# Electronic Devices and Circuits Lab (EE2301)
# Experiment 7 : MOSFET Characteristics


EE19BTECH11041,

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## 1 Aim

our aim is to understand MOSFET characteristics i.e. both output and transfer characteristics

**MOSFET:**

The metal–oxide–semiconductor field-effect transistor (MOSFET, MOS-FET, or MOS FET) is a type of insulated-gate field-effect transistor that is fabricated by the controlled oxidation of a semiconductor, typically silicon. The voltage of the covered gate determines the electrical conductivity of the device; this ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals.

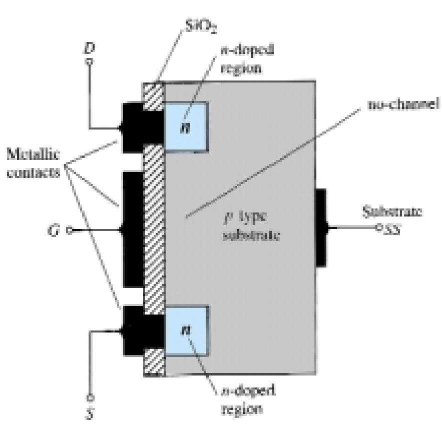



Figure 1: **NMOSFET**

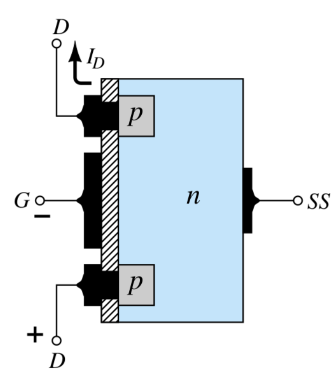
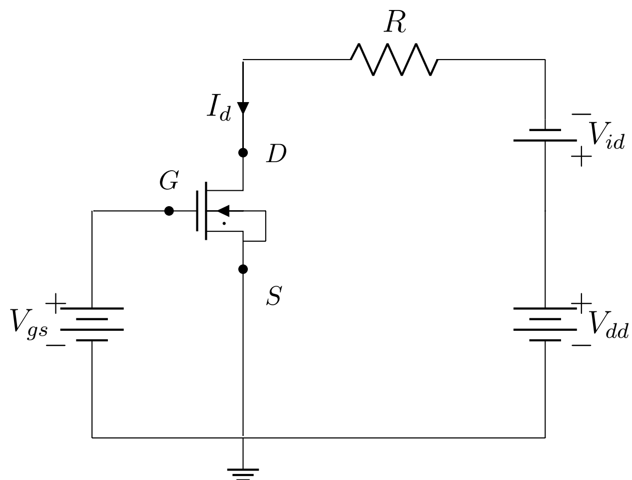



Figure 2: **PMOSFET**

**NMOSFET(GROUP 1)**




**NMOSFET circuit diagram**

- Given R = 1k$\Omega$ and $V_{id}$ = 0V.

### Output characteristics

- Vary drain bias($V_{dd}$) and measure the drain current($I_d$) with a fixed gate bias($V_{gs}$).

- Now plot $I_d$ vs $V_{dd}$ for a fixed $V_{gs}$.

### Transfer characteristics

- Vary gate bias($V_{gs}$) and measure the drain current($I_d$) with a fixed drain bias($V_{dd}$).

- Now plot $I_d$ vs $V_{gs}$ for a fixed $V_{dd}$.

## 2 Problem statement(Group 1)

- Group 1 - NMOSFET

. • Plot the $I_D$-$V_D$ output characteristics ($V_G$ = 1, 2, 3, 4, 5 V) and mark the
. important regions of operation.

. • Plot the $I_D$-$V_G$ transfer characteristics for ($V_D$ = 1, 2, 3, 4, 5 V).

. • Explain the working of the MOSFET and the nature of the characteristics.

## 3 Procedure

**NMOSFET-GROUP 1**

**Output characteristics**

• First we need to write spice scripts for the NMOSFET circuit with given values and varying drain bias($V_{dd}$).

• Now we need to fix the gate bias($V_{gs}$) and run dc simulation of drain bias($V_{dd}$) and print the drain current($I_d$).

• Now we need to do the same for 5 different gate bias($V_{gs}$) values i.e. for $V_G = 1, 2, 3, 4, 5$ V.

• Now we need to plot the drain current($I_d$) vs drain bias($V_{dd}$) for the 5 different gate bias($V_{gs}$) in the same figure using matlab or octave.

**Transfer characteristics**

• First we need to write spice scripts for the NMOSFET circuit with given values and varying gate bias($V_{gs}$).

• Now we need to fix the drain bias($V_{dd}$) and run dc simulation of gate bias($V_{gs}$) and print the drain current($I_d$).

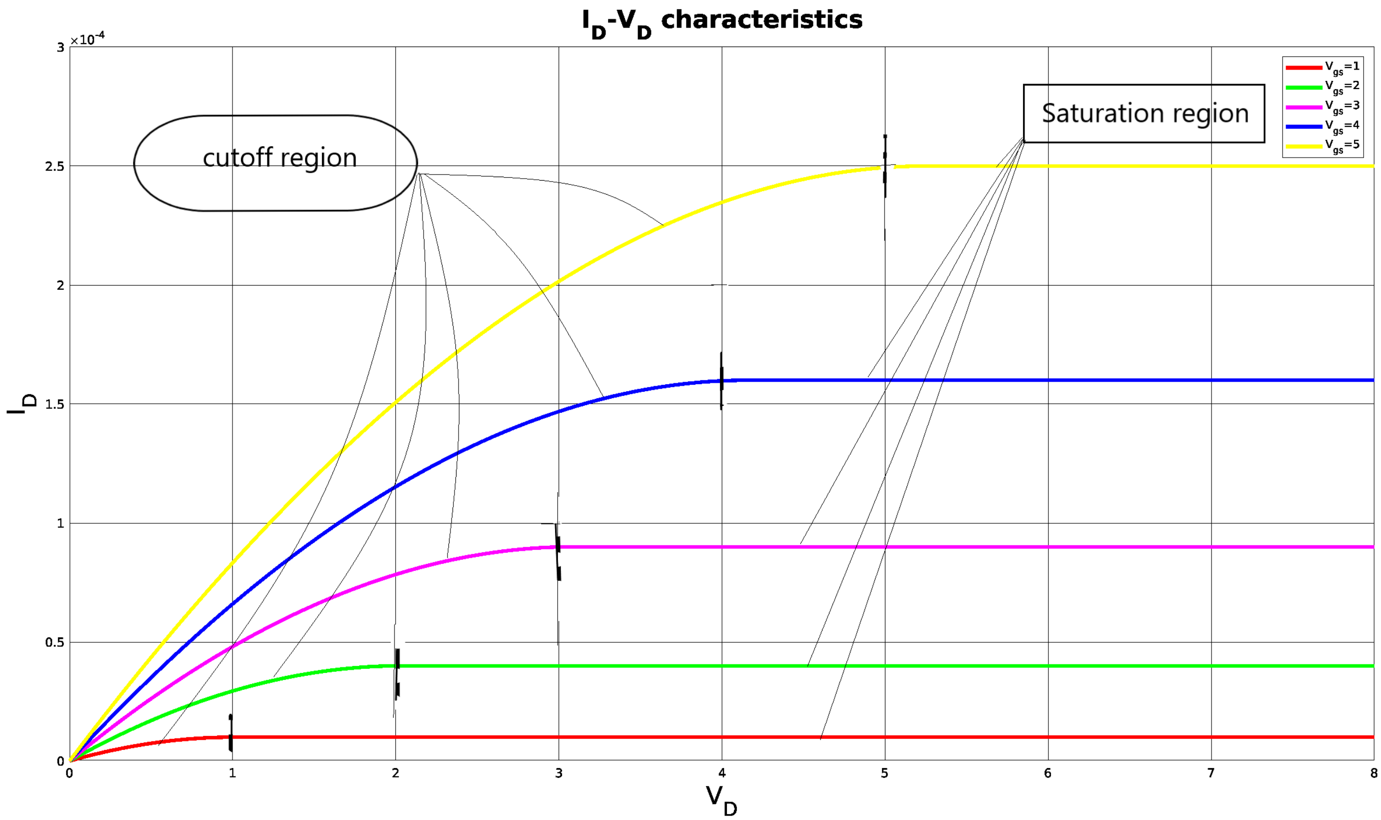
• Now we need to do the same for 5 different gate bias($V_{dd}$) values i.e. for $V_D = 1, 2, 3, 4, 5$ V.

• Now we need to plot the drain current($I_d$) vs gate bias($V_{dd}$) for the 5 different drain bias($V_{dd}$) in the same figure using matlab or octave.

• We should now analyze the obtained results and explain the circuit working.

# 4 Results and observations

### Output characteristics




**Plot:** $I_d$ **Vs** $V_{dd}$

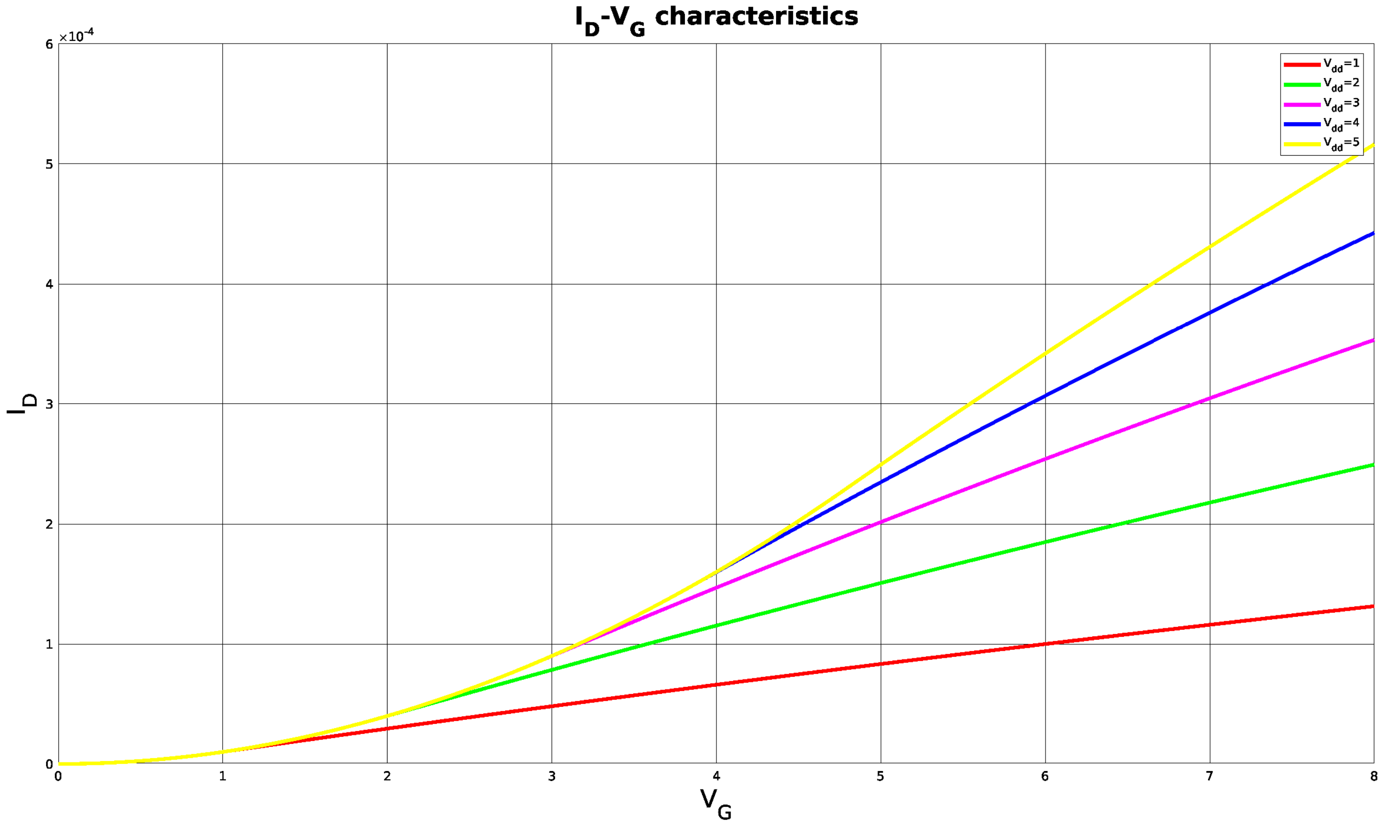
• In the above plot the drain current increases upto a value and then saturates at that value.

• As the value of $V_G$ increases the current saturation value($I_{DS}$) decreases and the saturation voltage decreases($V_{DS}$) saturates quickly.

• The MOSFET used here is an enhancement type NMOSFET i.e. there is no n-channel initially between n-doped regions.

• The output characteristics are similar to the BJT but here it is voltage controlled whereas in BJT it is current controlled.

**Transfer characteristics**




**Plot:** $I_d$ **Vs** $V_{gs}$

- In the above plot the drain current($I_d$) increases as the gate bias($V_G$) increases.

- As the value of $V_{dd}$ increases the slope of the plot $I_d$ vs $V_G$ increases too.

- The plot looks like a parabola whose equation is given by.

$$I_D = k(V_G - V_T)^2 \ , \ V_G > V_T \tag{1}$$

$$I_D = 0 \ , V_G \leq V_T \tag{2}$$

where k is a constant and $V_T$ is the value of $V_G$ at which $I_D$=0.

- We can see from the graph that the value of k increases with increase in $V_{dd}$ where as $V_T$ doesn't.

**Working the MOSFET circuit**

• If $V_{GS}$ is set at 0 V and a voltage applied between the drain and source of the device,the absence of an n-channel will result in a current of effectively zero amperes.

• Now if we set the both $V_{DS}$ and $V_{GS}$ at some positive voltage greater than 0 V,establishing the drain and gate at a positive potential with respect to the source. The positive potential at the gate will pressure the holes (since like charges repel) in the p-substrate along the edge of the $SiO_2$ layer to leave the area and enter deeper regions of the p-substrate, as shown in the figure.

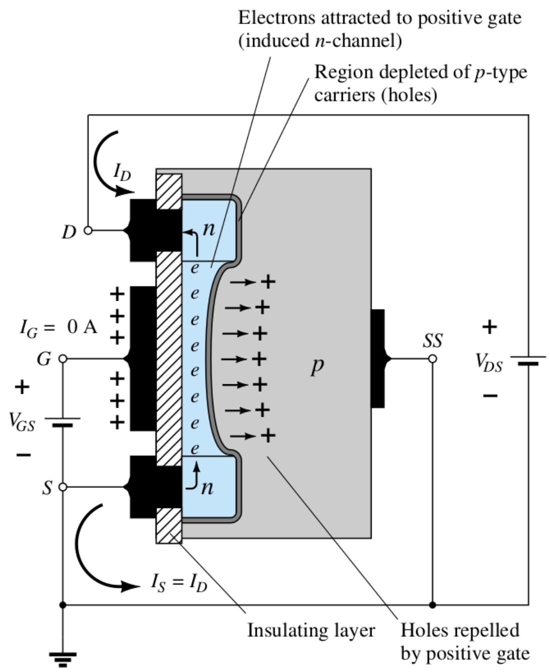



**Figure 3: n-Channel formation in the NMOSFET.**

• As $V_{GS}$ increases in magnitude, the concentration of electrons near the $SiO_2$ surface increases until eventually the induced n-type region can support a measurable flow between drain and source. The level of $V_{GS}$ that results in the significant increase in drain current is called the threshold voltage and is given the symbol $V_T$.

• The above reasons explain the transfer characteristics of the NMOSFET circuit.

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• Now if we hold $V_{GS}$ constant and increase the level of $V_{DS}$ , the drain current will eventually reach a saturation level,The leveling off of $I_D$ is due to a pinching-off process depicted by the narrower channel at the drain end of the induced channel as shown in Figure 4.

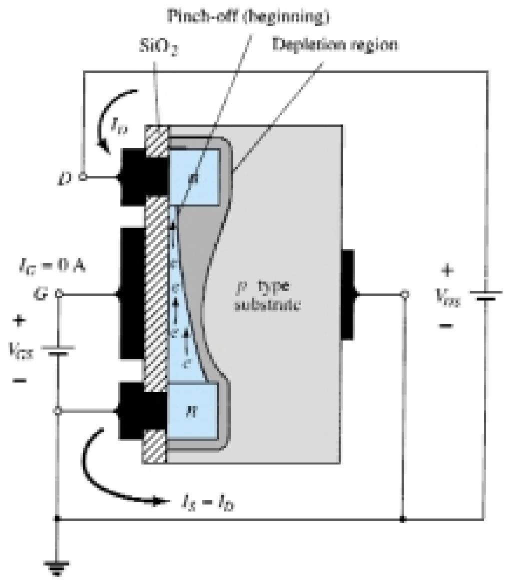


**Figure 4: Change in channel and depletion region with increasing level of $V_{DS}$ for a fixed value of $V_{GS}$**

• If $V_{GS}$ is held fixed at some value such as 8 V and $V_{DS}$ is increased from 2 to 5V, the voltage $V_{DG}$ i.e $V_{DS}$-$V_{GS}$ will drop from -6 to -3 V and the gate will become less and less positive with respect to the drain.

• This reduction in gate-to-drain voltage will in turn reduce the attractive forces for free carriers (electrons) in this region of the induced channel, causing a reduction in the effective channel width. Eventually, the channel will be reduced to the point of pinch-off and a saturation condition will be established.

• Even though the channel width is reduced the is high density of carriers for the current flow.

• The above reasons explain the output characteristics of the NMOSFET circuit.

# 5 Conclusions

• The saturation level for $V_{DS}$ is related to the level of applied $V_{DS}$ by
$V_{DS_{sat}} = V_{GS}$ - $V_T$.

• We also note that there is no current at gate ($I_G$) due to the insulating material.

• MOSFET is a voltage controlled device which is a lot fexible than BJT.

• Key advantage of a MOSFET is that it requires almost no input current to control the load current.

• The MOSFET is the most widely used type of transistor and the most critical device component in integrated circuit (IC) chips..

# 6 References


• Electronic devices and circuit theory by ROBERT BOYLESTAD and LOUIS .Link

• MOSFET-Wikipedia Link


*Thank you*