ENGR 305 – Lab #4

NMOS I-V Characteristics

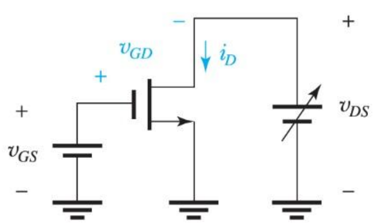
Objectives:

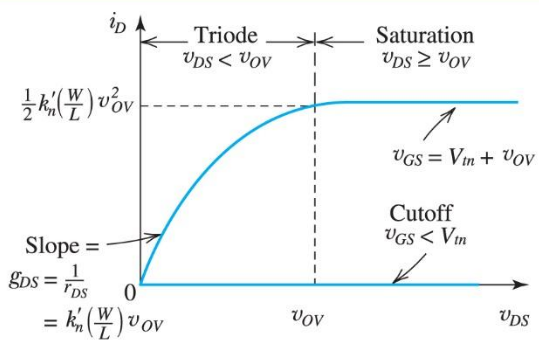
The objectives of this lab are to study NMOS I-V characteristics by (1) implementing a circuit and taking measurements of the I_D vs V_{GS} and I_D vs V_{DS} curves and (2) extracting values of k_n, V_{TN}.

Materials:

- Laboratory setup, including breadboard
- 1 enhancement-type NMOS transistor (2N7000)
- Several wires

Table 5.1 Regions of Operation of the Enhancement NMOS Transistor





- $v_{GS} < V_{tn}$: no channel; transistor in cutoff; $i_D = 0$
- $v_{GS} = V_{tn} + v_{OV}$: a channel is induced; transistor operates in the triode region or the saturation region depending on whether the channel is continuous or pinched off at the drain end;

Triode Region

Continuous channel, obtained by:

$$v_{GD} > V_{tn}$$

or equivalently:

$$v_{DS} < v_{OV}$$

Then,

$$i_D = k_n'\left(\frac{W}{L}\right)\left[(v_{GS} - V_{tn})v_{DS} - \frac{1}{2}v_{DS}^2\right]$$

or equivalently,

$$i_D = k_n'\left(\frac{W}{L}\right)\left(v_{OV} - \frac{1}{2}v_{DS}\right)v_{DS}$$

Saturation Region

Pinched-off channel, obtained by:

$$v_{GD} \leq V_{tn}$$

or equivalently:

$$v_{DS} \geq v_{OV}$$

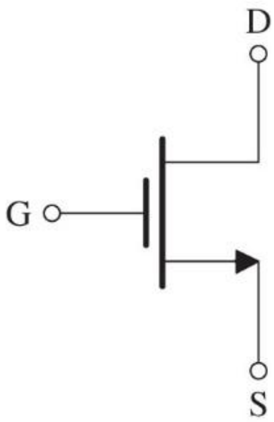
Then

$$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(v_{GS} - V_{tn})^2$$

or equivalently,

$$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)v_{OV}^2$$

The table shows the circuit setup for measurements of the NMOS transistor.



(c) Circuit symbol for n-channel enhancement mode MOSFET

Measurements:

I_D vs V_{GS}

While setting V_{DS} to a constant value of 5 V, sweep the gate voltage from 1.0 V to 3.5 V in increments of 0.25 V, and measure the drain current using the power supply (or handheld multimeter). Note that not all power supplies allow you to measure current accurately; if this is the case you may place a small resistor in series with the drain (100 Ω) and measure the voltage drop across the resistor. Plot a curve of I_D vs V_{GS}. At what value of V_{GS} does the NMOS turn on?

I_D vs V_{DS}

For three values of V_{GS} (2.5 V, 3.0 V and 3.5 V), sweep the drain voltage from 0 V to 3.5 V in increments of 0.5 V, and measure the drain current using the power supply (or handheld multimeter). Plot the curves for I_D vs V_{DS} onto a single graph, clearly indicating the value of V_{GS} next to each curve.

Post-measurement exercise:

1. **Threshold voltage, V_{TN}**
   From the measured I_D vs V_{GS} curve, at what value of V_{GS} does the NMOS turn on? Set this as the threshold voltage V_{TN}, of your transistor.

2. **MOSFET transconductance parameter, k_n**
   Based on the value of drain current I_D at V_{GS} = 3.0V, and using the saturation model for the transistor, i.e., $I_D = (1/2)k_n(V_{GS} - V_{TN})^2$, extract the value of $k_n = \mu_n C_{ox}(W/L)$. Using your extracted values of V_{TN} and k_n, plot a curve of I_D vs V_{GS}, using the saturation model. Compare with your measured curve.