Study of the MOSFET Parameters Effect on Drain and Transfer Characteristics

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Abstract - *The goal of this paper is to observe the effect of change of the MOSFET parameters on the value of its drain current. Designing the MOSFET with appropriate parameters like source area, drain area, and aspect ratio enables the design of integrated digital circuits with the best performance, depending on the selected MOSFET parameters and the operation conditions.*

Key Words: MOSFET structural parameters, drain characteristics, transfer characteristics, aspect ratio, drain current.

1. INTRODUCTION

In digital electronic circuits the Metal Oxide Semiconductor Field Effect Transistor is considered as the essential element which is based on different types of MOS transistors. The MOSFET is the most widely used switching device in the design of digital integrated circuits based on the structure, the technological advantages, and the relative minimalism of MOSFET operation. [1] As compared to BJT, the MOSFET occupies a relativity smaller silicon area and has lower dissipation power. Because of these advantages it is possible to group many MOSFETs on a particular integrated circuit, resulting in the highest packing density of that digital integrated circuits. In this present study NMOS structure is considered for parametric variations like channel width, channel length, drain area, source area to signify the effect on transfer and drain characteristics. This in turn will enhance the MOSFET performance depending on different applications.[5]

2. WORKING PRINCIPLE OF MOSFET

The main theory of the MOSFET is to control the voltage and current flow amid the source and drain terminals. The functionality of the device is dependent on the MOS capacitor which is the main part of the MOSFET. The MOSFET acts like a switch. [3] By the use of either a positive or negative gate voltages, the semiconductor surface at the lower oxide layer, located between the source and drain terminal can be reversed from p-type to n-type respectively. The holes present under the oxide layer are pushed down along with the substrate as soon as we apply a repulsive

force for the positive gate voltage. The bound negative charges which are related with the acceptor atoms are present in the depletion region. A channel is formed when the electron reach there. [2]The electrons from the n+ source and drain regions are attracted into the channel formed by the positive voltages. Now, when we apply a voltage between the drain and source, the current flows amid the source and drain. If a negative voltage is given, a hole channel will be created below the oxide layer.
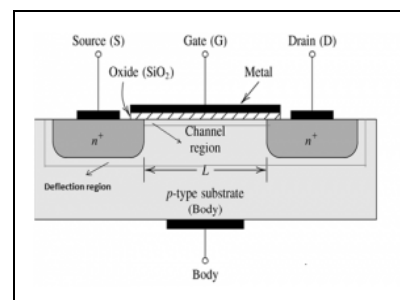

Fig -1: Block Diagram of MOSFET

3. STRUCTURE OF NMOS

The four-terminal device having the terminals as gate, drain, source, body with a N-channel region between the heavily doped n+ source and n+ drain is called the N-channel MOSFET. In this device the substrate or body is of P-type. The negatively charged electrons are the major charge carriers. [4]
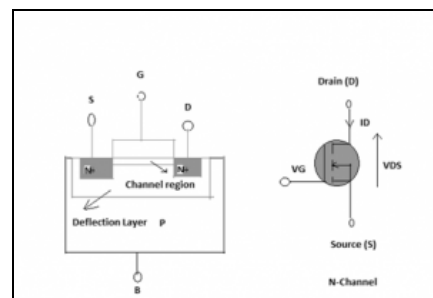

Fig -2: Structure of NMOS
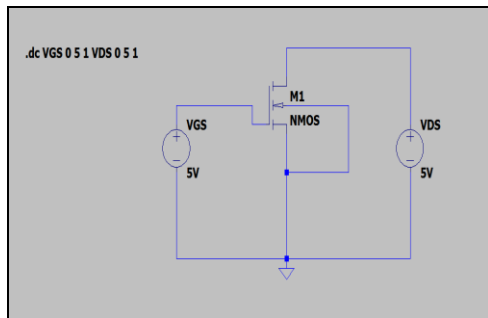

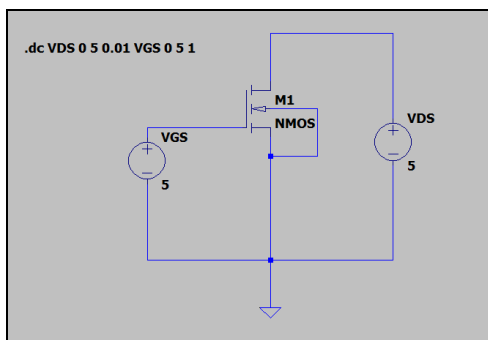## 4. CIRCUIT CONFIGURATION

Fig -3: Transfer Characteristics

Fig -4: Drain Characteristics

$$I_D = \mu_n C_{ox} \frac{W}{L}\left[(V_{GS} - V_{TH})V_{DS} - \frac{1}{2}V_{DS}^2\right] \quad - - - - - (1)$$

where ,

μ_n is the mobility of charge carriers

$W \& L$ is the width and length of the NMOS

$V_{GS} \& V_{DS}$ is the gate to source voltage and drain to source voltage.

V_{TH} is the Threshold voltage

C_{ox} is the oxide capacitance

5. OBSERVATIONS WITH DISCUSSION

We have used LT Spice XVII software for performing these parametric variations on NMOS structure.

Table -1: Parameter Selection for design of Drain Characteristics

|				V_{DS} = 0-5 V	
Observation no.	Aspect ratio $\frac{W}{L}$	Drain area, Source area	Source parameter ,Drain parameter	V_{GS} (v)	I_D
Case 1	$5*10^{-7}$	5p	1u	0	9.28 pA
				1	15.30 pA
				2	30.11 pA
				3	54.65 pA
				4	90.07 pA
				5	134.98 pA
Case 2	$1*10^{-8}$	10p	20u	0	09.99 pA
				1	10.04 pA
				2	10.37 pA
				3	10.90 pA
				4	11.63 pA
				5	12.49 pA
Case 3	1	50p	100u	0	0 uA
				1	10.16 uA
				2	40.16 uA
				3	90.48 uA
				4	160.16 uA
				5	249.68 uA
Case 4	0.1	100p	50u	0	0 uA
				1	0.097 uA
				2	0.392 uA
				3	0.900 uA
				4	1.606 uA
				5	2.497 uA
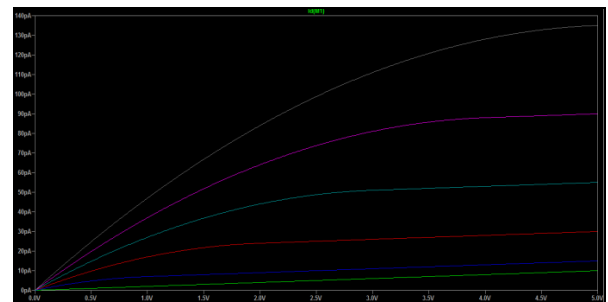
Fig -5: Drain Characteristics Graph for Case 1
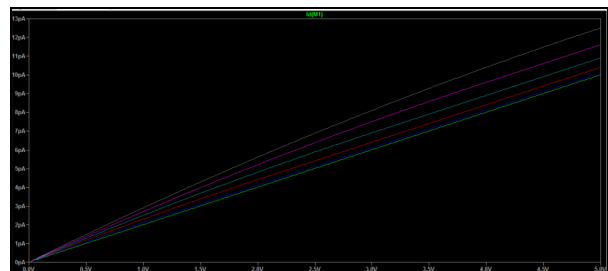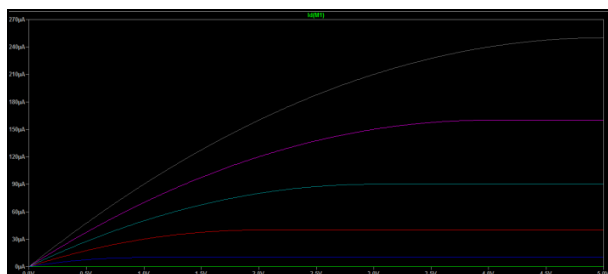

Fig -6: Drain Characteristics Graph for Case 2

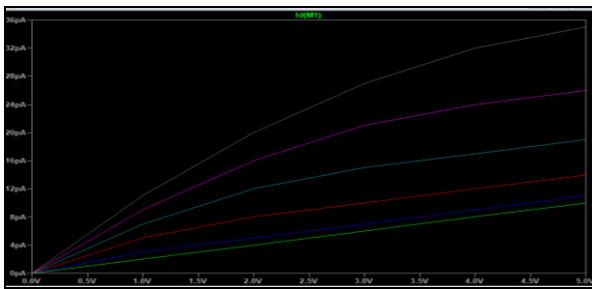**Fig -7**: Drain Characteristics Graph for Case 3

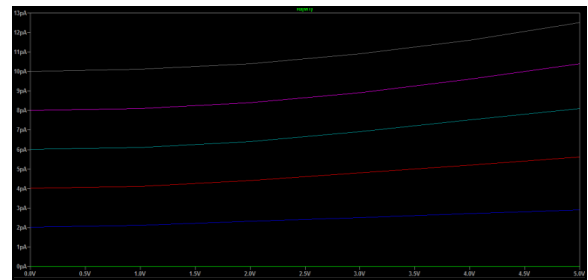**Fig -8**: Drain Characteristics Graph for Case 4

Table -2: Parameter Selection for design of Transfer Characteristics

Observation no.	Aspect ratio $\frac{W}{L}$	Drain area, Source area	Source parameter ,Drain parameter	V_{DS} (v)	I_D
Case 1	$5*10^{-7}$	5p	1u	0 1 2 3 4 5	0 pA 46.67 pA 83.68 pA 110.39 pA 127.45 pA 134.53 pA
Case 2	$1*10^{-8}$	10p	20u	0 1 2 3 4 5	0 pA 2.67 pA 5.75 pA 8.13 pA 10.40 pA 12.55 pA
Case 3	1	50p	100u	0 1 2 3 4 5	0 uA 89.38 uA 159.52 uA 208.55 uA 240.21 uA 249.52 uA
Case 4	0.1	100p	50u	0 1 2 3 4 5	0 uA 0.900 uA 1.595 uA 2.092 uA 2.402 uA 2.508 uA

V_{GS} = 0-5 V

Fig -9: Transfer Characteristics Graph for Case 1

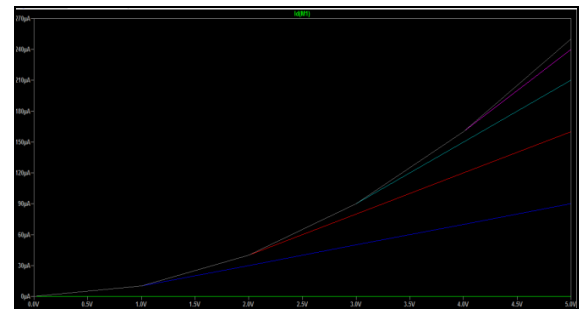**Fig -10**: Transfer Characteristics Graph for Case 2

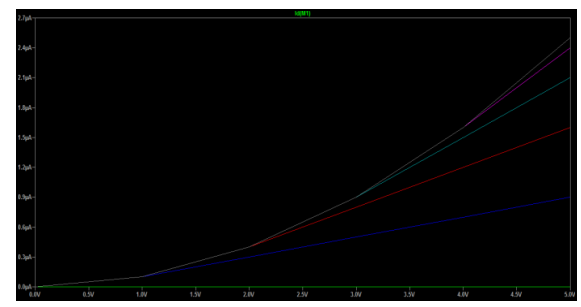
Fig -11: Transfer Characteristics Graph for Case 3

Fig -12: Transfer Characteristics Graph for Case 4

According to ohm's law :

$$V = IR \implies I = \frac{V}{R} \qquad - - - - (2)$$

which implies that R(resistance) and current are inversely proportional. comparing drain current equation (1) with equation (2), aspect ratio (W/L) is equivalent to conductance. Hence (L/W) is considered to be the resistance of the drain current through the channel. Hence by varying the aspect ratio we are able to control the drain current. As (W/L) works as conductance, by increasing the ratio (W/L), or by decreasing the ratio (L/W), flow of current through the channel is increased through the channel. So, aspect ratio and drain current (I_D) are proportional to each other. As the drain and source area and drain and source parameter are determined based on W(width of the channel) and L(length of the channel),during stimulation as well as during manufacture, hence the drain current equation (1) varies proportionally (alike aspect ratio) with the drain and source parameter and their area.
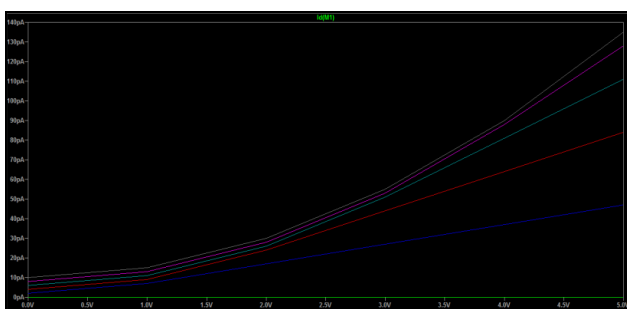
From the above observation table it is realized that when the aspect ratio is minimum ,least amount of current flows through the channel(both in drain as well as transfer characteristics). Gradually with the increasing value of the aspect ratio, current increases. Hence observation follows the above explanation.

6. CONCLUSIONS

The above observation and the discussions comes to a conclusion that, drain current varies proportionally with the drain and source parameters and drain and source area, as the similar relationship also follows for aspect ratio (W/L).

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