Communication Circuits Design – 2018-19, semester II

Lab 1 - Week 2

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I-V Characteristics of MOSFETs

The objective of this lab is to measure and plot the current-vs-voltage (I-V) operating curves of the Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

Introduction

A metal-oxide-semiconductor field-effect transistor (MOSFET) is a three-terminal device that can be used as a switch (e.g. in digital circuits) or as an amplifier (e.g. in analog circuits). The three terminals are referred to as the Source, Gate, and Drain terminals. Current flow between the source and drain terminals is controlled by the voltage V_{GS} applied between the gate and source terminals. If the gate-to-source voltage V_{GS} is less than the threshold voltage value V_T, no current can flow between the source and the drain – i.e. the transistor is OFF; if $V_{GS} > V_T$, then current can flow between the source and the drain – i.e. the transistor is ON. The circuit symbol for an n-channel enhancement-mode ($V_T > 0$ Volts) MOSFET is shown in Figure-1, along with the terminal current reference directions.
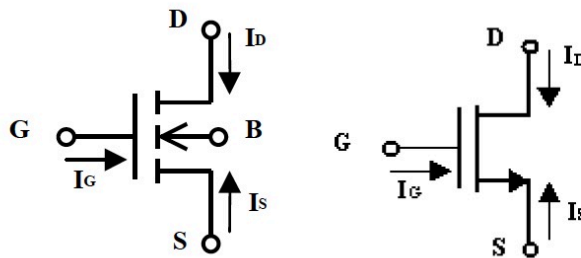

Figure-1: Circuit symbol for n-channel enhancement MOSFET

In the ON state, the current I_{DS} flowing from the drain to the source will depend on the potential difference V_{DS} between the drain and the source: I_{DS} increases with increasing drain-to-source voltage V_{DS} as long as the drain voltage is at least V_T below the gate voltage, i.e. as long as $V_{GS} - V_T > V_{DS}$. When V_{DS} increases above $V_{GS} - V_T$, I_{DS} saturates at a constant value (i.e. it no longer increases with increasing V_{DS}.).

Practical Procedure

1. Build the circuit shown in the Fig. 2 below. In the circuit you will use a potentiometer (P_1) to vary the gate voltage. Use the following circuit with R_D=1 kΩ and the power boxes as a DC voltage supplies.

2. First, the transfer characteristics, i.e. the dependence of the drain current (I_D) on the input voltage (V_{GS}), will be measured at a fixed drain bias $V_{DS} = 5.0$ V. Since the resistivity of the MOSFET changes as V_{GS} is changed, V_{DD} have to be adjusted for each point to keep V_{DS}=5.0 V. It is suitable to have V_{IN} =5 V to be able to vary V_{GS} with the potentiometer. Measure the points in the table below and plot the data as I_D vs V_{GS}. In this task V_{GS} is measured as a function of set I_D values instead of the other way around to avoid too high currents through the MOSFET.
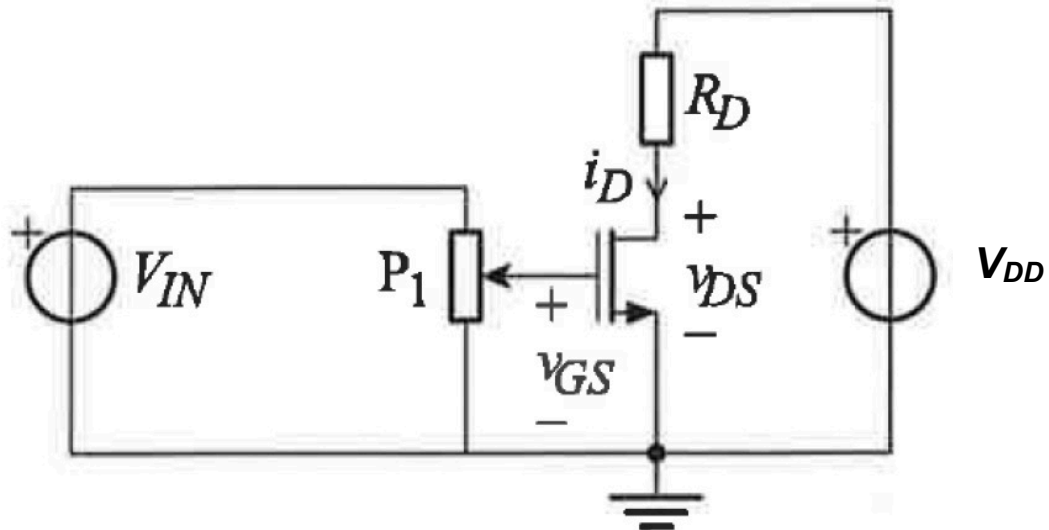
Figure-2: A simple circuit for obtaining the I-V characteristics of a MOSFET.

3. Set V_{DD} according to the table. Adjust the potentiometer until the indicated I_D is reached and measure VGS.

V_{DD} (V)	I_D (mA)	V_{GS} (V)
15.0	10.0	
10.0	5.0	
8.0	3.0	
6.0	1.0	
5.1	0.1	
5.0	0.0	

4. Plot the transfer characteristic I_D vs V_{GS} using the collected data in the Table-1.

5. Does I_D follow the expected long or short (velocity saturated) channel behaviour? Remember that I_D is proportional to V_{GS} for a velocity saturated MOSFET.

6. Now the output characteristics, i.e. the dependence of the drain current (I_D) on the drain voltage (V_{DS}), will be measured at a fixed gate bias. Adjust V_{DD} to 10 V and adjust the potentiometer so that you obtain I_{DS} = 5 mA with V_{DS}= 5 V. Keep this setting of the potentiometer (controlling V_{GS}) throughout the measurement while varying V_{DD} to obtain the V_{DS} values in the table. Fill out I_D in the table and plot the data in the diagram as I_D vs V_{GS}.

V_{DS} (V)	I_D (mA)
0	
0.2	
1.0	
3.0	
5.0	
10.0	

7. Does I_D saturate? If not, what is the reason.

8. Now set V_{GS} to 4 V and measure V_{DS} and I_D as V_{DS} is varied from 0 to 10 V. Repeat this experiment with V_{GS} equal to 6 V, 8 V and 10 V. Plot the I-V characteristics of this MOSFET. The horizontal axis should be V_{DS} and the vertical axis I_D. The various V_{GS} values generate a family of curves.

V_{GS} (V) = 4 V		V_{GS} (V) = 6 V		V_{GS} (V) = 8V		V_{GS} (V) = 10V	
V_{DS} (V)	I_D (mA)	V_{DS} (V)	I_D (mA)	V_{DS} (V)	I_D (mA)	V_{DS} (V)	I_D (mA)
0		0		0		0	
1		1		1		1	
2		2		2		2	
3		3		3		3	
4		4		4		4	
5		5		5		5	
6		6		6		6	
7		7		7		7	
8		8		8		8	
9		9		9		9	
10		10		10		10	

9. Identify and explain the operating regions of the I-V curve generated for the transistor.