Lab #3: MOSFET Regions of Operation

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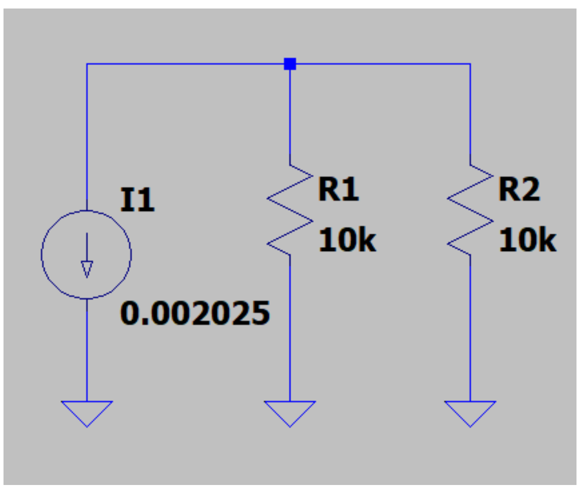
Abstract

In this Experiment students will learn about the different regions of operations for a MOSFET device. This will be achieved through designing circuit devices for different circuit applications.

1 Pre-lab

- For the circuit shown in the figure below, calculate the current that flows in each resistor.



- Assuming that an NMOS is operating in the saturation region and a $k_p = \frac{100\mu A}{V^2}$,$V_{GS} = 5V$ and $V_{th} = 0.5V$, find $\frac{W}{L}$ that generates an $I_D = 0.002025A$.

2 Lab Tasks:

2.1 Task #1:

- Replace the current source in the circuit shown in the pre-lab with an NMOS device (Use the NMOS parameters in the pre-lab). Note that the

NMOS needs to be biased so that it delivers a fixed I value. Here, you will be met with a challenge of choosing a V_{DS} and V_{GS} values, in your opinion, how those values should be chosen?

- Upon choosing the V_{DS} & V_{GS} values, show through simulation that the current delivered by the source is shared equally between $R_1$and R_2.

- An independent current source is assumed to deliver a fixed current regardless of the changes applied to the circuit. Show that the source you have developed is satisfying this condition by changing $R_1$to 5 $K\Omega$. You should observe that the current I_1 does not change, its only the current through R_1 that is adjusted.

2.2 Task #2:

- Assume that you are limited to the width and length values you found in the pre-lab section but not limited to the number of NMOS devices you can use, and you are tasked to adjust current source in task #1 to deliver $2I_1$, show theoretically how you can achieve this task and sketch the circuit. (Show the instructor your solution before moving forward to the following step)

- Simulate your proposed solution and show that the new circuit indeed delivers $2I$.

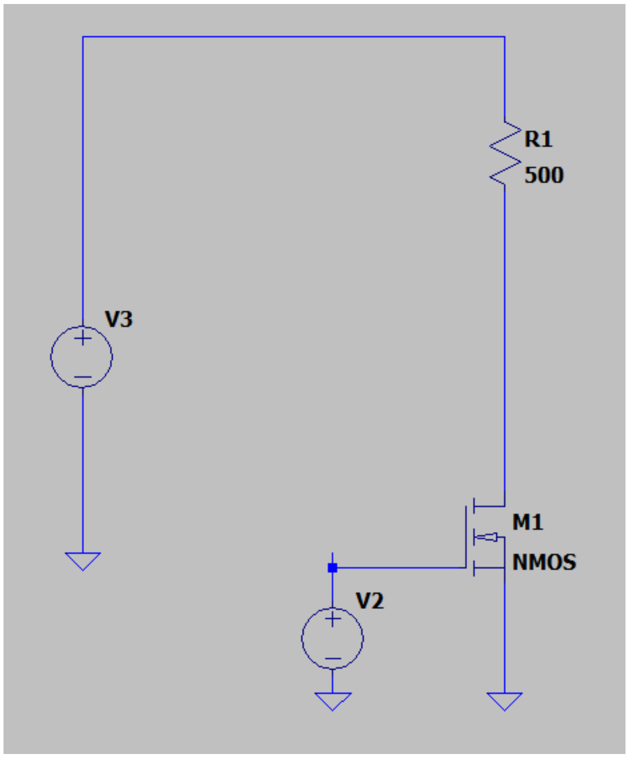
2.3 Task #3:

You have learned that a MOS device can be used as a voltage controlled resistor. In this section you will implement the MOS as a resistor:

- Using the physical dimensions for the MOS device in the pre-lab section, design an NMOS circuit with an $R_{ON} \approx 500\Omega$. This means you need to use the R_{ON} equation in your notes and solve for V_{GS} (what is the region of operation that guarantees a resistive behavior for the NMOS?). Answering this question should help you assign the appropriate V_{DS} value. Sketch the circuit and show your design to the instructor.

- Simulate the circuit in the previous step using LT-spice and verify that the simulation results match your analytical results.

- Create a voltage divider out of the NMOS circuit you simulated in the previous step and an additional resistor of $R = 500\Omega$ and a 10V DC source as shown in the circuit below. Since you have designed the NMOS to model a 500Ω resistor then V_{DS} should be ≈ 5 V. Verify this via simulation. Adjust V_{GS} so that the voltage across the NMOS (i.e. V_{DS}) drops to 3 V, then repeat the process for a $V_{DS} = 2$ V. Verify those results mathematically by calculating the corresponding R_{ON} for every V_{GS} case.


R1
500
V3
M1
NMOS
V2