Department of Electrical Engineering

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Semester: 4th **Section: D**

EE215: ELECTRONIC DEVICES AND CIRCUITS

Lab 09: MOSFET operation and IV characteristics

Name	Reg. No	PLO4/CLO4		PLO5/CLO5	PLO8/CLO6	PLO9/CLO7
		Viva /Quiz / Lab Performance 5 marks	Analysis of data in Lab Report 5 marks	Modern Tool Usage 5 marks	Ethics and Safety 5 marks	Individual and Teamwork 5 marks
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Lab 09: MOSFET operation and IV characteristics

Objective

- To gain working knowledge of an n-Channel Metal Oxide Semiconductor Field effect Transistor (MOSFET) in Common-source configuration by studying I-V characteristics

EQUIPMENT REQUIRED

The following components and test equipment is required.

- MOSFET 2N7000
- Multimeter
- Resistors
- DC Power Supply

The Experiment:

The experiment is broken down into two exercises. The first exercise involves the simulation of the circuit on PSpice using OrCAD-Capture module. The second one involves the practical setup of the circuit and making required measurements, tabulation, and its analysis.

Theory:

MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) is a type of transistor that is commonly used in electronic circuits as a switch or an amplifier. It is made up of three layers: a source, a gate, and a drain. The gate is separated from the other two layers by a thin layer of insulating material called the gate oxide.

When a voltage is applied to the gate, an electric field is created between the gate and the source, which controls the flow of current between the source and the drain. MOSFET operates in three different regions: the cutoff region, the saturation region, and the linear or triode region.

In the cutoff region, the MOSFET is effectively turned off, and there is no current flowing between the source and the drain. In the saturation region, the MOSFET is fully turned on, and there is a maximum current flowing between the source and the drain. In the linear or triode region, the MOSFET is partially turned on, and the current flowing between the source and the drain is proportional to the voltage applied to the gate.

MOSFET: N-Channel
Enhancement Type

MOSFET: P-Channel
Enhancement Type

MOSFET: N-Channel
Depletion Type

MOSFET: P-Channel
Depletion Type

MOSFETs have several advantages over other types of transistors, such as low power consumption, high input impedance, and high switching speed. They are commonly used in digital circuits, power amplifiers, and switching circuits, among other applications.
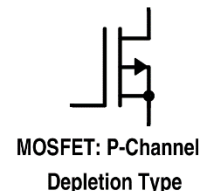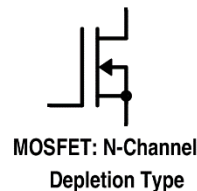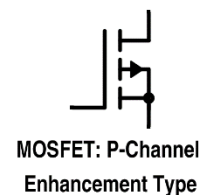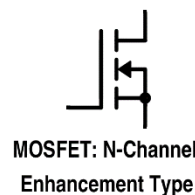
IV characteristics:

The IV characteristics of a MOSFET show how the current flowing between the source and drain changes with the voltage applied to the gate. These characteristics can be described in terms of the MOSFET's operating modes: cutoff, triode, and saturation.

In the cutoff region, the MOSFET is not conducting, and the current between the source and drain is very small, even when a voltage is applied to the drain. This occurs when the voltage applied to the gate is below the MOSFET's threshold voltage, which is the minimum voltage required to create a conducting channel between the source and drain.

In the triode region, the MOSFET is partially conducting, and the current between the source and drain increases linearly with the voltage applied to the gate. This region occurs when the voltage applied to the gate is above the threshold voltage, but not high enough to fully turn on the MOSFET. In this region, the MOSFET behaves like a variable resistor, and the current flowing through the MOSFET is proportional to the voltage applied to the gate.

In the saturation region, the MOSFET is fully conducting, and the current between the source and drain is almost constant, regardless of the voltage applied to the gate. This region occurs when the voltage applied to the gate is high enough to fully turn on the MOSFET, and the MOSFET behaves like a switch, allowing a large current to flow between the source and drain.

The IV characteristics of a MOSFET can be visualized on a graph of drain current versus drain-source voltage, with the gate-source voltage as a parameter. The characteristics are typically shown for different gate-source voltages, allowing the MOSFET's behavior to be observed across a range of operating conditions.

It's important to note that the exact shape of the IV characteristics can vary depending on the specific MOSFET's design and manufacturing process and can be influenced by factors such as temperature and power supply voltage.
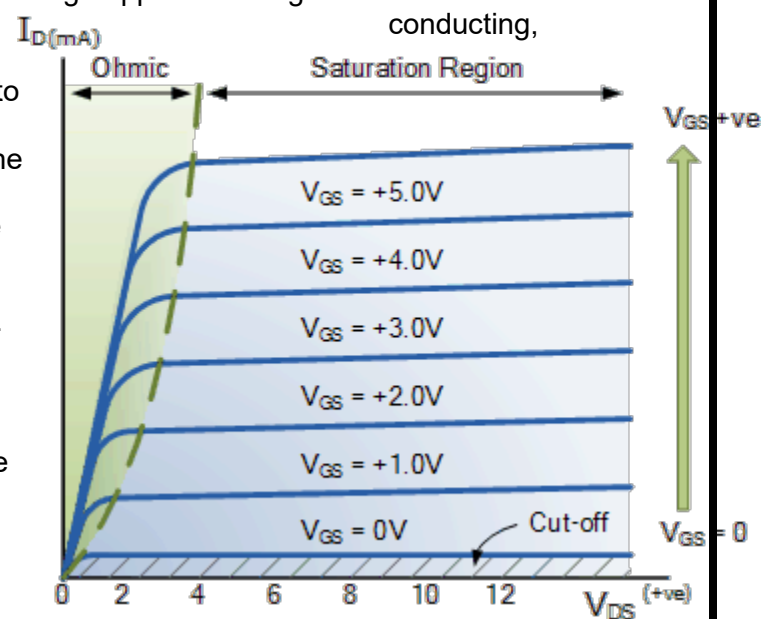
Difference between threshold and overdrive voltage:

The threshold voltage and overdrive voltage are two important parameters in MOSFET (Metal Oxide Semiconductor Field Effect Transistor) circuit design.

The threshold voltage (Vth) of a MOSFET is the minimum gate-source voltage required to turn on the transistor and allow current to flow between the source and drain terminals. When the Vgs is less than Vth, the MOSFET is in the off state and has very little current flow. Vth is typically specified in the MOSFET datasheet and is dependent on the physical characteristics of the MOSFET structure, such as channel length and oxide thickness.

The overdrive voltage (Vov) of a MOSFET is the amount of voltage required to fully turn on the transistor and achieve maximum current flow. It is the difference between the Vgs and Vth, which means Vov = Vgs - Vth. The higher the overdrive voltage, the more current flows through

the transistor, and the lower the resistance of the MOSFET. The overdrive voltage is also dependent on the MOSFET structure and can vary depending on the fabrication process and operating conditions.

In summary, the threshold voltage is the minimum voltage required to turn on the MOSFET, while the overdrive voltage is the amount of voltage required to fully turn on the MOSFET and achieve maximum current flow. Both of these parameters are important in MOSFET circuit design, as they determine the level of conduction between the source and drain terminals, and the amount of power that can be handled by the MOSFET.

kp of MOSFET:

Kp is a parameter commonly used to describe the characteristics of MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) in circuit design. Kp is also known as the transconductance parameter or the amplification factor.

Kp represents the transconductance gain of a MOSFET and is defined as the ratio of the drain current (Ids) to the square of the gate-source voltage (Vgs) when the MOSFET is operating in the saturation region. Kp is expressed in units of amperes per volt squared (A/V^2) or Siemens (S).

Kp is related to the physical characteristics of the MOSFET, such as the channel length, width, and oxide thickness. MOSFETs with higher Kp values have higher transconductance gains and can handle more power. Kp is an important parameter to consider when selecting a MOSFET for a specific application, as it affects the MOSFET's performance and power handling capabilities.

In summary, Kp is a parameter that describes the transconductance gain of a MOSFET and is related to the physical characteristics of the MOSFET. It is an important parameter to consider when selecting MOSFET for a specific application.

EXERSCISE

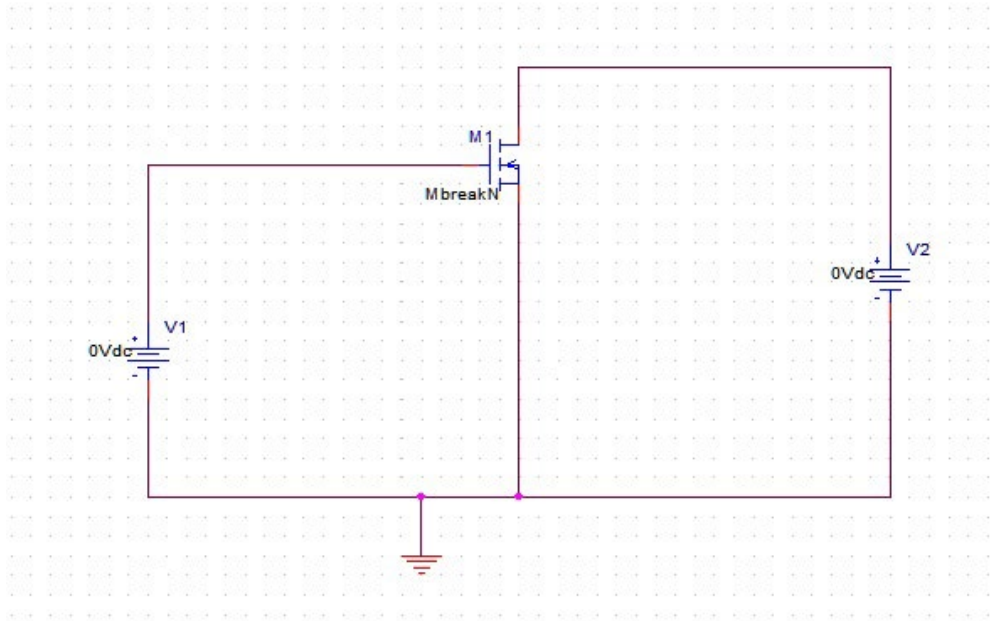A suggested circuit for determining the behavior of a MOSFET is shown in fig no. 1.


Fig no. 1

Simulation:

- Create the circuit shown in Figure 1 in PSpice.

- Use an Mbreak N3 part for the FET.

- Right click on FET and select "Edit PSpice model".

- Set the parameter as follows:

**.model Mbreakn NMOS KP=35m W=200u L=100u VTO=2.1**

- Create a new simulation profile and set the analysis type as DC Sweep.

- Set the "primary sweep" to sweep V2 in fig 1, linearly from 0 to 10 V with a 0.01V increment.

- Select a secondary sweep and sweep V1 from 1.5 to 3.5V with a 0.1V increment.

- Run the simulation.

- Obtain the transfer curve of the circuit simulated in fig 1 i.e. Plot Id versus Vds.

Simulation:
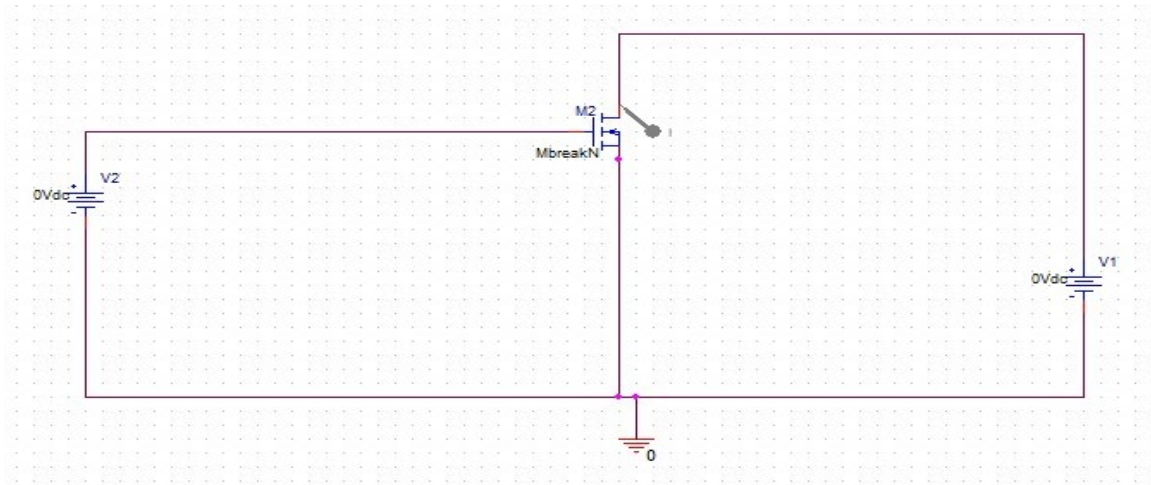
Output:
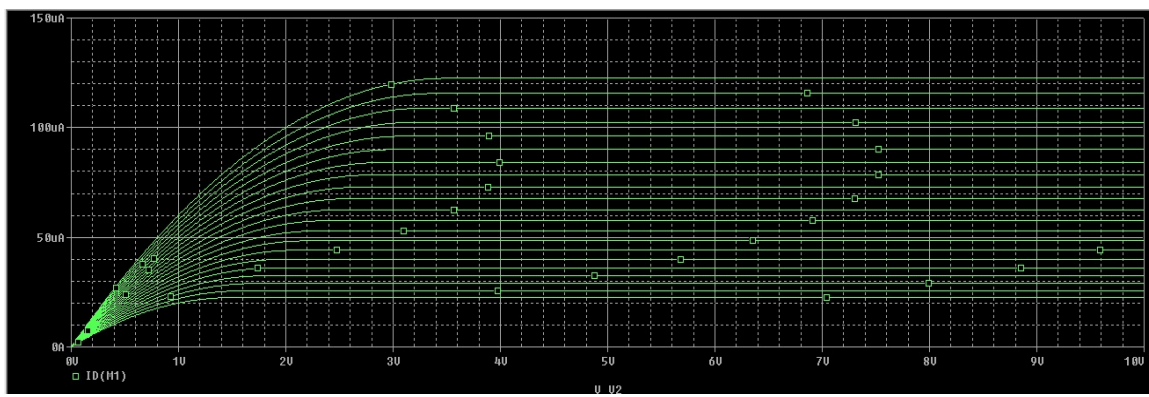
Testing of MOSFET using multimeter:

Note: before moving on to the implementation part of lab, each group must check the MOSFET using multimeter to make sure the component is in working condition.

2N7000

To test a MOSFET using a multimeter, you can perform a simple continuity test and measure the resistance between the source, gate, and drain terminals.
Here are the steps to follow:

1. Turn off the power to the circuit and remove the MOSFET   from the circuit.
2. Set the multimeter to continuity or resistance mode.
3. Identify the source, gate, and drain terminals of the MOSFET. Refer to the datasheet or markings on MOSFET to identify the terminals.
4. Connect the black (negative) lead of the multimeter to the source terminal of the MOSFET, and the red (positive) lead to the drain terminal. The multimeter should read a high resistance or no continuity, indicating that the MOSFET is in the cutoff region.
5. Reverse the leads of the multimeter, connecting the black lead to the drain terminal and the red lead to the source terminal. The multimeter should still read a high resistance or no continuity.
6. Connect the red lead of the multimeter to the gate terminal of the MOSFET, and the black lead to the source terminal. The multimeter should read a high resistance or no continuity, indicating that the MOSFET is in the cutoff region.
7. Slowly increase the voltage applied to the gate terminal using a power supply or battery, while monitoring the multimeter reading. As the voltage applied to the gate increases, the MOSFET should transition from the cutoff region to the triode and then the saturation region, and the multimeter reading should decrease accordingly.
8. To verify that the MOSFET is fully conducting, connect the red lead of the multimeter to the drain terminal and the black lead to the source terminal, and measure the resistance. The multimeter reading should be very low, indicating that the MOSFET is fully conducting and allowing current to flow freely between the source and drain.
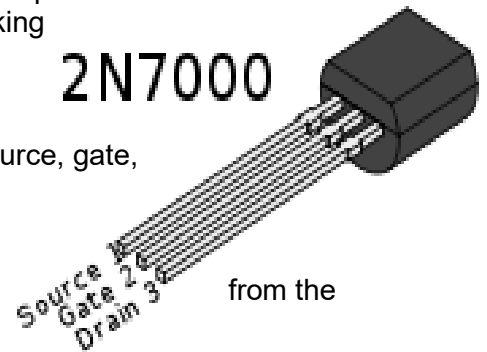
Note that the exact values of resistance and voltage required to turn on the MOSFET will depend on the specific MOSFET being tested and may vary depending on factors such as temperature and power supply voltage. It's also important to follow proper safety precautions when testing electronic components.

Implementations of the next task was not completed due to the unavailability of working MOSFETS

IMPLEMENTATION
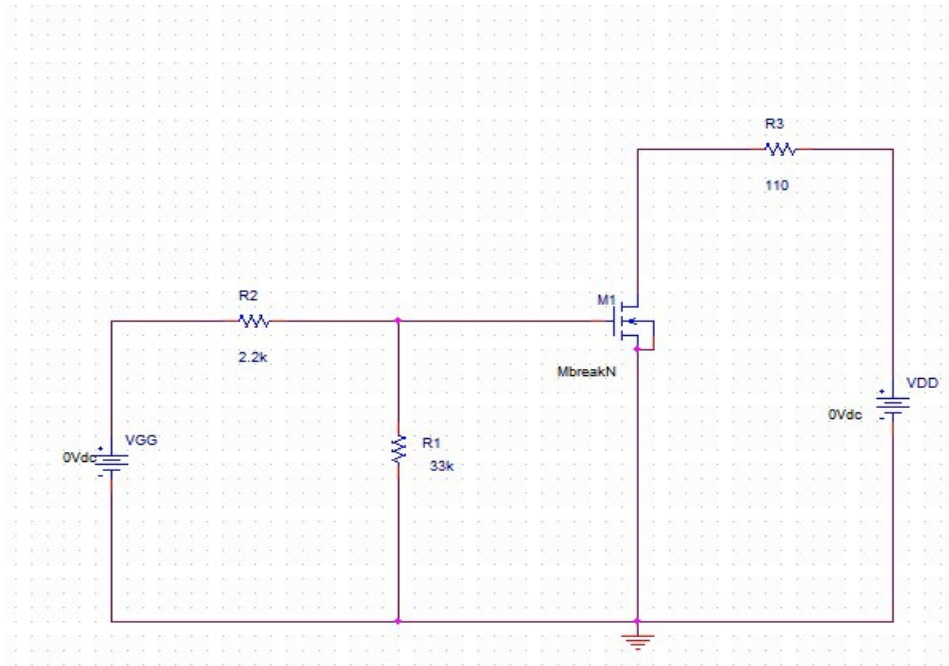
1) Construct the circuit above. Use the multi-meter to measure the drain current, Id and to measure VDS and VGS. Use the DC power supply for VGG and for VDD.

2) Set VGG to 0V and VDD to 5V and measure VDS and ID.

3) Slowly increase VGG until the transistor just begins to conduct current as evidence by small drop in VDS. Record the value of VGS as gate threshold voltage, Vth

Vth=_____

4) Adjust VGG to increase VGS by 0.2V above the threshold. Readjust VDD to return VDS to 5V and then measure the drain current Id. Record the value of VGS in the first column of table 1 and record value of Id in second column (the VDS=5V column)

5) Continue to increase VGS in steps of 0.2V while maintaining VDS at 5V. Measure the drain current at each step. Record the values of VGS and Id in table 1.

6) Complete the entries in table 1 by adjusting VDD and VGG to obtain various required VDS and VGS values, then measuring ID at each value.

7) Plot the data for each value of VGS to obtain ID vs VDS curve.

OUTPUT / DRAIN CHARACTERISTICS

VGS = 0V		VGS = 1		VGS = 1.5		VGS = 2		VGS = 2.5	
VDS (V)	ID (mA)	VDS (V)	ID (mA)	VDS (V)	ID (mA)	VDS (V)	ID (mA)	VDS (V)	ID (mA)
0		0		0		0		0	
1		1		1		1		1	
2		2		2		2		2	
3		3		3		3		3	
4		4		4		4		4	
5		5		5		5		5	
6		6		6		6		6	
7		7		7		7		7	
8		8		8		8		8	

Conclusion

In conclusion, studying the n-Channel MOSFET in Common-Source configuration has revealed its voltage-controlled behavior, with drain current (ID) modulated by gate-source voltage (VGS). The MOSFET operates as a voltage-controlled current source in saturation and as a variable resistor in the linear region. It exhibits cutoff and pinch-off characteristics at low and high VGS, respectively. Understanding these I-V characteristics is crucial for designing and analyzing analog and digital circuits.