EE315 - Electronics Laboratory

Experiment - 5 Simulation
MOSFET Characteristics and Small Signal Amplifier

Preliminary Work

1. The inverter in Figure **1** utilizes an N-channel enhancement-mode MOSFET with the parameters $\mathbf{K_n = 50\ mA/V^2}$ and $\mathbf{V_{TN} = 2.0\ V}$. Find the MOSFET drain current i_D when $v_{in} = 3.0\ V$ and $v_{in} = 3.5\ V$. Plot the v_{in}-v_{out} transfer characteristics of the inverter.

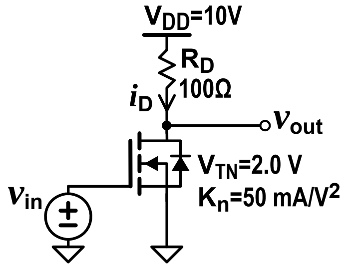

Figure 1

Equations for the N-channel MOSFET are given below.

$$i_D = K_n(v_{GS} - V_{TN})^2 \quad \text{(in SAT region: } v_{DS} \geq v_{GS} - V_{TN})$$

$$i_D = K_n\left[2(v_{GS} - V_{TN})v_{DS} - v_{DS}^2\right] \quad \text{(in triode=non-SAT region: } v_{DS} < v_{GS} - V_{TN})$$

2. Consider the MOSFET amplifier in Figure **2** with the parameters $\mathbf{K_n = 50\ mA/V^2}$ and $\mathbf{V_{TN} = 2.0\ V}$. Determine the resistor values to obtain roughly $\mathbf{I_D = 10\ mA}$ and to set $\mathbf{V_D}$ roughly midway between $\mathbf{V_{DD}}$ and $\mathbf{V_G}$.

Hint: Set the approximate voltage gain $\mathbf{A_V \approx R_D/R_S}$ between **4.0** and **5.0** while the drain-to-source bias voltage is $\mathbf{V_{DS} \approx (V_{DD} - V_{SS})/2}$.

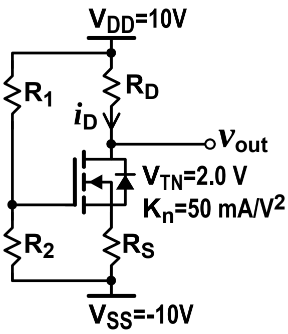

Figure 2

Procedure

1.a) Build the inverter circuit given in Figure **1** using $\mathbf{R_D = 100\ \Omega}$ and $\mathbf{V_{DD} = 10\ V}$. Place a MOSFET using "**nmos**" symbol and select the MOSFET part number **BSS145**.

1.b) Use a ramp function (`PULSE(0 5 0 10m 1u 1m)`) as v_{in} that rises from **0 V** to **5 V** in **10 ms** and set simulation time to **10 ms**. Run simulation and display $v_{in} = v_{GS}$, $v_{out} = v_{DS}$ and $i_{RD} = i_D$ on the waveform window. Determine the v_{GS} threshold voltage $\mathbf{V_{TN}}$ and the drain current coefficient $\mathbf{K_n}$ based on the waveform plots.

$\mathbf{V_{TN}}$ = $\mathbf{K_n}$ =

1.c) Measure the drain current i_D for v_{in} **= 3.0 V** and v_{in} **= 3.5 V** on the plotted waveforms and fill in the following table. Calculate the drain current i_D again based on $\mathbf{V_{TN}}$ and $\mathbf{K_n}$ found above.

	i_D calculated in preliminary work	i_D measured on the plotted waveforms	i_D calculated based on $\mathbf{V_{TN}}$ and $\mathbf{K_n}$ above
v_{in} **= 3.0 V**			
v_{in} **= 3.5 V**			

2.a) Build the circuit in Figure **3** and apply an input ramp function as v_{in} that rises from **0 V** to **10 V**.

2.b) Run simulation and display v_{in}, $v_{GS} = v_G - v_S$, $v_{DS} = V_{DD} - v_S$ and $i_{RS} = i_D$ on the waveform window. Verify that the values on drain current waveform can be calculated based on the $\mathbf{V_{TN}}$ and $\mathbf{K_n}$ values found above.

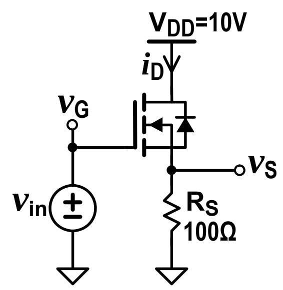

Figure 3

2.c) Explain the linearized behavior of the drain current i_D as a function of the input voltage v_{in}.
Hint: Write i_D as a function of v_{in} and describe the feedback mechanism (if v_{in} rises then $i_{RS} = i_D$ increases ⇒ v_S rises ⇒ v_{GS} decreases ⇒ $i_{RS} = i_D$ decreases).

3.a) Build the circuit in Figure **4** using the resistor values you calculated in the preliminary work. Set v_{in} to obtain a **1 kHz** sinusoidal source with **1 Vpeak** amplitude.

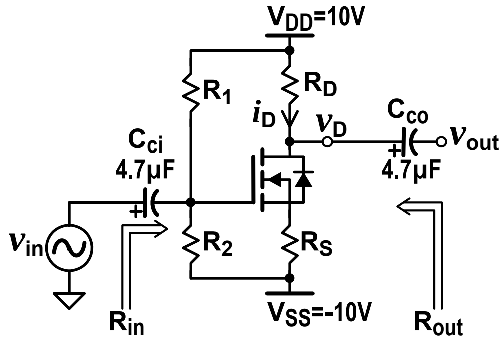

Figure 4

3.b) Run simulation and display v_{in}, v_{out}, v_D and $i_{RD} = i_D$ on the waveform window. Check the DC voltage at v_D and if necessary, adjust the resistor values to obtain a sinusoidal output without any clipping. If you changed any of the resistors, then explain why it was necessary.

Measure the output voltage and calculate the voltage gain.

V_{out} = A_v =

3.c) Connect a **100 kΩ** resistor between the input voltage source and the coupling capacitor, C_{ci}. Measure the voltage gain and use the results from step **3.b** to deduce the amplifier input resistance, R_{in}.

R_{in} =

3.d) Measure the output resistance, R_{out}, of the amplifier.

R_{out} =

3.e) Calculate R_{in} and R_{out} of the amplifier according to the circuit components and explain any deviations from the measured R_{in} and R_{out}.