CSE251 Lab - 04

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Group No: 04

Experiment-04

Study of I-V Characteristics of MOSFET and Implementation of Logic Functions

CSE251 - Electronic Devices and Circuits Lab

Objective

1. To observe and understand the I-V characteristics of MOSFET.
2. To implement a NAND gate and a Logic Function using MOSFETs and verify the truth tables.

Background Theory

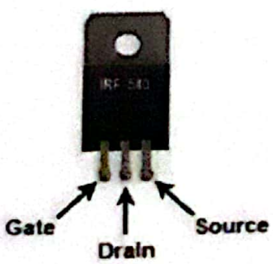
Introduction to MOSFET

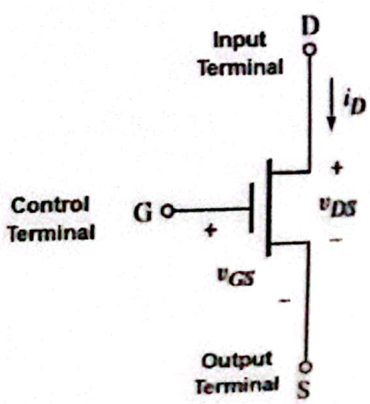
Three-terminal devices are far more useful than two-terminal ones (such as Diodes) because they can be used in a multitude of applications, ranging from signal amplification to digital logic and memory. The basic principle involved is the use of the voltage between two terminals to control the current flowing in the third terminal. In this way a three-terminal device can be used to realize a controlled source.

The control signal can be used to cause the current in the third terminal to change from zero to a large value, thus allowing the device to act as a switch. Switch is the basis for the realization of the logic inverter, which is a basic element of digital circuits.

There are two major types of three-terminal semiconductor devices: (i) MOSFET (Metal-Oxide Semiconductor Field-Effect Transistor) and (ii) BJT (Bipolar Junction Transistor). Although both of them offer unique features and areas of application, MOSFET has become by far the most widely used electronic device, especially in the design of integrated circuits (ICs).

There are two kinds of MOSFET: (i) NMOS and (ii) PMOS. In this experiment, we will study about the I-V characteristics of NMOS and design an NAND gate and a Boolean Logic Function using the NMOS transistor. The figure above shows the IC and the circuit diagram of a MOSFET (NMOS).





2. Set the oscilloscope in X-Y mode. Invert the Channel-1.
3. Observe the plot in the oscilloscope when the data switch is ON and OFF. This plot shows the I-V characteristics of a MOSFET as a switch. Capture the plots using your mobile camera.
4. Now, disconnect the data switch from the gate of the MOSFET and connect the dc power supply to the gate terminal so that we can increase or decrease V_{GS}.
5. Rotate the voltage knob of the dc power supply slowly from 0V to 5V. You should observe the change in the I-V characteristics.
6. Use your mobile camera to capture the image of the I-V characteristics graphs for 3 different V_{GS}. Measure the values of V_{GS} of the captured images and write them in Data Table 2.

Data Table 2: Different Values of V_{GS} to observe the change in MOSFET I-V Characteristics

Values of V_{GS}	
1st Value	0
2nd Value	3.3
3rd Value	3.1

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Signature of the lab faculty

Test Your Understanding

Answer the following questions:

1. We can use the MOSFET as a switch. Which operating regions do we need for this purpose and why? *[2 marks]*

Answer:

We can use the Mosfet as a switch, for this purpose the regions we need are "Cut-off" and "Triode" region.

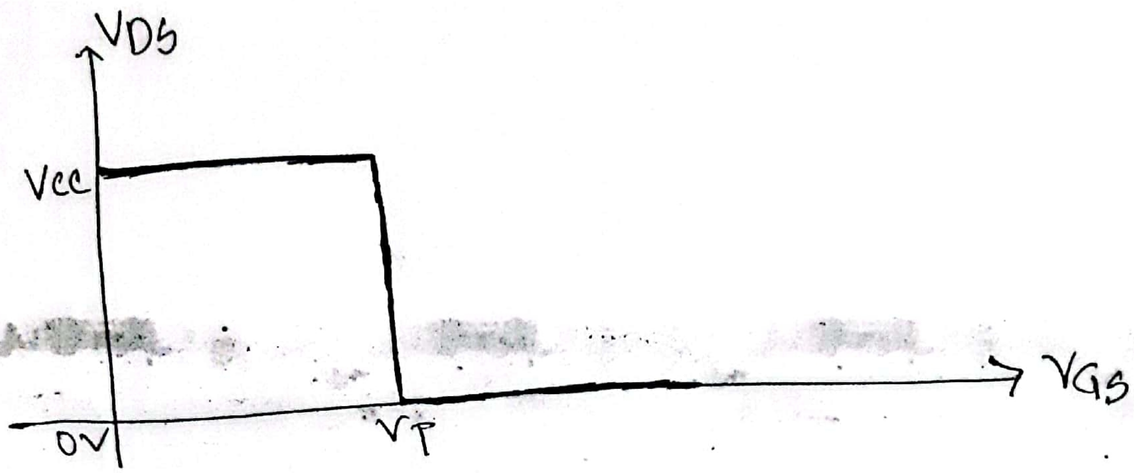
Here,

(1) In Cutoff region, $V_{GS} \leq V_t$, which means the mosfet is off ($I_D = 0$), It's acts like an open source. Thus $I_{ds} = 0$, in ~~Static~~ switch, if we compare, it acts like the switch in terms of is off.

(2) In triode region, $V_{GS} \geq V_t$ which means the Mosfet is on, here it acts like short circuit and $I_{DS} = K(V_{OV} V_{DS} - 1/2 V_{DS}^2)$, In terms of switch, if we compare, it acts like the switch is on.

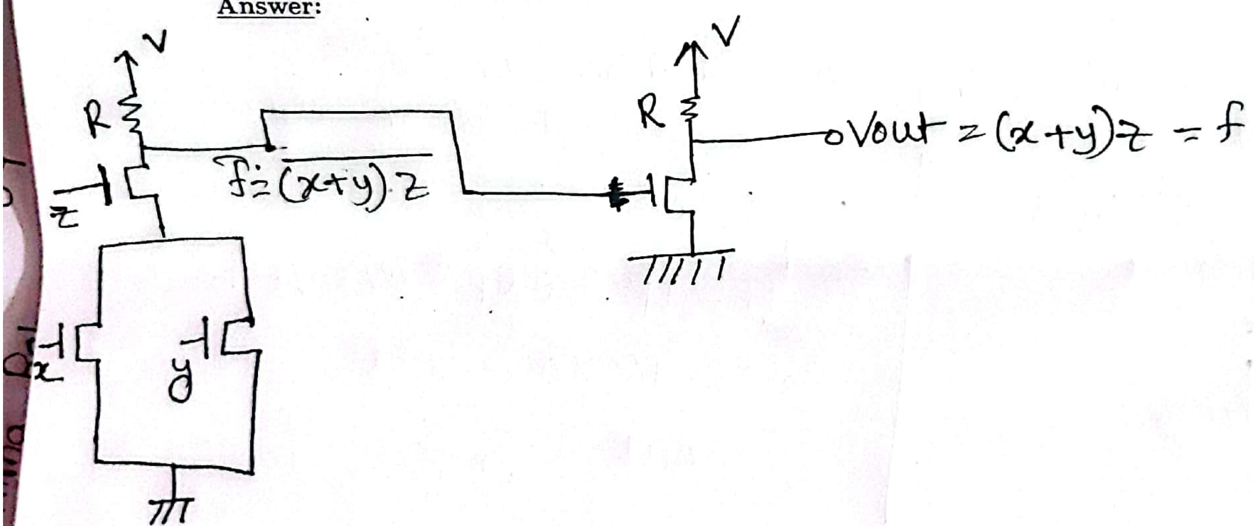
2. Draw the VTC (V_{DS} vs V_{GS}) graph of a MOSFET inverter operating as a switch.

Answer: *[1 mark]*



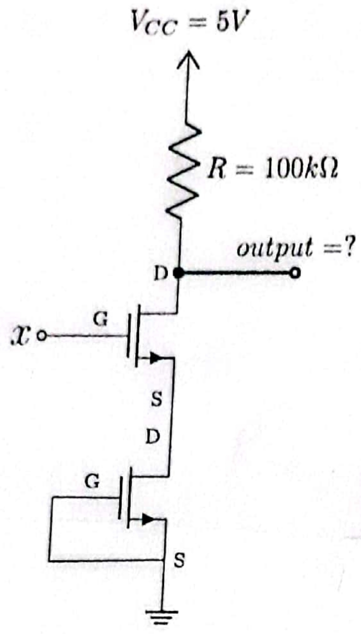
3. Draw a circuit using MOSFETs that implements the following logic function, $f = (x+y)z$

Answer: *[2 marks]*



4. When a MOSFET is in triode mode, does it display zero, finite or infinite resistance? Justify your answer.

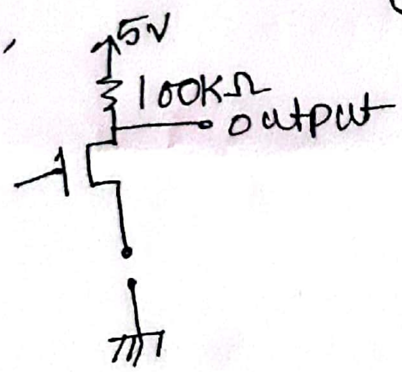
Answer: When a MOSFET is in triode mode. *[2 marks]* it displays finite resistance. In this mode, the MOSFET acts like a controllable resistance. Also from graph of figure-6 in the ~~region~~ triode region, it is a slope. If it is zero it means the x-axis and if ~~es~~ it is infinit, it means the y-axis. These are not the possible cases (from the given graph as shown). That's why it displays finite resistance.



5. What is the value of the output of the circuit above? [2 marks]

Answer: Assuming $V_{GS} = 0$ $\therefore V_{GS} < V_T$ (the mosfet is in cut-off mode)

so,



$\therefore I = 0$

So, $5 - IR =$ ~~output~~ Vout

$\Rightarrow 5 - 100 \times 0 = V_{out}$

$\therefore V_{out} = 5V$

6. If $V_{DS} = 3V$, $V_{GS} = 3V$ and $V_T = 1V$, find the gate current, drain current and source current of a MOSFET given that $k = 0.5mA/V^2$. [1 mark]

Answer: $I_G = 0$ (any mode)

$I_S = I_D$ (in triode and saturation)

We know, $V_{ov} = V_{GS} - V_t = 3 - 1 = 2$ $\therefore V_{GS} > V_t$.

$\therefore V_{DS} > V_{ov}$ which means saturation.

Now, $I_D = I_S = 1/2\, K (V_{ov})^2$

$= 1/2 \times 0.5 \times (2)^2$

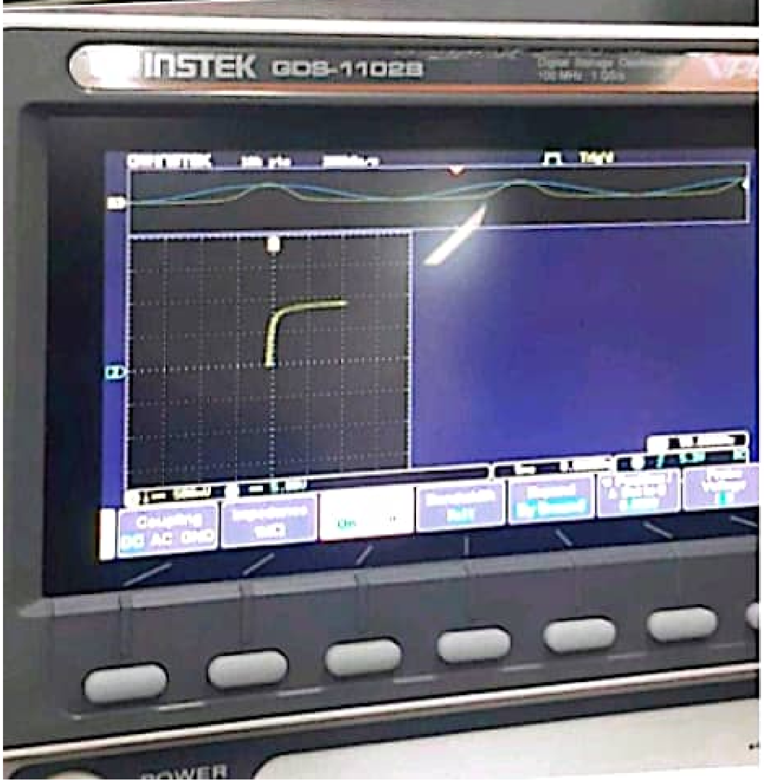
$= 1mA$.


GW INSTEK GDS-1102B
Measurement Summary
CH1
CH2
Math
Display All
Source
CH2
OFF
Add Measurement
Remove Measurement
Gating Screen
Display All CH2
High-Low Auto
Statistics


GW INSTEK
POWER


GW INSTEK GDS-1102B
Digital Storage Oscilloscope 100 MHz 1 GS/s
Measurement Summary
CH1
CH2
Math
Display
Source
CH1
OFF
Add Measurement
Remove Measurement
Gating Screen
Display All CH1
High-Low Auto
Statistics


POWER


INSTEK GDS-1102B
Coupling DC AC GND