Experiment 10

MOS Transistor

Objectives:

In this experiment you will investigate the characteristics of the Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) and study its applications as:

- voltage-controlled resistor
- logic gate
- amplifier
- current source

❶ *M*OSFET Characteristics:

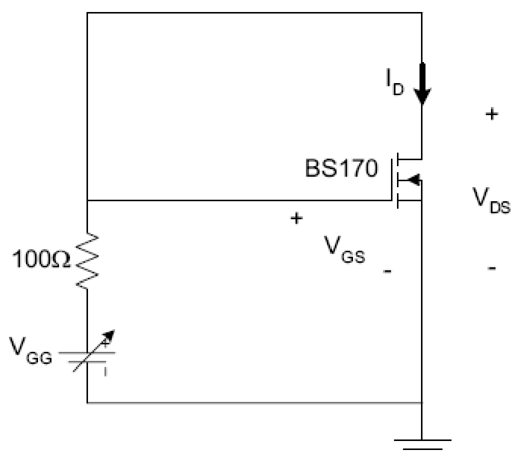

Fig. 1

The drain current of the MOSFET in the saturation region is:

$$I_D = \frac{k}{2}(V_{GS} - V_T)^2 \text{ when } V_{GS} > V_T \text{ and } V_{DS} > V_{GS} - V_T$$

- **Connect the circuit in figure 1.**
- **Starting with V_{GG} = 0.5 V, slowly increase the value of V_{GG} by the digital multimeter until the drain current is exactly 10**

mA. Read the value of V_{GS}. Increase V_{GG} further until the drain current is exactly 25 mA. Read the value of V_{GS}.

- Now we have two different values of I_S and V_{GS} and thus we could now solve two equations with two unknowns to find the trans conductance parameter k and the threshold voltage V_T according to the above equation.

❷ MOSFET as Voltage-Controlled Resistor:

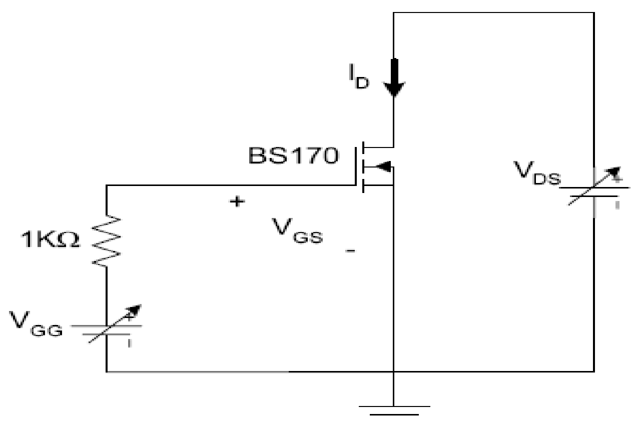

Fig. 2

❸ **Note:** ***The MOSFET is effectively acting as a linear resistor connected between the drain and source terminals, since $I_D=V_{DS}/R_{DS}$. The value of this resistor, however, is not constant, but depends on V_{GS} - V_T. The MOSFET in this case is a voltage controller resistor.***

The current equation in the linear or ohmic region is given by:

$$I_D = \frac{k}{2}(2(V_{GS} - V_T)V_{DS} - V_{DS}^2)$$

In order for the MOSFET to operate as a voltage controlled resistor, it must operate in the lower part of the triode region for which V_{DS} has relatively small values. This region obeys ohm's law ($V_{DS} = R_{DS}\ I_D$) as there exists a linear relationship between current and voltage. Thus this region is called linear or ohmic

because the MOSFET is working as a resistor controlled by a voltage.

❹ *M*OSFET Logic Gate:

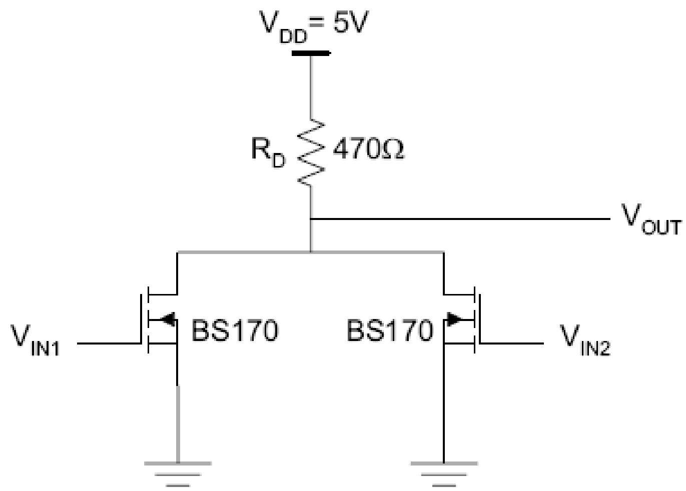

Fig. 3

NOR GATE

We see that the logic function is true only for I_{N1} and I_{N2} are both false; it is false otherwise. This circuit thus implements the NOR logic function that is we get V_{OUT} = (V_{IN1} OR $V_{IN\,2}$)'.

This circuit implements a logic gate; there are two inputs I_{N1} and I_{N2}, and one output OUT.
To build the truth table of this gate, we apply all possible combinations of inputs, and observe the output. Start with I_{N1} = logic 0 and I_{N2} = logic 0. To get a logic 0, we will connect the input nodes to ground. What is the value of the output in this case? This is the value of voltage that corresponds to logic 1. Apply logic 1 at I_{N1}, and logic 0 at I_{N2}, and observe the output.

Note ***The MOSFET*** **must** ***be in the saturation region to use it as an amplifier.***

❺ MOSFET as an Amplifier:

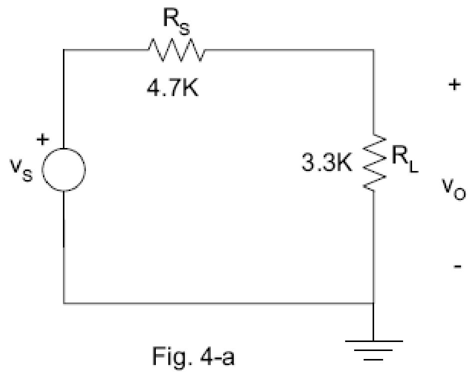

Fig. 4-a

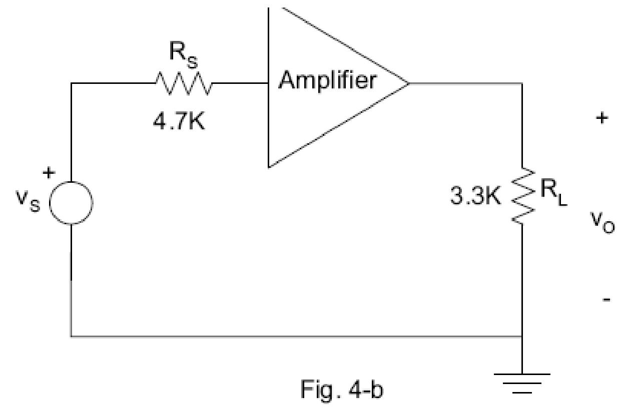

Fig. 4-b

When the MOSFET amplifier block was not connected, the bandwidth was much larger than that when we used the amplifier block.

When the MOSFET amplifier block was not connected, the output voltage did not show any distortion even when the input amplitude became large. This is not the case when the amplifier block is connected.

Remark: **The formula doesn't apply for different values of resistors. The plot is linear only in the ohmic region. Therefore, we can use such devices in circuits were we can only control the voltages.**