**Laboratory Six**

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**EE348L – Electronic Circuits**

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**Introduction**

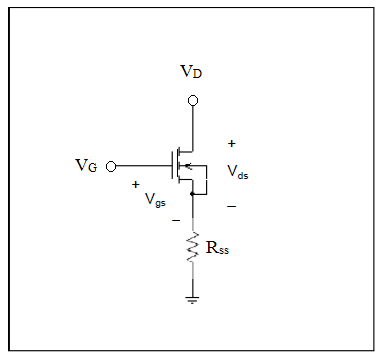
In this laboratory, implementation of hand analysis and HSPICE simulations were done to understand the behavior of MOSFETs (MOS Field-Effect Transistor). Furthermore, different circuits were built in class with the MOSFET and different tests were done to corroborate our hand calculations and simulation results.

Exercise 1

**Procedure**

A circuit was built using a MOSFET and a resistor using the value of VD = 5V and RSS = 50Ω. ID was measured while varying VGS from 0V to 5V in 0.25V increments. The results were plotted and µn and Vth for this transistor were calculated.

**Data**



Schematic of the circuit

|  |  |
| --- | --- |
| Vgs | Sqrt(I) |
| 0 | 0 |
| 0.25 | 0 |
| 0.5 | 0 |
| 0.75 | 0 |
| 1 | 0 |
| 1.25 | 0 |
| 1.5 | 0 |
| 1.75 | 0.045 |
| 2 | 0.243 |
| 2.25 | 0.986 |
| 2.5 | 2.517 |
| 2.75 | 4.392 |
| 3 | 6.199 |
| 3.25 | 7.845 |
| 3.5 | 9.315 |
| 3.75 | 14.141 |
| 4 | 14.142 |
| 4.25 | 14.142 |
| 4.5 | 14.142 |
| 4.75 | 14.142 |
| 5 | 14.142 |

Gate-Source Voltage and Current Values

Gate-Source Voltage and Current Graph

|  |  |
| --- | --- |
| Vgs | Sqrt(I) |
| 2.25 | 0.972196 |
| 2.5 | 6.335289 |
| 2.75 | 19.289664 |
| 3 | 38.427601 |
| 3.25 | 61.544025 |
| 3.5 | 86.769225 |

Gate-Source Voltage and Current Values only in the Linear Region

Gate-Source Voltage and Current Graph only in the Liner Region

**Questions**

From the linear region, we get that IS0.5 = 6.7925\*Vgs – 14.319.

µn-

m = 6.7925\*101.5 A0.5/V. Now, plug in the values to the formula µn = (2\*L\*m2)/(Cox\*W) and µn is equal to 806 cm2/(Vs).

Vth-

To find Vth, the intercept with the x-axis must be found making IS = 0 and VGS = Vth. Therefore, Vth = 2.1V.

The values for µn and Vth are different as the ones from the pre-lab. The value for thermal voltage is larger than the one from the pre-lab 0.83V. This change in thermal voltage is due to the component we used. Additionally, µn is different due to the fact that we used a model to compute the pre-lab value, but in reality the MOSFET can have holes from its process of fabrication.

**Discussion**

Even though the actual laboratory results do not perfectly match the results from the pre-lab exercises, the results are similar. Therefore, the MOSFET and the circuit respond similarly to the voltage and current variations even if the MOSFET properties of the actual device do not perfectly match with the ones from the simulation.

Exercise 2

**Procedure**

The pre-lab Problem 2 was repeated using the results from laboratory Exercise 1. Gm versus VGS was plotted.

**Data**



Mathematical Formula used to calculate Gm

|  |  |
| --- | --- |
| Vgs | gm |
| 0 | 0 |
| 0.25 | 0 |
| 0.5 | 0 |
| 0.75 | 0 |
| 1 | 0 |
| 1.25 | 0 |
| 1.5 | 0 |
| 1.75 | 0.008 |
| 2 | 0.228 |
| 2.25 | 3.656 |
| 2.5 | 21.456 |
| 2.75 | 51.812 |
| 3 | 76.56 |
| 3.25 | 92.48 |
| 3.5 | 100.88 |

Gate-Source Voltage and Transconductance Values

Gate-Source Voltage and Transconductance Graph

**Questions**

The slope of gm from the plot is larger and the linear region is not ideal as the plot from the pre-lab Problem 2.

**Discussion**

The results shown in this laboratory exercise show that even though the results from the pre-lab and the actual laboratory experiments are not the same, they match and have similar results because both of them have a linear region and the curve starts increasing after the Vth value.

Exercise 3

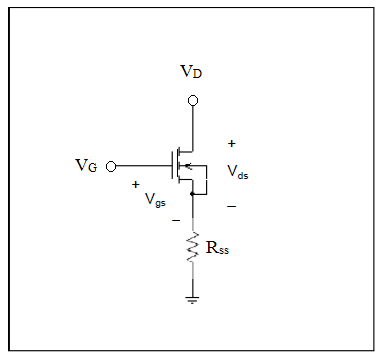
**Procedure**

The pre-lab Problem 3 was done, but with measurements instead of calculations. VD was set to 7V and VGS was set from 0V to 5V in 0.25V increments

**Data**



Mathematical Formula used to calculate Gds



Schematic of the circuit

|  |  |
| --- | --- |
| Vgs | ro |
| 0 |  |
| 0.25 |  |
| 0.5 |  |
| 0.75 |  |
| 1 |  |
| 1.25 |  |
| 1.5 |  |
| 1.75 |  |
| 2 | 333333 |
| 2.25 | 32787 |
| 2.5 | 12270 |
| 2.75 | 3704 |
| 3 | 2062 |
| 3.25 | 820 |
| 3.5 | 985 |

Gate-Source Voltage and ro Values

Gate-Source Voltage and ro Graph

**Questions**

Both graphs look very similar because their behavior and order of magnitude matches with the expectations we had from the experiment.

**Discussion**

The precision from the laboratory experiment the the pre-lab exercise vary because we would get more decimal points from the pre-lab exercise and it is really complicated to get those precision values in a laboratory environment. Nevertheless, the results show the behavior expected from the circuit and match the expectations.

Exercise 4

**Procedure**

The procedure in pre-lab Problem 4 was followed using the results from laboratory Exercises 2 and 3. This was done in order to determine the optimal biasing voltage range from measured data.

**Data**

|  |  |  |  |
| --- | --- | --- | --- |
| Vgs | ro | gm | gm\*ro |
| 0 | - | - | - |
| 0.25 | - | - | - |
| 0.5 | - | - | - |
| 0.75 | - | - | - |
| 1 | - | - | - |
| 1.25 | - | - | - |
| 1.5 | - | - | - |
| 1.75 | - | - | - |
| 2 | 333333 | 0.228 | 75999.924 |
| 2.25 | 32787 | 3.656 | 119869.272 |
| 2.5 | 12270 | 21.456 | 263265.12 |
| 2.75 | 3704 | 51.812 | 191911.648 |
| 3 | 2062 | 76.56 | 157866.72 |
| 3.25 | 820 | 92.48 | 75833.6 |
| 3.5 | 985 | 100.88 | 99366.8 |

Gate-Source Voltage and gm\*ro Values

Gate-Source Voltage and gm\*ro Graph

**Questions**

The bias current for the intrinsic gain is 6.337 mA for Vds equal to 5V and 6.5 mA for Vds equal to 7V.

**Discussion**

The magnitude of the intrinsic transistor gain is what we expected from the experiment. On the pre-lab exercise, our result was a gain that was approximately 10 times as larger as the gain obtained in the actual experiment. This is a carry-on error due to the fact that from the simulations we got larger values for ro and because we were using a perfectly built model in the simulations. This affects the actual results because in real life, the MOSFETs can have fabrication errors. Even though the values are smaller in the actual experiment, the behavior for the gain is similar to the one from the simulations.

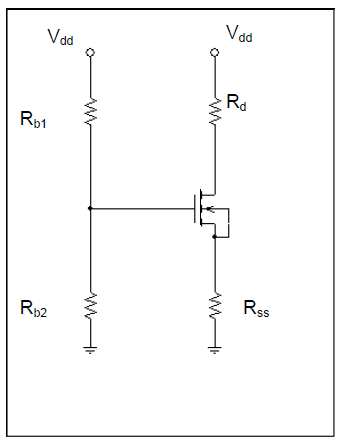
In our previous calculations based on the SPICE simulation, we had determined that Vth was around the value of 2.1V. From the experiment, the optimal biasing condition for our transistor occurs at Vgs equal to 2.5V. Therefore, both results are close numbers and the simulation and the circuit results match.

Exercise 5

**Procedure**

The circuit in the “Data” section was built but instead of using a resistor for Rb2, a potentiometer was used and adjusted until the gate voltage reached 3.75V.

**Data**



Schematic of the circuit

|  |  |
| --- | --- |
| Rss | 500 |
| Rd1 | 1492 |
| Rb1 | 988 |

Resistor values for the experiment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Rd2 (Ω) | Vs (V) | Vg (V) | Ids (mA) |
| Initial Values | 3000 | 3.735 | 1.245 | 2.49 |
| Final Values | 1250 | 0.508 | 2.765 | 1.016 |

Values that change during the experiment

**Questions**

The current through the transistor is not within ± 2% of the specifications the circuit was designed for because Vs = 1.245V, Rss = 500 Ω. Id = 1.245/500 = 2.49 mA. Therefore, the values of Rd2, Vs, Vg, and Ids were adjusted to get a current that was within the desired range of ±2%. The potentiometer was adjusted until the current through the transistor was 1 mA. Vg = 2.765V, Vs = 0.508V, Id = 1.016 mA.

**Discussion**

The difference in results from the theoretical results and the measured data is due to the fact that the simulation model is practically perfect compared to the actual components used in the lab. Another reason is because the assumption for the value of thermal voltage, Vth, was done setting the value to 3V. We can discuss that Vth is a major influence in our results because in previous experiments we got the thermal voltage value equal to 2.1V.

**Conclusion**

The experimental results could have been more accurate if the MOSFET used in the experiment would have the exact same properties used in the simulations. The results clearly agree with the objective of the lab that is to learn how MOSFETs behave. In addition, we use HSpice and WaveView Analyzer to corroborate our hand calculations and our measured values. The mathematical expressions and formulas were reinforced with this laboratory.