Experiment No: 08

Name of the Experiment: Study of Switching Characteristics

Introduction:

The most common transistor types are the Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) and the Bipolar Junction Transistors (BJT). BJTs based circuits dominated the electronics market in the 1960's and 1970's. Nowadays most electronic circuits, particularly integrated circuits (ICs), are made of MOSFETs. The BJTs are mainly used for specific applications like analog circuits (e.g. amplifiers), high-speed circuits or power electronics.

There are two main differences between BJTs and FETs. The first is that FETs are charge- controlled devices while BJTs are current or voltage controlled devices. The second difference is that the input impedance of the FETs is very high while that of BJT is relatively low.

As for the FET transistors, there are two main types: the junction field-effect transistor (JFET) and the metal oxide semiconductor field effect transistor (MOSFET). The power dissipation of a JFET is high in comparison to MOSFETs. Therefore, JFETs are less important if it comes to the realization of ICs, where transistors are densely packed. The power dissipation of a JFET based circuit would be simply too high. The combination of n- type and p-type MOSFETs allow for the realization of the Complementary Metal Oxide Semiconductor (CMOS) technology, which is nowadays the most important technology in electronics. All microprocessors and memory products are based on CMOS technology. The very low power dissipation of CMOS circuits allows for the integration of millions of transistors on a single chip. In this experiment, we will concentrate on the MOSFET transistor. We will investigate its characteristics and study its behavior when used as a switch.

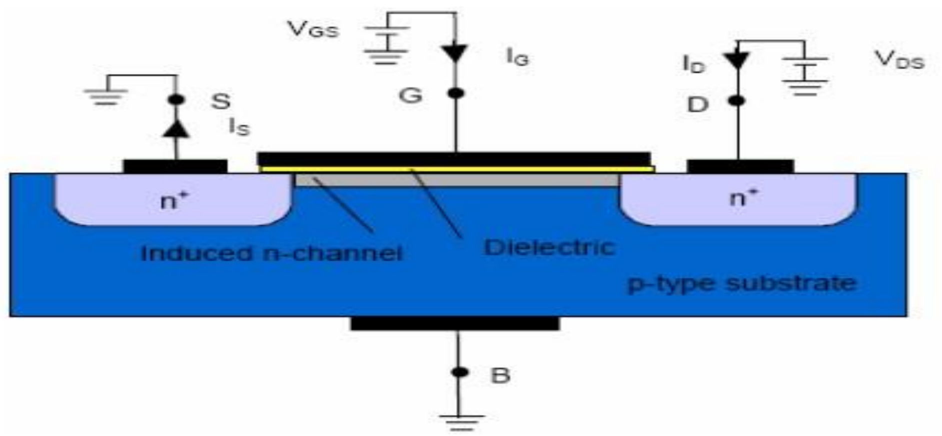
Theory:

MOSFETs Structure and Physical Operation

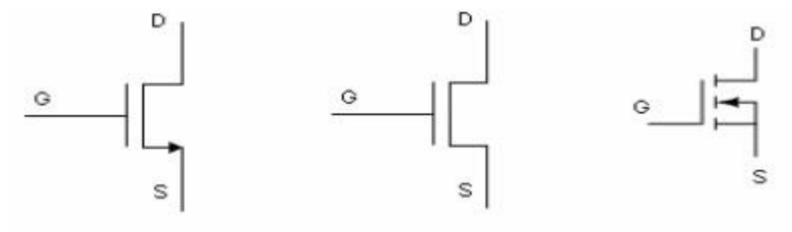
The MOSFETs are the most widely used FETs. Strictly speaking, MOSFET devices belong to the group of Insulated Gate Field Effect Transistor (IGFETs). As the name implies, the gate is insulated from the channel by an insulator. In most of the cases, the insulator is formed by a silicon dioxide ($SiO2$), which leads to the term MOSFET. MOSET like all other IGFETs has three terminals, which are called Gate (G), Source (S), and Drain (D). In certain cases, the transistors have a fourth terminal, which is called the bulk or the body terminal. In PMOS, the body terminal is held at the most positive voltage in the circuit and in NMOS, it is held at the most negative voltage in the circuit.

There are four types of MOSFETs: enhancement n-type MOSFET, enhancement p-type MOSFET, depletion n-type MOSFET, and depletion p-type MOSFET. The type depends whether the channel between the drain and source is an induced channel or the channel is physically implemented and whether the current owing in the channel is an electron current or a hole current.

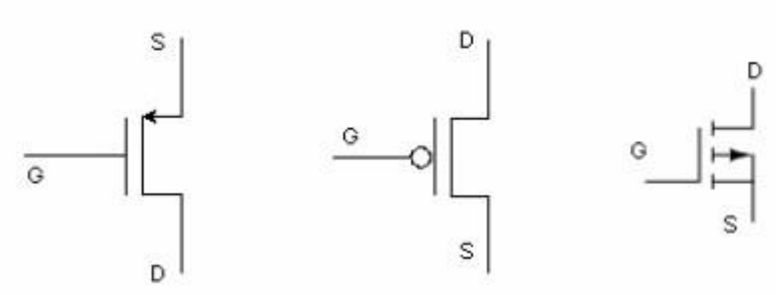
The cross section of an enhancement NMOS transistor is shown in figure below. If we put the drain and source on ground potential and apply a positive voltage to the gate, the free holes (positive charges) are repelled from the



Schematic cross section of an enhancement type NMOS transistor



Symbols for Enhancement NMOS Transistor



Symbols for Enhancement PMOS Transistor

region of the substrate under the gate (channel region) due to the positive voltage applied to the gate. The holes are pushed away downwards into the substrate leaving behind a depletion region. At the same time, the positive gate voltage attracts electrons into the channel region.

When the concentration of electrons near the surface of the substrate under the gate is higher than the concentration of holes, an n region is created, connecting the source and the drain regions. The induced n-region thus forms the channel for current flow from drain to source. The channel is only a few nanometers wide. Nevertheless, the entire current transport occurs in this thin channel between drain and source.

A common application of MOSFETs is switches in analog and digital circuits.
Switches in analog circuits can be used for example in data acquisition systems, where they serve as analog multiplexors, which allow the selection of one of several data inputs.

A simple example of a switching circuit based on an n-type enhancement transistor and a resistor is shown below. The voltage applied to the gate controls the conductance of the channel. A zero or low value of V_{GS}, the conductance is very low so that is the transistor acts like an open circuit and no current flows through the load resistor R_L. When V_{GS} exceeds the threshold, the channel conductance becomes higher and the transistor acts like a closed switch. The channel resistance is not getting zero but the resistance is getting small so that the output voltage V_{out} is getting small. Fig.(a) below shows an NMOS switching FET and its models for Vin = 0 (Fig. (b)) and Vin = +5V (Fig. (c)). In each case, the FET is modeled as a mechanical switch.

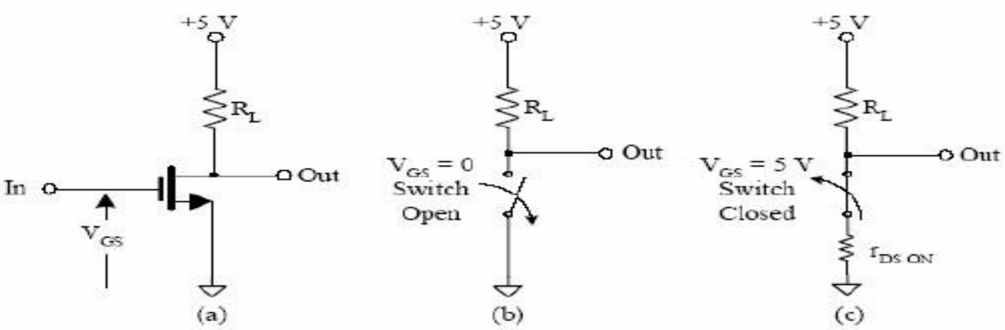


Fig: NMOS transistor switch

As for PMOS, a negative value of V_{GS} has to be applied to turn the transistor on. The operation can be described using the curves shown in figure below. When the input voltage, V_{GS}, of the transistor shown is zero, the MOSFET conducts virtually no current, and the output voltage, Vout, is equal to V_{DD}. When V_{GS} is equal to 5V , the MOSFET Q-point moves from point A to point B along the load line, with V_{DS} = 0.5V . Thus, the circuit acts as an inverter. The inverter forms the basis of all MOS logic gates.

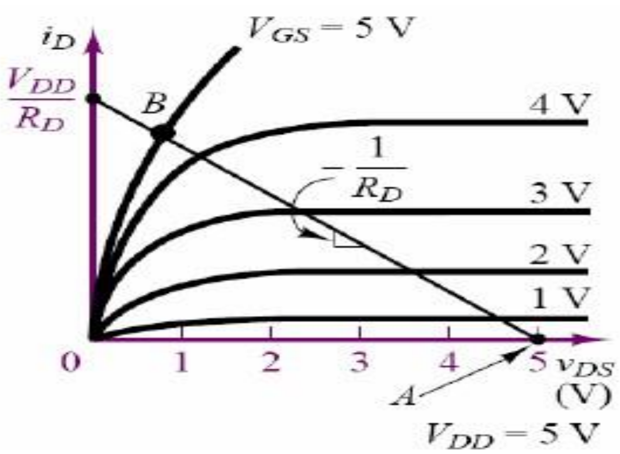
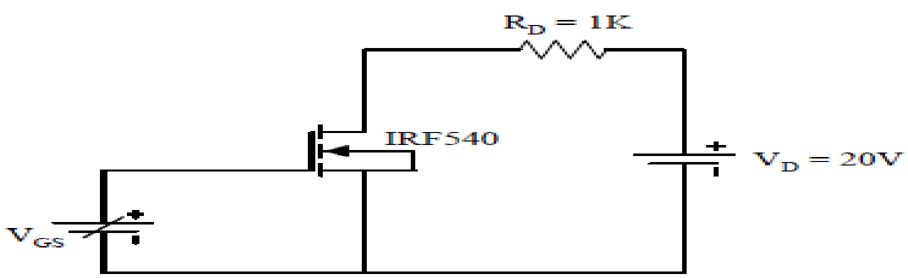


Fig: MOSFET switching characteristics

Equipments And Components :

Serial no.	Component Details	Specification	Quantity
1.	MOSFET	IRF540	1 piece each
2.	Resistor	1KΩ	1 piece each
3.	POT		1 unit
4.	Trainer Board		1 unit
5.	DC Power Supply		2 unit
6.	Digital Multimeter		1 unit
7.	Chords and wire		as required

Experimental Setup:



Procedure:

1. Set V_{GS} to zero and record the V_{DS}, V_L and I_D.
2. Increase the gate voltage V_{GS} gradually and record the readings.
3. Take reading until I_D = 20mA (or the saturation current of the MOSFET).
4. Note the condition of V_{DS} and I_D of steps 1 and 3.
5. Repeat the experiment for V_{DD} = 15 Volts.

V_{DD} = 15V				V_{DD} = 20V			
V_{GS}	V_{DS}	V_L	I_D	V_{GS}	V_{DS}	V_L	I_D

Report:

1. Add the PSPICE simulation waveforms of all the experimental circuits.