EE236: Experiment No. 7
MOSFET I/V Characteristics and Device Parameters

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April 13, 2022

1 Overview of the experiment

1.1 Aim of the experiment

Aim of this experiment is to measure the threshold voltage (V_{TN}) of NMOS.
To measure the output DC characteristics, I_D vs V_{DS}.
To measure the I_D vs V_{GS} characteristics in the saturation region for NMOS and to obtain the small signal transconductance (g_m).

1.2 Methods

Firstly, we checked and ensured that the components given to me such as ALD1106, Zener diode and multimeters. Then, we performed Experiment 1 which was the forward I-V characteristics of Zener diode and plotted them. Then, we performed Experiment 2 in which we calculated the threshold voltage of NMOS, I_D vs V_{DS} and I_D vs V_{GS} characteristics of NMOS and Small Signal characteristics of NMOS. We built all the circuit on breadboard using all the components with connecting wires.

2 Design

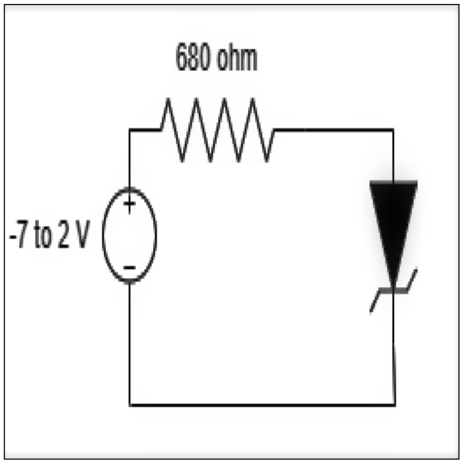


Fig. 1 : I-V Characteristics of Zener Diode

The circuit in Fig. 1 is for the I-V characteristics simulation of Zener diode. We gave the voltage supply from the DC power supply unit in steps of 0.5V from -7V to 2V. We noted the corresponding I_D and V_D values.

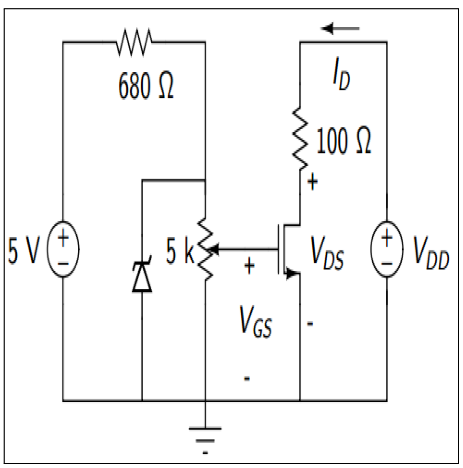


Fig. 2 : NMOS Characteristics

After that, we built the circuit in Fig. 2 on breadboard to calculate the threshold voltage, V_{TN} of and analyze I_D vs V_{DS} characteristics of NMOS. We ensured that V_{DS} was kept to be 200mV for all readings of V_{TN}. V_{GS} was varied using the 5k pot. We again noted the values.
For I_D vs V_{DS} characteristics, V_{GS} was kept a constant 2.5V throughout.

V_{DS} was varied in steps of 0.5V from 0 to 5V. The whole operation was repeated for V_{GS} = 3V and V_{GS} = 3.5V .

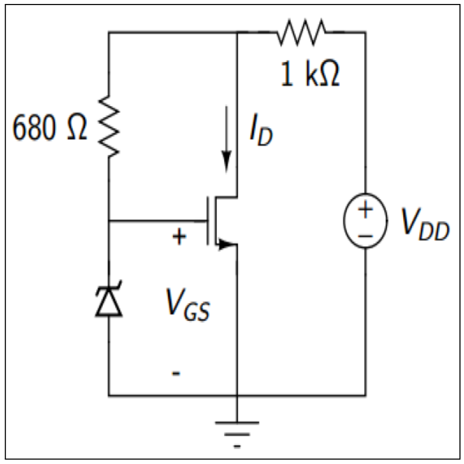


Fig. 3 : NMOS I_D vs V_{GS} Characteristics

Then, we built the circuit shown in Fig. 3 for plotting the I_D vs V_{GS} characteristics of NMOS. The circuit ensured that the device is always in saturation. VGS was varied in steps of 0.5V from 0 to 5V by varying V_{DD} values.

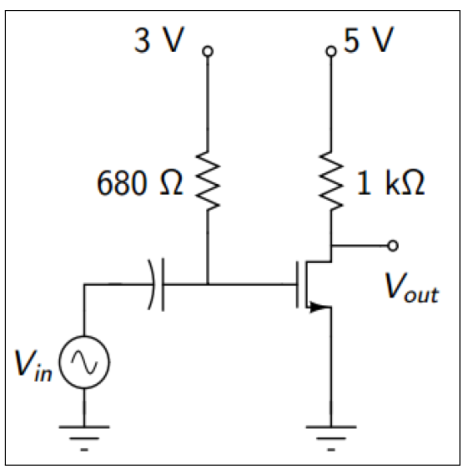


Fig. 3 : NMOS Small Signal Analysis

A sine wave input was applied having the parameters as 100mV peak-to-peak and 1kHz frequency using Arbitrary Function Generator (AFG). The output waveform was obtained in a Digital Storage Oscilloscope (DSO) to calculate the small signal parameters.

3 Simulation results

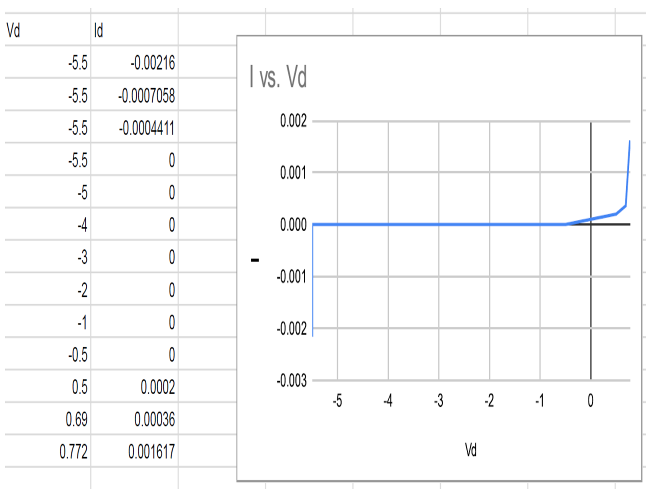
3.1 Code Snippets

Not applicable for this experiment.

3.2 Simulation results

Not applicable for this experiment.

4 Experimental results



Vd	Id
-5.5	-0.00216
-5.5	-0.0007058
-5.5	-0.0004411
-5.5	0
-5	0
-4	0
-3	0
-2	0
-1	0
-0.5	0
0.5	0.0002
0.69	0.00036
0.772	0.001617

Fig. 5 : I_D-V_D Characteristics of Zener diode

Fig. 5 shows the I_D-V_D Characteristics graph of zener diode. Also, values used for plotting the graph are given aside. Breakdown voltage for the given zener diode was around **-5.8V**.

Part 2 i	At Vdd = 0.2V	
Vgs	Id	
0.5	0.01	
0.8	0.02	
1	0.05	Vt = 0.78
1.5	0.15	gm = 1.02e-4
2	0.22	SS = 997.88
2.5	0.29	
3	0.35	
3.5	0.4	
4	0.46	
4.5	0.51	
5	0.55	

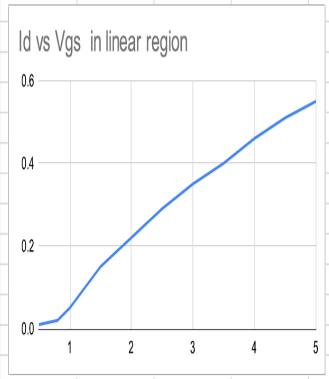


Fig. 6 : I_D-V_{GS} Characteristics of NMOS

Fig. 6 shows the I_D-V_{GS} Characteristics graph of NMOS. Also, values used for plotting the graph are given aside. Threshold voltage (V_{TN}) voltage for the given NMOS diode was around **0.78V**. Whereas, the transconductance (g_m) was around $\mathbf{1.02{\times}10^{-4}}\Omega^{-1}$.

Part 2 ii			
Vds	Id at Vgs 2.5	Id at Vgs 3	Id at Vgs 3.5
0	0	0	0
0.5	0.68	0.86	1.02
1	1.06	1.44	1.79
1.5	1.24	1.79	2.31
2	1.27	1.92	2.61
2.5	1.29	1.96	2.73
3	1.31	1.98	2.77
3.5	1.32	2	2.79
4	1.33	2.01	2.81
4.5	1.34	2.03	2.83
5	1.35	2.04	2.85
ro (ohm)	50k	35k	25k

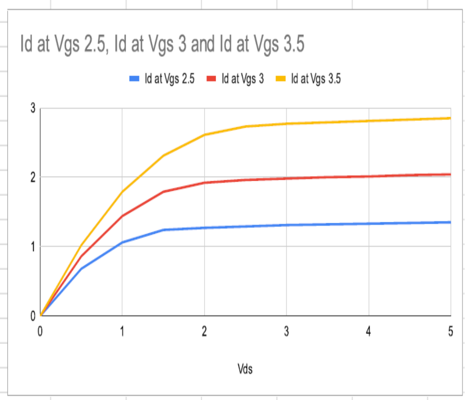
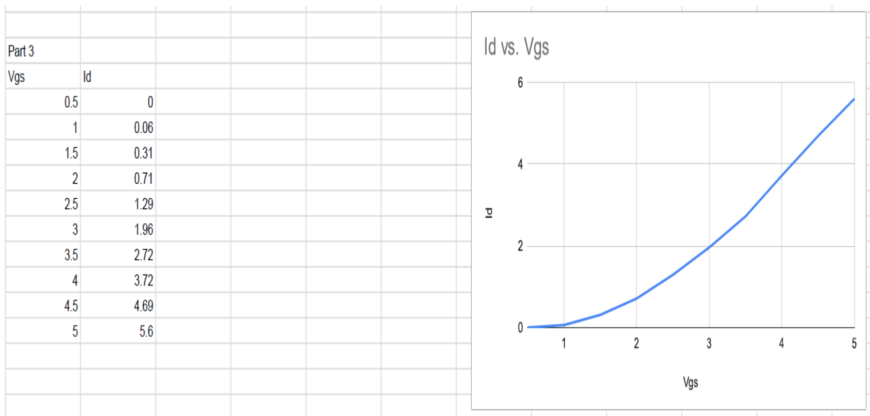


Fig. 7 : I_D-V_{DS} Characteristics of NMOS

Fig. 7 shows the I_D-V_{DS} Characteristics graph of NMOS. Also, values used for plotting the graph are given aside. V_{GS} values are varied as 2.5V, 3V and 3.5V. I_D increases with increase in V_{GS}. Output impedance values are 50kΩ, 35kΩ and 25kΩ.



Part 3

Vgs	Id
0.5	0
1	0.06
1.5	0.31
2	0.71
2.5	1.29
3	1.96
3.5	2.72
4	3.72
4.5	4.69
5	5.6

Fig. 8 : I_D-V_{GS} Characteristics of NMOS

Fig. 8 shows the I_D-V_{GS} Characteristics graph of NMOS. Also, values used for plotting the graph are given aside.
Now, for the small signal analysis, following are the results we observed using DSO.
Av = 2.42
Vout = 242mV
gm = 2.42m Ω^{-1}

5 Experiment completion status

I have completed all sections as well as exercises in this lab.

6 Questions for reflection

Q1 Find out effect on threshold voltage of NMOS, if (a) Positive Body voltage is applied and (b) Negative Body voltage is applied.
Answer : For a positive body voltage, the threshold voltage decreases. For negative body voltage, threshold voltage decreases.
Q2 Subthreshold slope is a key metric for any switching device. Why?
Answer : Switching devices operate in the cut-off region, i.e. $V_{GS} < V_T$, when off and in saturation when on. During transition and in the off state, subthreshold current affects performance.
Q3 The linear I_D-V_{GS} curve is not perfectly linear. It's slope increases first

and decreases after attaining a peak value. For such a case, find out accurate method to calculate the Threshold voltage.

Answer : The most accurate method to find threshold voltage is to extrapolate the region of the graph with the highest slope as around this point the parasitic effects of R_{DS} are low.

Q4 Given the I_D-V_{GS} characteristics in saturation, How will you find Threshold voltage?

Answer : We can solve for

$$I_{DS} = \frac{1}{2}\mu_n C_{ox}(V_{GS} - V_T)^2$$

using any three points for calculation.

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