EE 236: Experiment No. 7
MOSFET I/V Characteristics and Device Parameters

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1 Overview of the experiment

1.1 Aim of the experiment

The following were the aims of the experiment:

- To measure the threshold voltage, V_{TN}.
- To measure the output DC characteristics, I_D vs V_{DS}.
- To measure the I_D vs V_{GS} characteristics in the saturation region.
- To obtain the small signal transconductance, g_m.

1.2 Methods

The method overview includes constructing the circuits as per given specifications on the breadboard using the zener diode, IC ALD1106, and the given resistors. Power supply was taken from the WEL lab DC supply unit. Two Digital Multimeters were used for the measurements.

2 Design

2.1 Experiment 1 - Zener Diode I-V Characteristics

The following circuit was implemented on a breadboard:

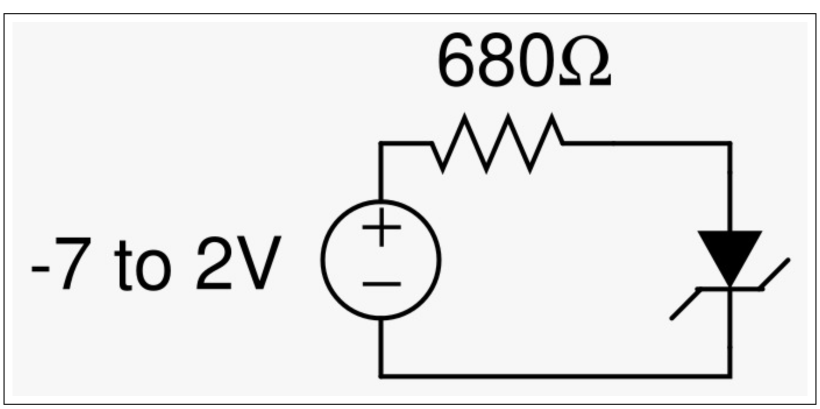

Figure 1: The Zener I-V Characterization Circuit

Supply was given and varied from the DC power supply unit in steps of 0.5V from -7V to 2V. The corresponding V_D and I_D values were recorded. Note that both the source and body were grounded.

2.2 Experiment 2 - NMOS

2.2.1 Threshold Voltage of NMOS

The following circuit was implemented on a breadboard:

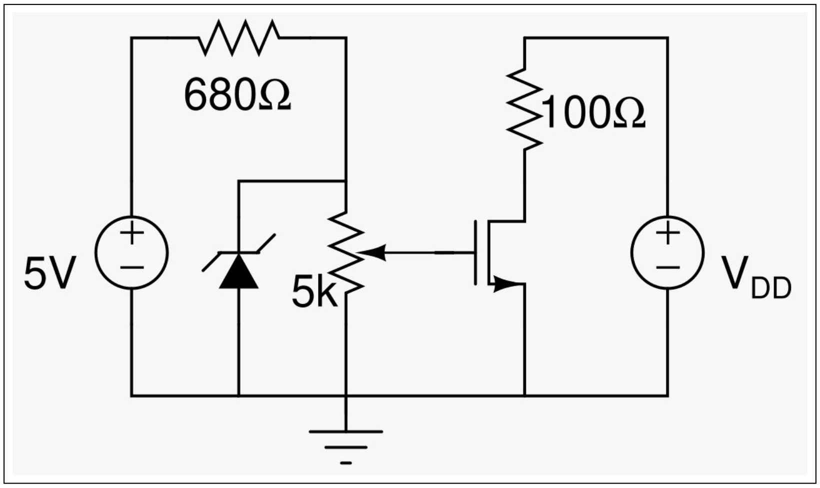

Figure 2: Expt. 2 Part 1 and 2

Supply was given from the DC power supply unit. It was ensured that V_{DS} be kept = 200mV for all readings. V_{GS} was varied using the 5k pot approximately in steps of 0.5V from 0 to 4.41V (highest possible value). The values of I_D were recorded and plots obtained.

2.2.2 I_D-V_{DS} Characteristics

Now, V_{GS} was kept a constant 2.5V throughout. V_{DS} was varied in steps of 0.5V from 0 to 5V and corresponding values of I_D were recorded. The whole operation was repeated for $V_{GS} = 3V$ and $V_{GS} = 3.5V$.

2.2.3 I_D-V_{GS} Characteristics in Saturation

The following circuit was implemented on a breadboard:

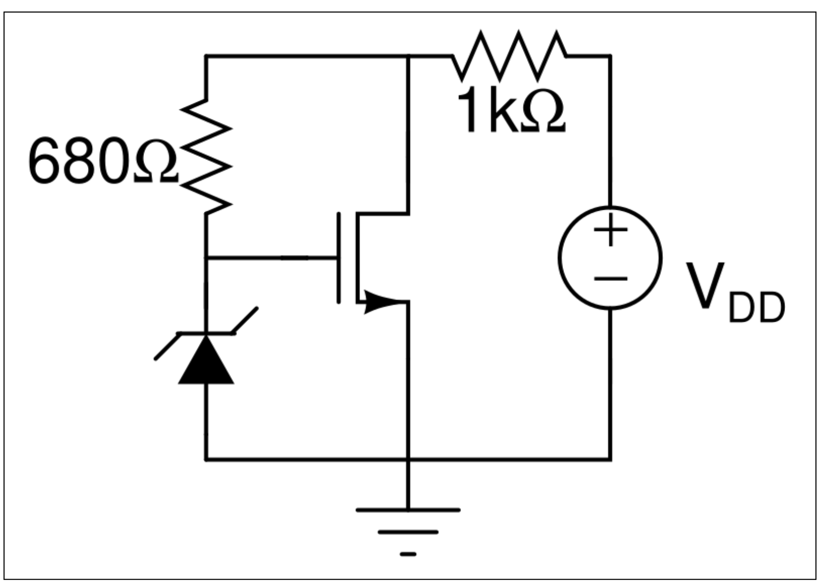

Figure 3: Expt. 2 Part 3

The circuit ensures that the device is always in saturation. V_{GS} was varied in steps of 0.5V from 0 to 5V by varying V_{DD} and corresponding values of I_D were recorded.

2.2.4 Small Signal Transconductance

The following circuit was implemented on a breadboard:

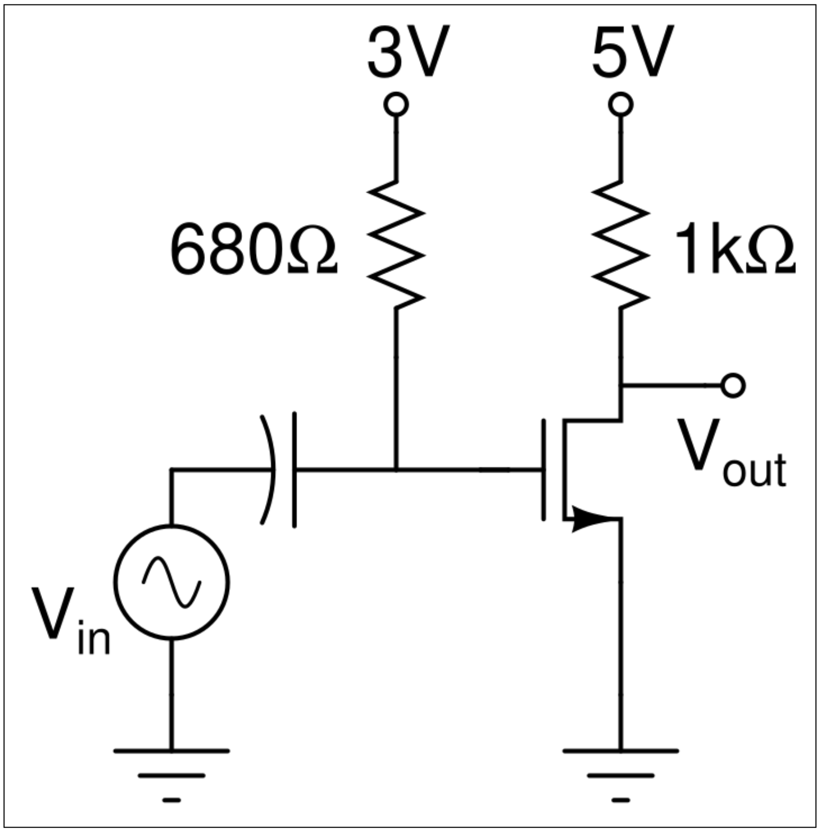

Figure 4: Expt. 2 Part 4

A sine wave with parameters: 100mV_{p-p} and 1kHz, was applied at the input using an Arbitrary Function Generator (AFG). The output waveform was obtained in a Digital Storage Oscilloscope (DSO) along with the output p-p and hence gain.

3 Experiment results

3.1 Experiment 1 - Zener Diode I-V Characteristics

Experiment - 1 (Zener Diode I-V)

V	Vd	Id
-7	-5.58	-1.899
-6.5	-5.56	-1.462
-6	-5.56	-0.709
-5.5	-5.54	-0.054
-5	-5.06	-0.0048
-4.5	-4.55	-0.0012
-4	-4.03	-0.0005
-3.5	-3.55	-0.0003
-3	-3.09	-0.0002
-2.5	-2.53	-0.0002
-2	-2.03	-0.0001
-1.5	-1.52	-0.0001
-1	-1.06	-0.0001
-0.5	-0.57	0
0	0	0
0.5	0.47	0.001
1	0.67	0.444
1.5	0.69	0.992
2	0.71	1.648

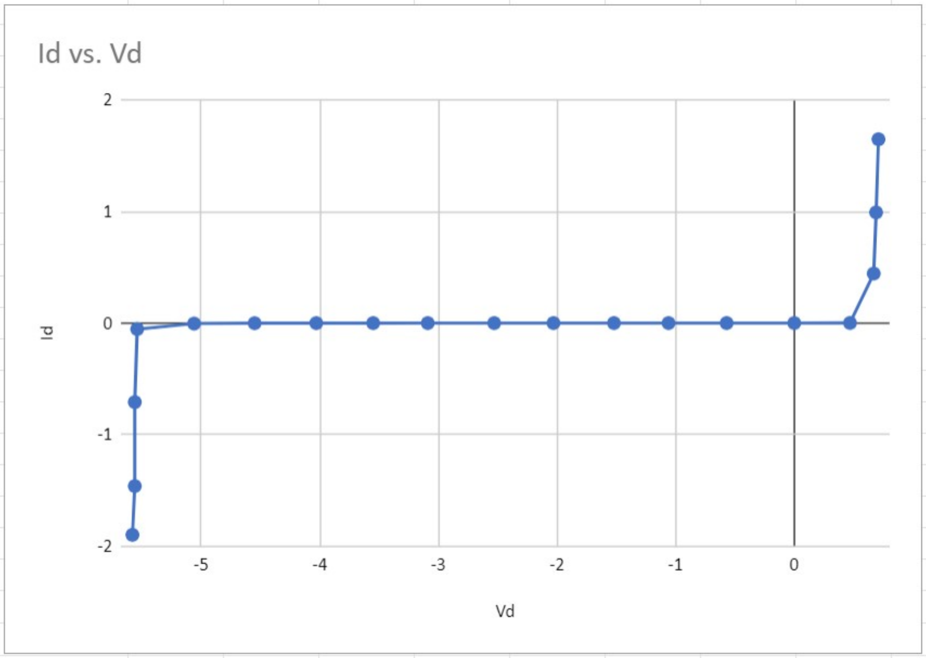

Figure 5: Zener $I_D - V_D$ Characteristics

Breakdown voltage = **-5.56V**.

3.2 Experiment 2 - NMOS

3.2.1 Threshold Voltage of NMOS

Experiment - 2 (Threshold Voltage NMOS)

Part-1

Vgs	Id	Slope (gm)	SS
0	0	0	
0.26	0	0.006206896552	0
0.55	0.0018	0.0728	0.0247252
0.8	0.02	0.1833333333	
1.22	0.097	0.1725	
1.62	0.166	0.25	
2.02	0.266	0.14375	
2.5	0.335	0.1865384615	
3.02	0.432	0.188	
3.52	0.526	0.1229166667	
4	0.585	0.1268292683	
4.41	0.637	0.1444444444	

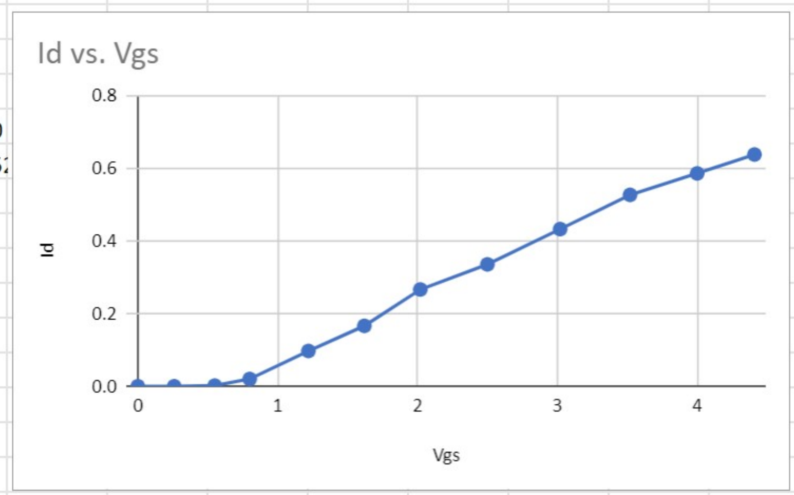

Figure 6: $I_D - V_{GS}$ Characteristics to find V_T

Threshold voltage, V_T = **0.8V**. Above 0.8V, g_m is maximum for $V_{GS} = 1.62V$.

3.2.2 I_D-V_{DS} Characteristics

Part2			
Vds	Id for Vgs=2.5	Id for Vgs=3	Id for Vgs=3.5
0	0	0	0
0.5	0.685	0.897	1.06
1	1.13	1.468	1.83
1.5	1.288	1.825	2.36
2	1.324	1.966	2.64
2.5	1.342	1.99	2.75
3	1.355	2.02	2.79
3.5	1.367	2.05	2.82
4	1.377	2.06	2.84
4.5	1.386	2.07	2.86
5	1.395	2.08	2.88

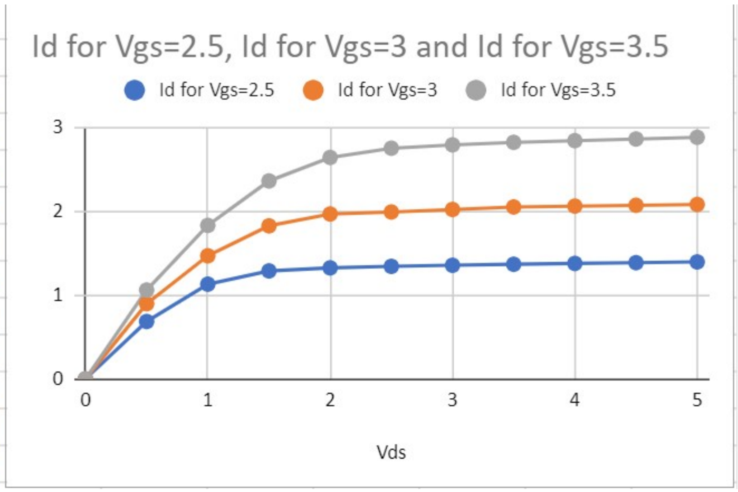

Figure 7: $I_D - V_{DS}$ Characteristics for different V_{GS}

Vds	Id for Vgs=2.5	Id for Vgs=3	Id for Vgs=3.5	Slope for Vgs=2.5	Slope for Vgs=3	Slope for Vgs=3.5
0	0	0	0	1.37	1.794	2.12
0.5	0.685	0.897	1.06	0.89	1.142	1.54
1	1.13	1.468	1.83	0.316	0.714	1.06
1.5	1.288	1.825	2.36	0.072	0.282	0.56
2	1.324	1.966	2.64	0.036	0.048	0.22
2.5	1.342	1.99	2.75	0.026	0.06	0.08
3	1.355	2.02	2.79	0.024	0.06	0.06
3.5	1.367	2.05	2.82	0.02	0.02	0.04
4	1.377	2.06	2.84	0.018	0.02	0.04
4.5	1.386	2.07	2.86	0.018	0.02	0.04
5	1.395	2.08	2.88	0.279	0.416	0.576

Figure 8: Slopes of graph for different V_{GS}

Ignoring the last values of slopes, the slopes for the three curves are 0.018, 0.02, and 0.04. Using these values at $V_{DS} = 4.5V$, we get early voltage as:

$$V_A = \frac{I_1 V_2 - I_2 V_1}{I_1 - I_2}$$

$$V_{A,2.5} = -72.5V$$

$$V_{A,3} = -99V$$

$$V_{A,3.5} = -67V$$

Taking average, $V_A = -79.5V$.

3.2.3 I_D-V_{GS} Characteristics in Saturation

Part3	
Vgs	Id
0	0
0.5	0.0003
1	0.0703
1.5	0.317
2	0.759
2.5	1.316
3	2.02
3.5	2.83
4	3.73
4.5	4.71
5	5.76

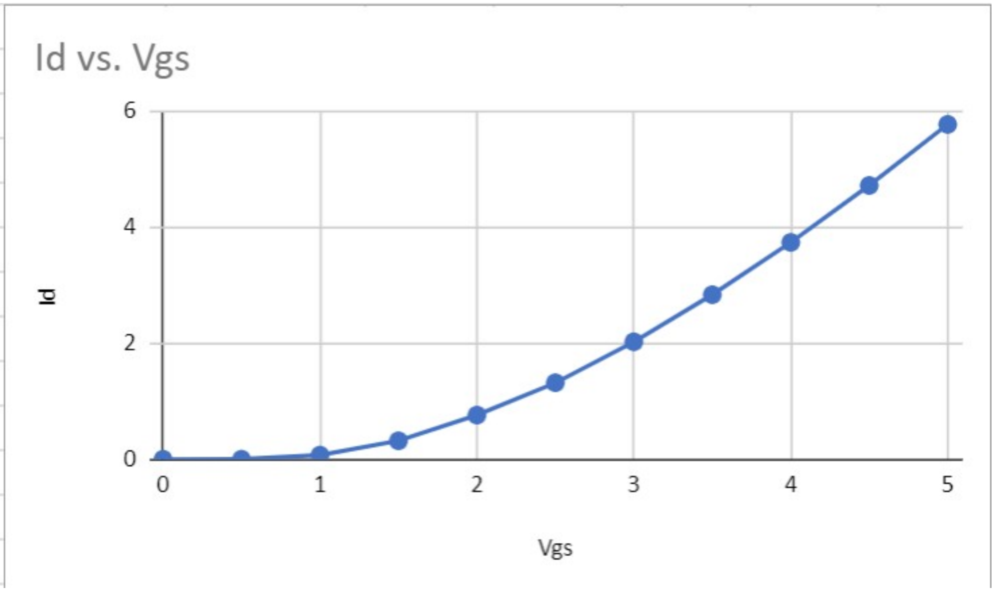

Figure 9: $I_D - V_{GS}$ Characteristics

The I_D rises faster until it somewhat reaches a linear behaviour.

3.2.4 Small Signal Transconductance

Input p-p voltage = 100mV
Output p-p voltage = 310mV
Gain = 3.1
Therefore, since $|A_v| = g_m R_D$.

$$g_m = 3.1/1k = 3.1 \times 10^{-3}$$

4 Post Lab Questions

Q1 For a positive body voltage, the threshold voltage decreases. For negative body voltage, threshold voltage decreases.

Q2 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 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 We can solve for $I_{DS} = \frac{1}{2}\mu_n C_{ox}(V_{GS} - V_T)^2$ using three points.

5 Experiment completion status

I could complete all the parts of the lab. The results were shown to the TA and then submitted.