| SANTA CLARA UNIVERSITY | ELEN 115<br>Spring 2023 | Dr. S. Krishnan |
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# Lab 7: Applications of the MOSFET in analog systems

## I. OBJECTIVES

- To study the MOSFET as a switch in sample and hold systems
- To study a MOS inverting amplifier

## II. LAB

### Part 1: MOSFET as a switch

#### A. NMOS switch

(a) Draw the MOS circuit given in Figure 1 in LTSpice. You will use the NMOS4 component from the library. Connect the bulk terminal to ground.

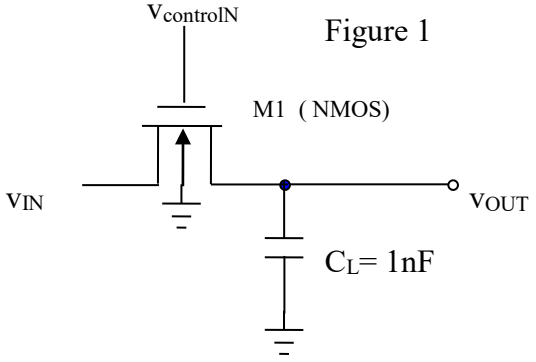


Figure 1

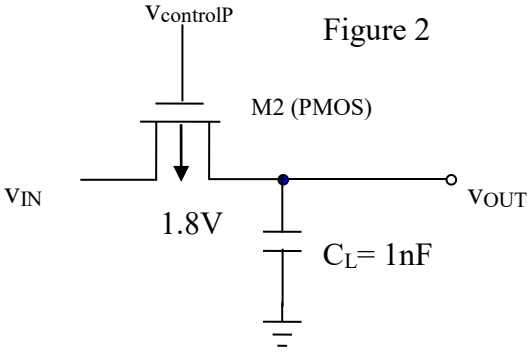


Figure 2

(b) Edit the MOSFET model for model parameters W=100µm, L=1µm.
(c) The sinusoidal input to $v_{IN}$ has a DC Offset of 0.9V and peak voltage 0.9V at a frequency of 100Hz.
(d) Connect a pulse to the gate voltage $v_{controlN}$ which switches from 0V to 1.8V with a time period of 1msec and pulse width of 0.5msec. Keep the rise and fall times at 1ns.
(e) The capacitor is 10nF.
(f) Run a transient simulation and plot input and output on one screen shot.
(g) Observe the voltage on the capacitor and explain the behavior.

#### B. PMOS switch

(a) Draw the MOS circuit given in Figure 2 in LTSpice. You will use the PMOS4 component from the library. Connect the bulk terminal to Vdd= 1.8V.
(b) Edit the MOSFET model for model parameters W=100µm, L=1µm.
(c) The sinusoidal input to $v_{IN}$ has a DC Offset of 0.9V and peak voltage 0.9V at a frequency of 100Hz.
(d) Connect a pulse to the gate voltage $v_{controlP}$ which switches from 1.8V to 0V with a time period of 1msec and pulse width of 0.5msec. Keep the rise and fall times at 1ns. The signal should be the complement of $v_{controlN}$
(e) The capacitor is 10nF.
(f) Run a transient simulation and plot input and output on one screen shot.

(g) Observe the voltage on the capacitor and explain the behavior.

**C. Transmission gate**

(a) Connect the NMOS and PMOS in parallel for this third circuit.
(b) Run a transient simulation and plot input and output on one screen shot.
(c) Observe the voltage on the capacitor and explain the behavior.

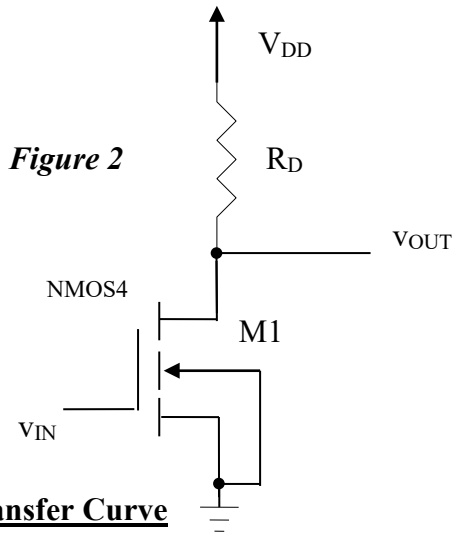
## Part 2: MOS inverting amplifier

(a) Draw the amplifier circuit in Figure 2.
(b) For the circuit and MOSFET use the following parameters:

$V_{DD}$ = 2.5V, $V_{to}$= 1V, k' = 30μA/$V^2$, λ = 0 , W/L = 100μm/1μm, $R_D$= 150KΩ

(c) Edit the MOSFET model to provide the model parameters as used in the prelab.
You can do this by including a command
.MODEL MYNMOS NMOS VTO=?? KP=?? LAMBDA=?? GAMMA=??

*Figure 2*




(d) **Voltage Transfer Curve**

Perform a DC sweep at the input $v_{IN}$ from 0 to 5V in steps of 50 mV.
Observe the voltage transfer curve (VTC) by plotting $v_{OUT}$ vs. $v_{IN}$.
Copy this plot and use this for the following observations.
Clearly indicate on the VTC, the regions of operation of the MOSFET.

**(e) MOS as an analog amplifier**

a. On your plot indicate for what portion the MOS transfer curve is linear.
b. Indicate what would be an optimal BIAS point for use of this circuit as an analog amplifier.
c. What is the gain at this point? Hint: Find the slope.
d. What is the input signal that can be given to satisfy the small signal approximation?
e. Give an input to this amplifier with the DC bias from (b) and signal input from (d).

f. Run a transient analysis with the input you obtain from € and observe the output signal. Note the DC and signal values.

**(f) MOS as a Logic Inverter**

a. Mark the portions of the curve that help you use the device as an inverter.

b. Find and note the values $V_{OH}$ and $V_{OL}$ from the VTC.

c. Run a transient analysis giving a pulse signal as logic input to this inverter and see the logic output. What do you observe for the high and low values at the output?

d. Find the current drawn from Vdd. Observe the values during the flat portions of the pulse and during the transitions from low to high and high to low. What do you observe for power consumed?

e. Increase $R_D$ to 500 KΩ and rerun part (c). What do you observe? What can you comment on the ideal load value for a perfect inverter.

## IV. REPORT

Prepare a detailed report that includes all simulation results. The lab report should contain the following:

Schematic printout of the circuits.
Printout of simulation results.
Answers to questions in the prelab and laboratory procedure.