Learning Objective: Small Signal Parameters

Problem 1. Consider the following I_D equation

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

Show the following equality.

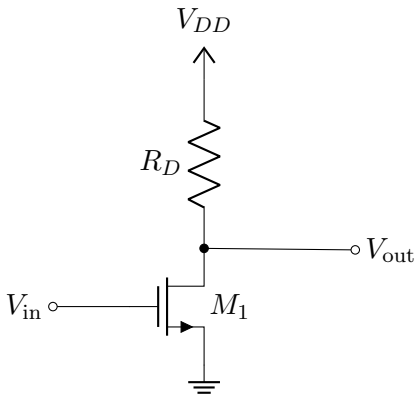
(a) $g_m = \mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH}) = 2K_n(V_{GS} - V_{TH})$

(b) $g_m = \sqrt{2\mu_n C_{ox}\frac{W}{L}I_D} = 2\sqrt{K_n I_D}$

(c) $g_m = \frac{2I_D}{V_{GS} - V_{TH}}$

Learning Objective: Maximum Voltage Swing Configuration

Problem 2. Consider a resistive load common source amplifier below, where $R_D = 1\,\text{k}\Omega$ and $V_{DD} = 5$ V. The n-channel MOSFET has a threshold voltage $V_{\text{TH}} = 0.7$ V, conduction parameter $K_n = 0.5$ mA/V^2. Assume $\lambda = 0$, $\gamma = 0$.



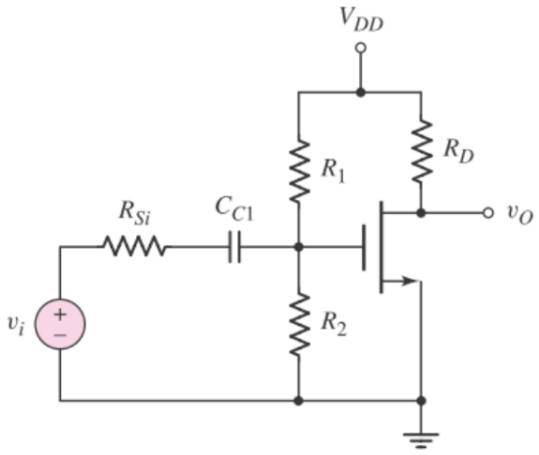
(a) Determine the **range of output voltage $\mathbf{V_{out}}$** to operate the MOSFET M_1 in saturation region.

(b) Determine the **range of input voltage $\mathbf{V_{in}}$** to operate the MOSFET M_1 in saturation region.

(c) Assume the MOSFET operates at the center of the saturation region, determine the **Q-point of the MOSFET ($\mathbf{V_{DS}}$, $\mathbf{I_D}$)** and the **input voltage $\mathbf{V_{in}}$**.

Learning Objective: Common Source Amplifier without R_s

Problem 3. A common-source amplifier circuit has following parameters: $Kn = 0.6$ mA/V^2, $V_{DD} = 3.5$ V, $R_D = 12$ kΩ, $R_1 = 144$ kΩ, $R_2 = 65$ kΩ, $R_{Si} = 12$ kΩ, $V_{TN} = 0.5$ V, and $\lambda = 0.018$ V^{-1}.



(a) Determine I_{DQ}.

(b) Prove that the transistor is biased in the saturation region.

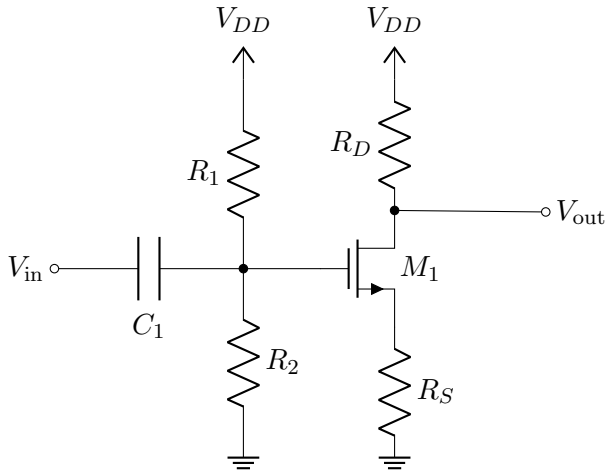
(c) Determine g_m and r_o for the small-signal FET model.

(d) Determine the **input and output resistances** of the common source amplifier.

(e) Determine the small **signal voltage gain**.

Learning Objective: Common Source Amplifier with R_s

Problem 4. Consider a resistive load common source amplifier below. Assume the MOSFET operates in saturation, $R_S \neq 0$, $\lambda = 0$, $\gamma = 0$.

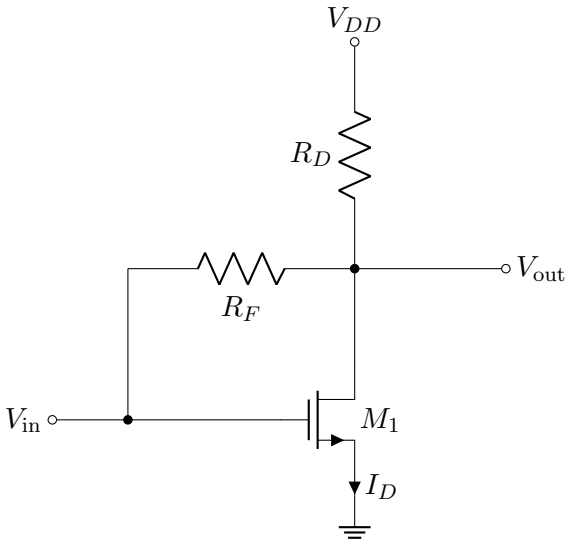


(a) Plot the **small signal equivalent circuit** of the given amplifier.

(b) Derive an expression of the **output voltage** and **small-signal voltage gain**.

Learning Objective: Common Source Amplifier

Problem 5. Consider a resistive load common source amplifier below. Assume the MOSFET operates in saturation, $\lambda \neq 0$, $\gamma = 0$.



(a) Plot the **small signal equivalent circuit** of the given amplifier.

(b) Determine the expression of **output voltage** and **small-signal voltage gain**.