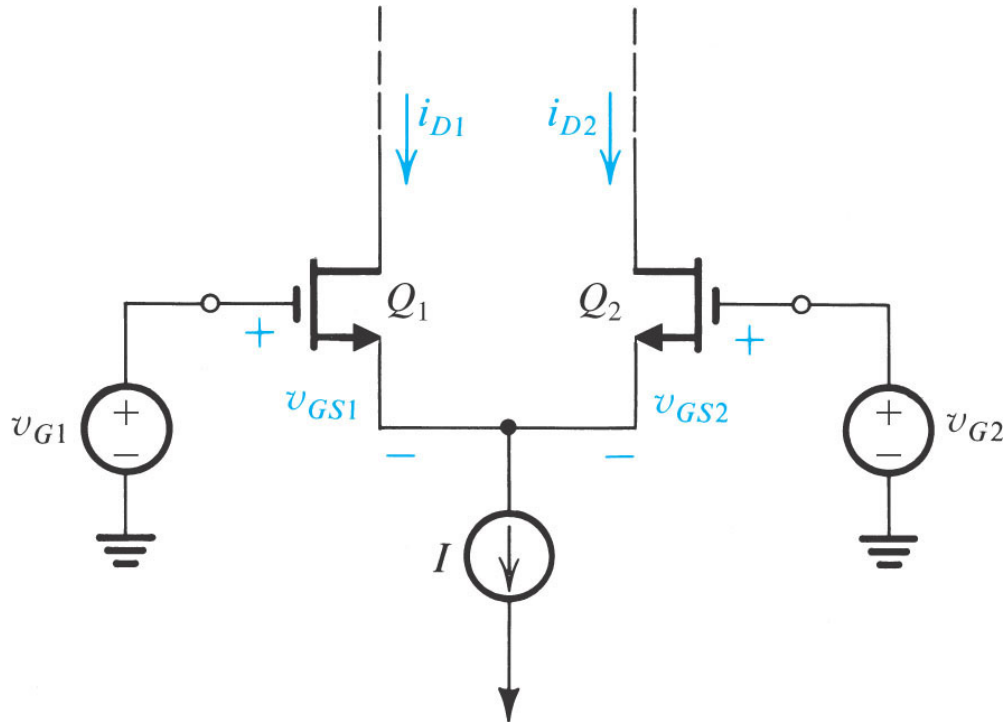


Operation With Differential Mode Input



$$-\sqrt{2}V_{OV} \leq v_{id} \leq \sqrt{2}V_{OV}$$

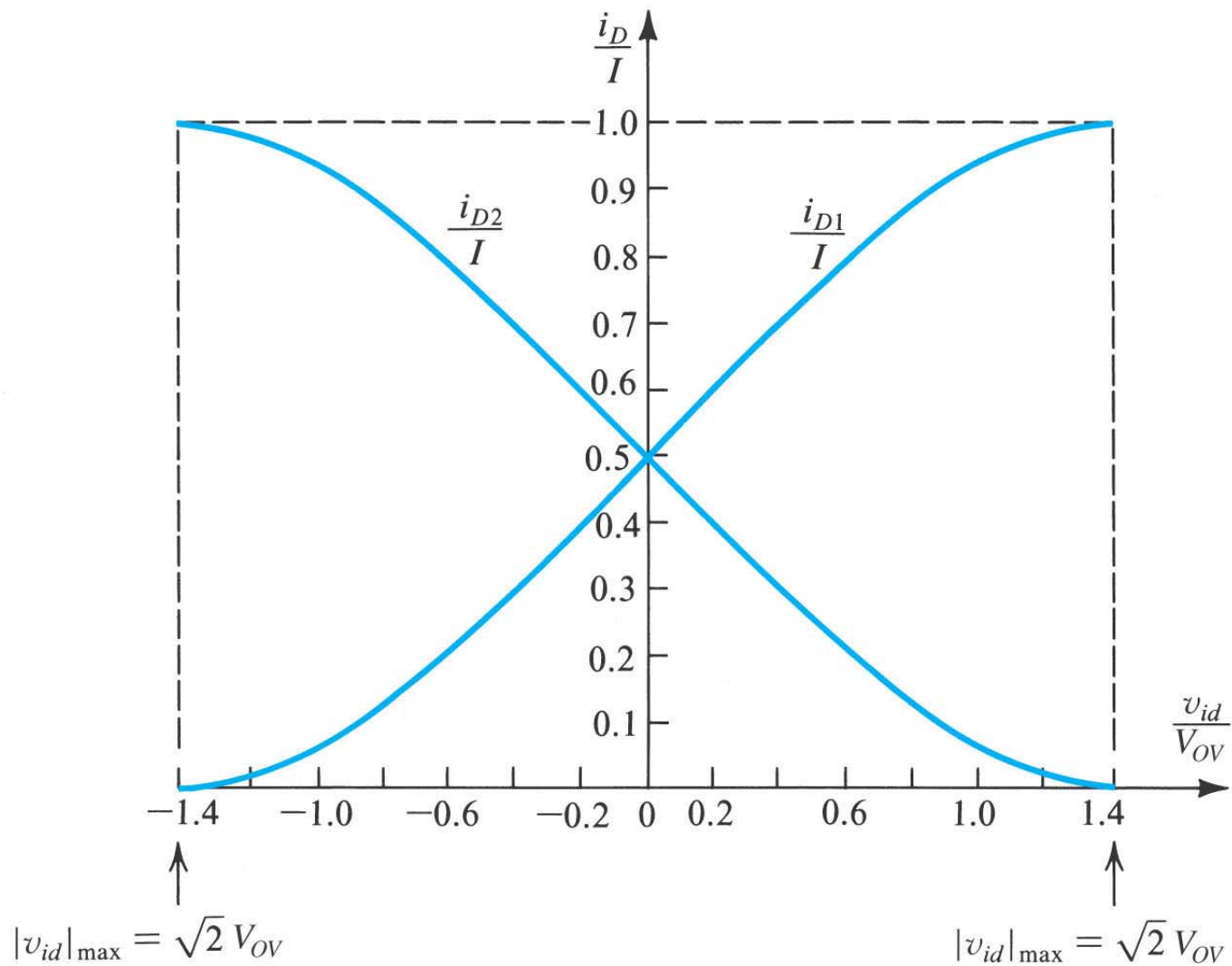
Large Signal Operation



$$i_{D1} = \frac{I}{2} + \left(\frac{I}{V_{OV}} \right) \left(\frac{v_{id}}{2} \right) \sqrt{1 - \left(\frac{v_{id}/2}{V_{OV}} \right)^2}$$

$$i_{D2} = \frac{I}{2} - \left(\frac{I}{V_{OV}} \right) \left(\frac{v_{id}}{2} \right) \sqrt{1 - \left(\frac{v_{id}/2}{V_{OV}} \right)^2}$$

Large Signal Operation



Small Signal Approximation

$$\left\{ \begin{array}{l} i_{D1} = \frac{I}{2} + \left(\frac{I}{V_{OV}} \right) \left(\frac{v_{id}}{2} \right) \sqrt{1 - \left(\frac{v_{id}/2}{V_{OV}} \right)^2} \\ i_{D2} = \frac{I}{2} - \left(\frac{I}{V_{OV}} \right) \left(\frac{v_{id}}{2} \right) \sqrt{1 - \left(\frac{v_{id}/2}{V_{OV}} \right)^2} \end{array} \right. \quad \left\{ \begin{array}{l} i_{D1} = \frac{I}{2} + \left(\frac{I}{V_{OV}} \right) \left(\frac{v_{id}}{2} \right) \\ i_{D2} = \frac{I}{2} - \left(\frac{I}{V_{OV}} \right) \left(\frac{v_{id}}{2} \right) \end{array} \right.$$



$$i_d = \left(\frac{I}{V_{OV}} \right) \left(\frac{v_{id}}{2} \right)$$

Linear Operation of Differential Amplifier

