SUBJECT CODE : 24-509-0105

SUBJECT NAME : DIGITAL INTEGRATED CIRCUITS LAB

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MOSFET CHARACTERISTICS

MOSFET is a very popular kind of IG-FET. The full form of MOSFET is the Metal Oxide Semiconductor Field Effect Transistor. It is a three-terminal device that uses the electric field to regulate and maintain the flow of current. The three terminals are Gate, Drain, and Source

LONG CHANNEL n-MOSFET

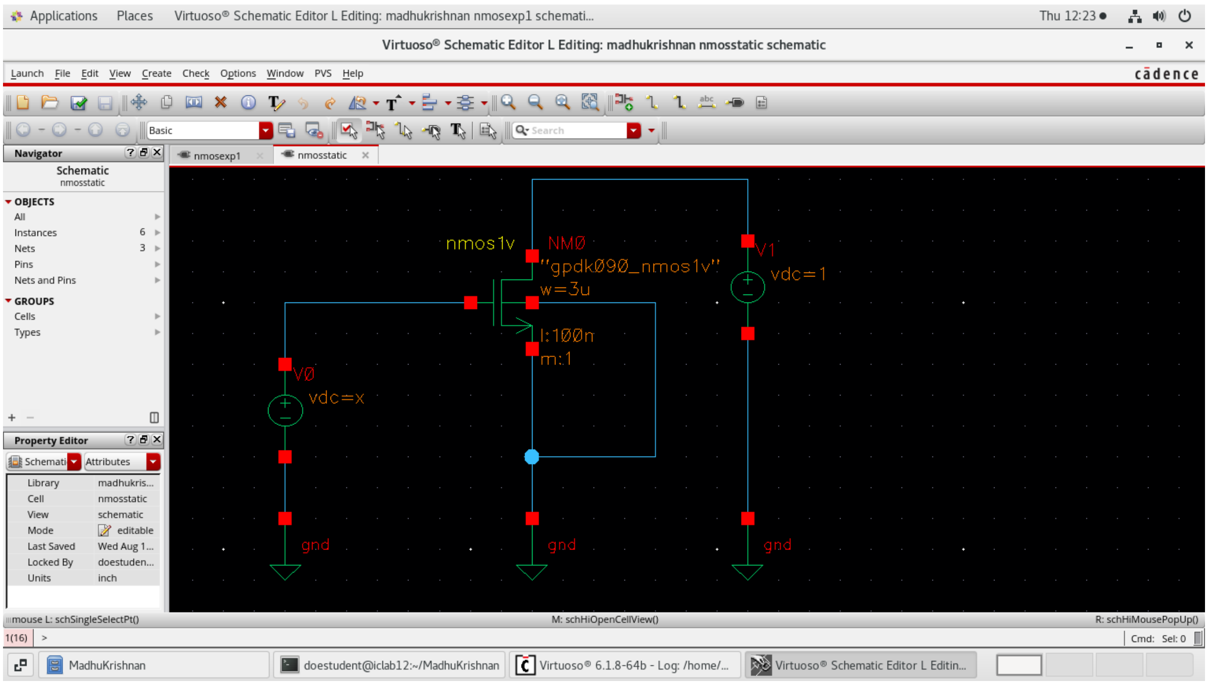
A long channel n-MOSFET with following dimensions were placed in Cadence Virtuoso.

Length, L = 1 + (Roll Number/5) = 1 + (10/5) = 3μm

Width, W = 1 + (Roll Number/5) = 1 + (10/5) = 3μm

Technology : 90 nm Technology

V_{DD} = 1V is connected to the MOSFET.

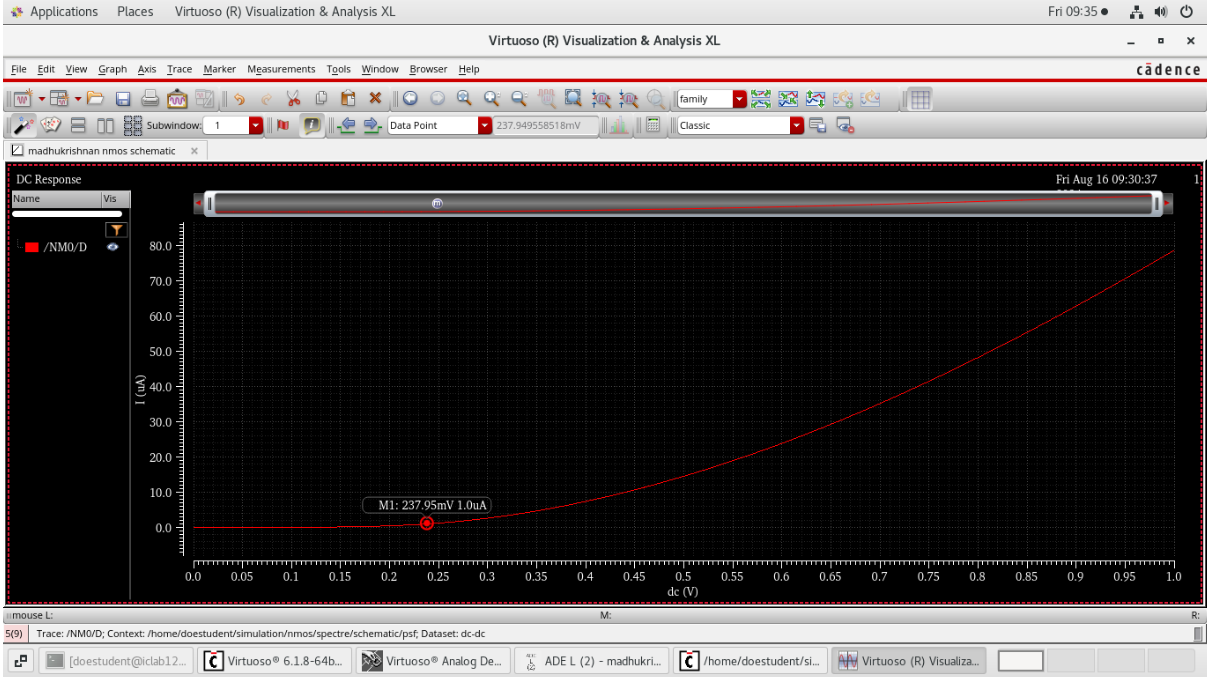


Schematic diagram

For this specific MOSFET, (W/L) = 1.

THRESHOLD VOLTAGE V_{T0}

V_{SB} is kept at 0V. The threshold voltage V_{T0} is found using DC analysis. V_{GS} is raised from 0 to 1V. The V_{GS} of corresponding point in DC analysis graph at which the I_{DS} turn from nanoampere range to microampere range is noted as V_{T0}



I_{DS} vs V_{DS} for V_{GS} = 1V

V_{T0} = 238 x 10^{-3} V

The I_D vs V_{DS} graph is plotted using DC analysis for varying V_{GS} and the following graph is obtained.

I_D vs V_{DS} for varying V_{GS}

EXTRACTION OF PARAMETERS

V_{T0} is found from the graph. The following calculations are done to calculate $\mu_n C_{ox}$ and λ.

2 Points are taken in saturation region with same V_{GS}

$$I_{DS} = \mu_n C_{ox} (W/2L) (V_{GS} - V_T)^2 (1 + \lambda V_{DS}) \qquad \text{[1]}$$

For M1

$I_{DS} = 30.9817 \times 10^{-6}$ A

W/L = 1

VGS = 666.7×10^{-3} V

For M2

$I_{DS} = 31.1165 \times 10^{-6}$ A

W/L = 1

VGS = 666.7×10^{-3} V

Substituting the above values in [1], we get

$\lambda = 0.0296751\ V^{-1}$

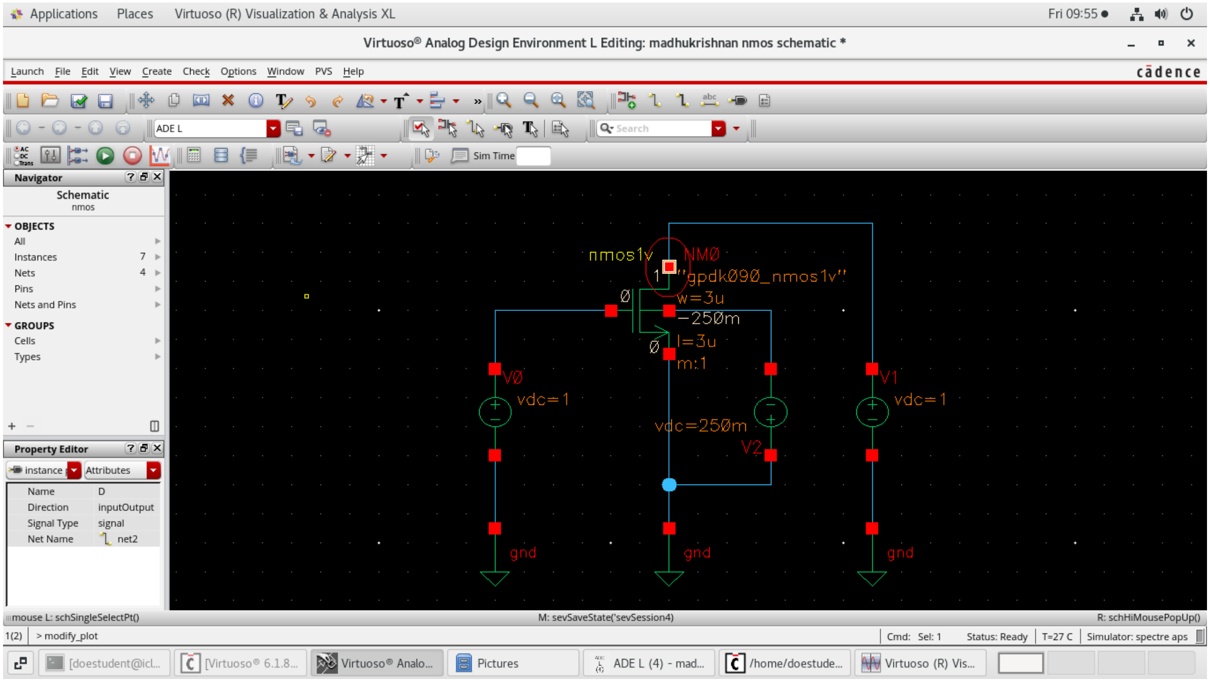
Substituting the value of λ and M1 in [1], we get $\mu_n C_{ox}$.

$\mu_n C_{ox} = 331.2862\ \mu A/V^2$

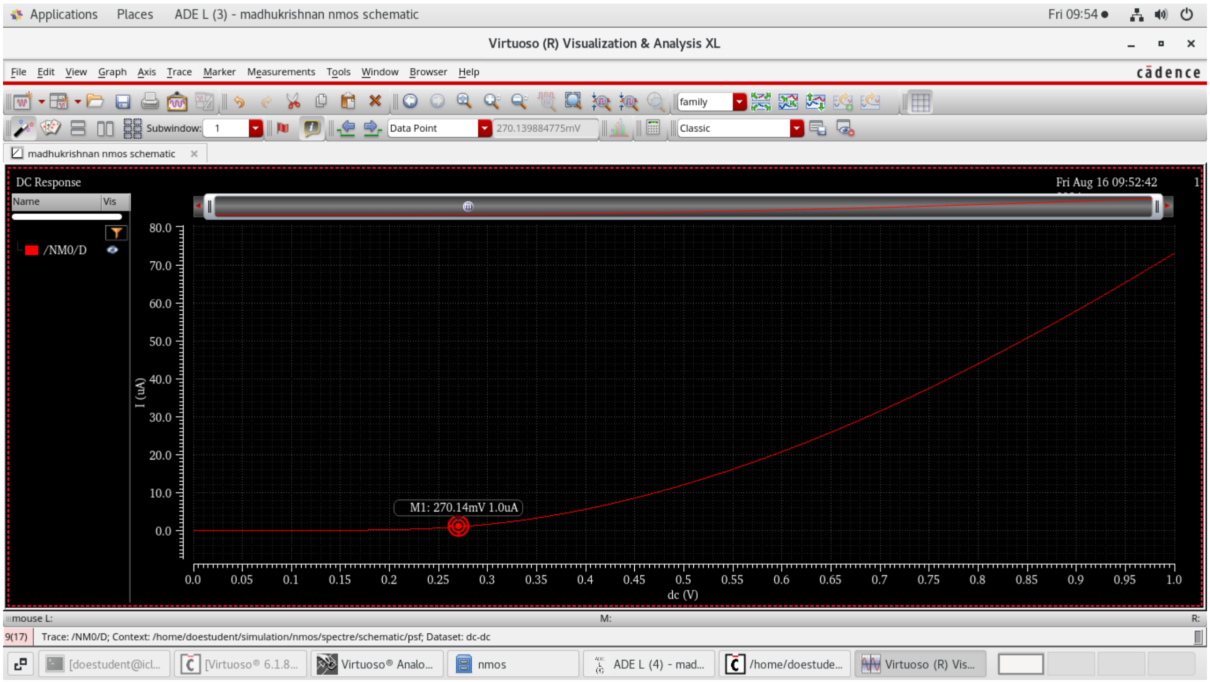
EXTRACTION OF PARAMETERS WITH VSB ≠ 0

V_{SB} is introduced between source and body. The corresponding DC analysis results are as following.

$V_{SB} = 0.250$ V



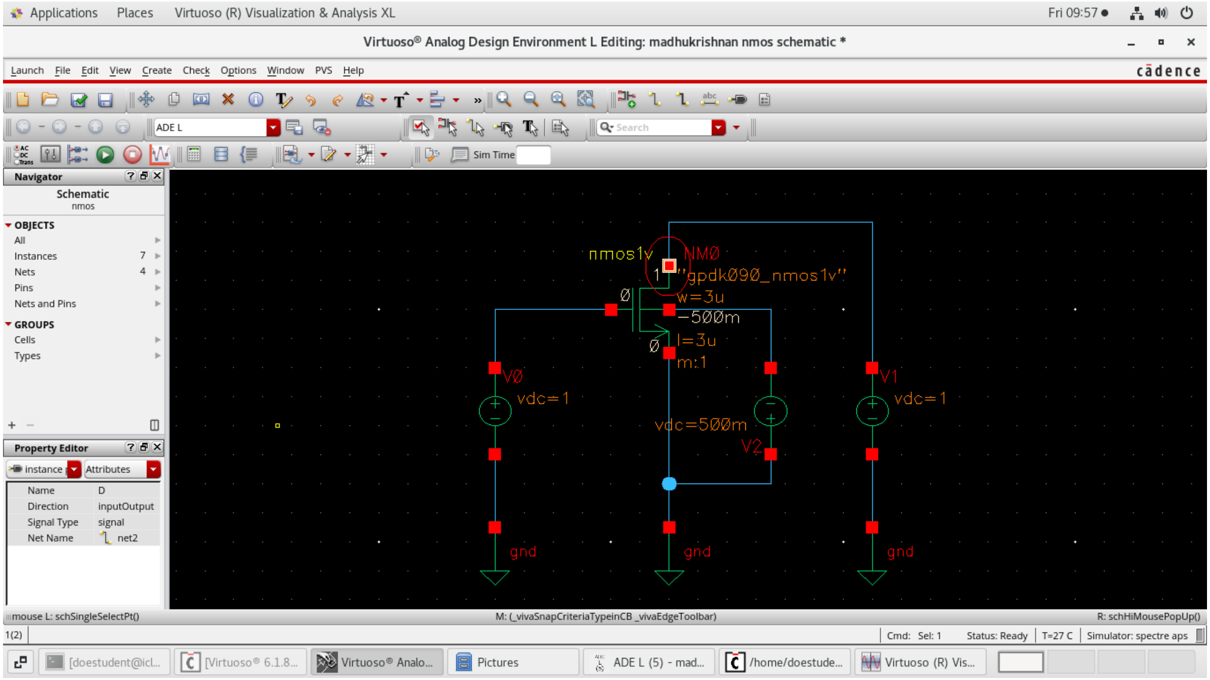
Schematic diagram for NMOS with $V_{SB} = 0.250$ V



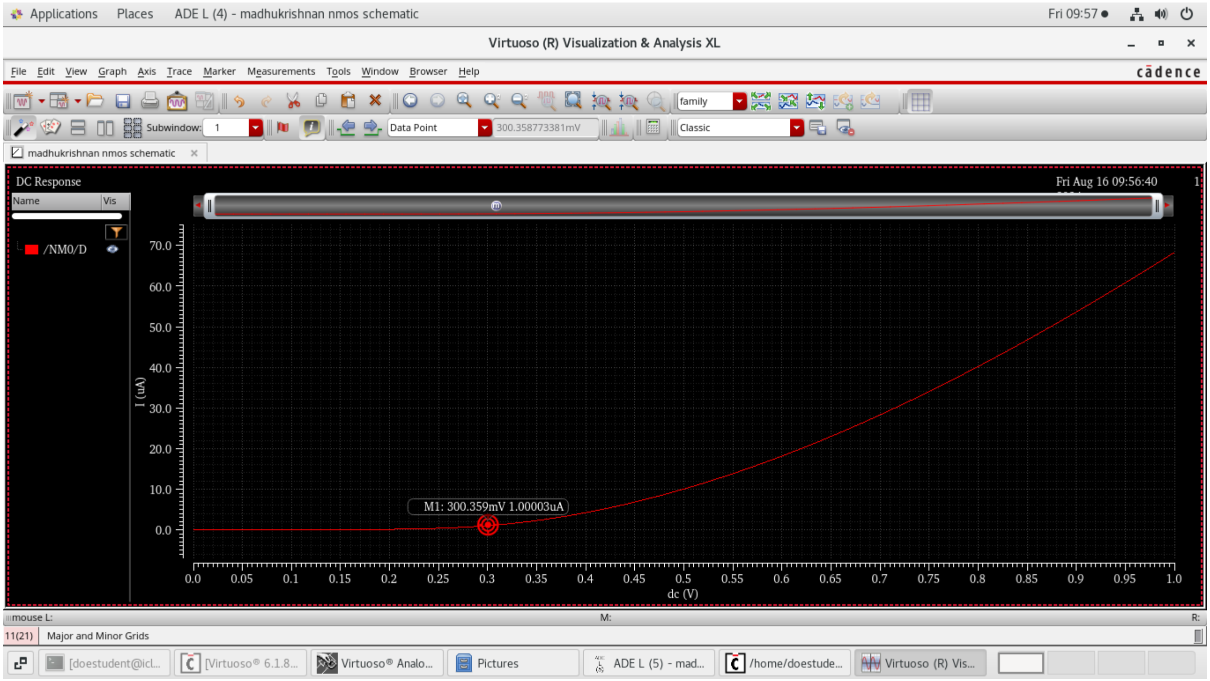
DC Analysis Graph for $V_{SB} = 0.250$ V

Threshold voltage, **V_T = 271 mV**

$V_{SB} = 0.500$ V



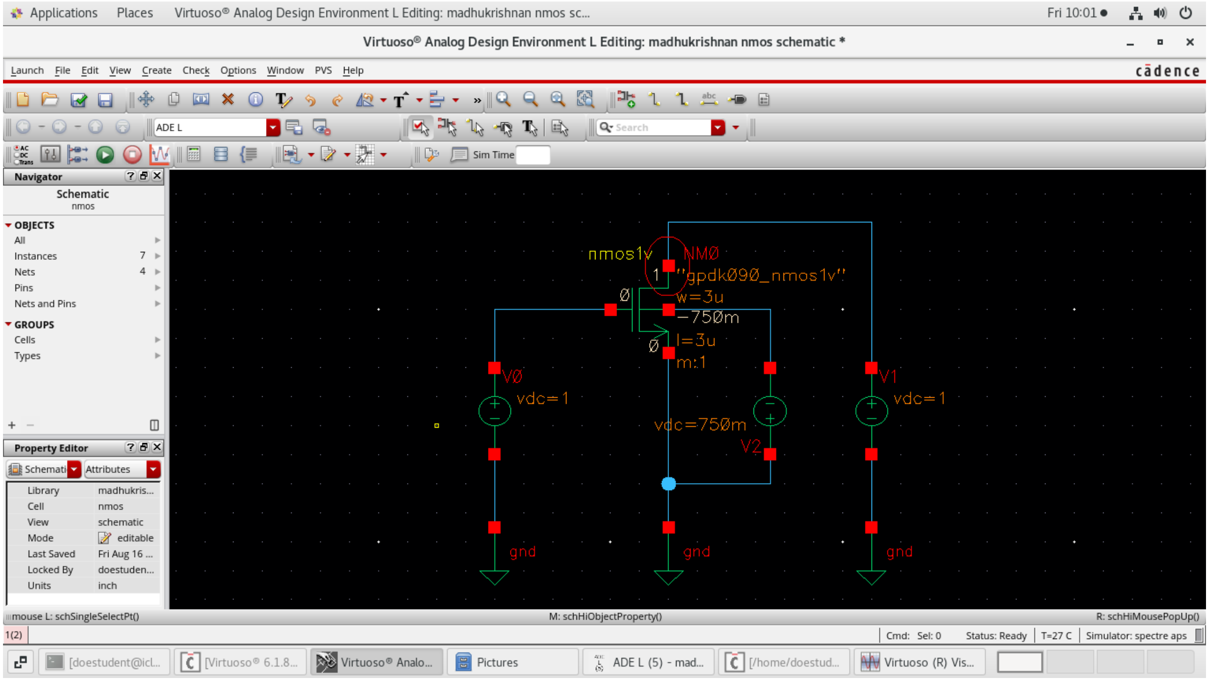
Schematic diagram for NMOS with $V_{SB} = 0.500$ V



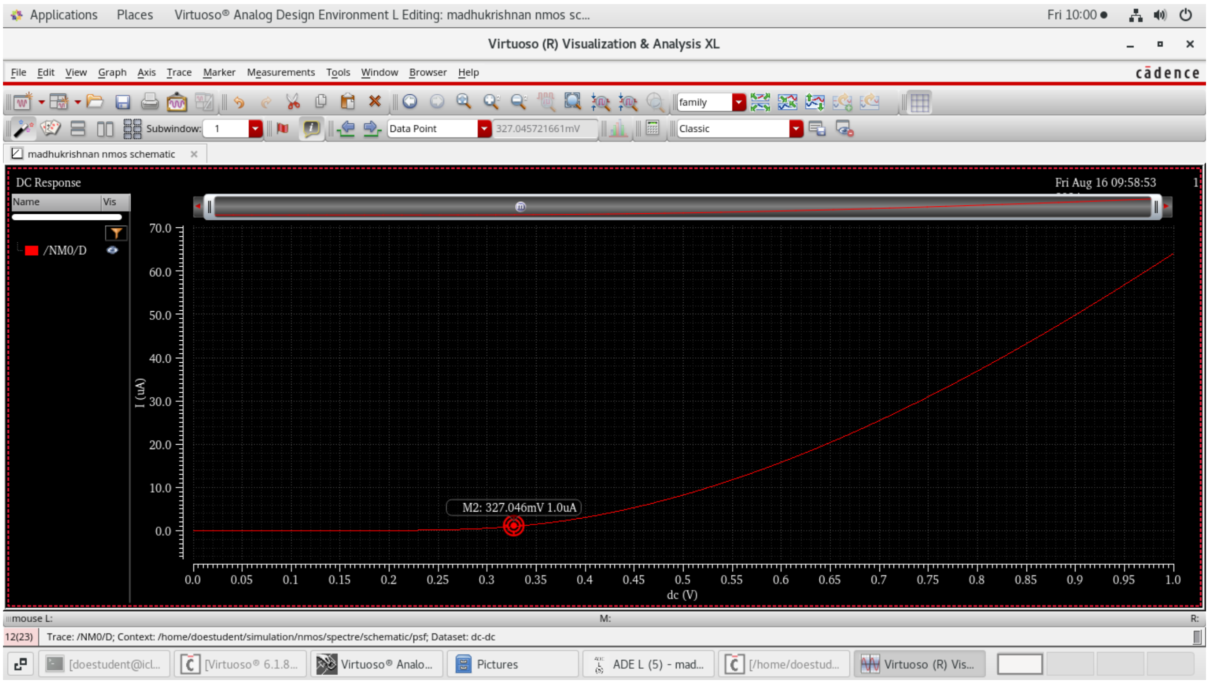
DC Analysis Graph for $V_{SB} = 0.500$ V

Threshold voltage, V_T **= 301 mV**

$V_{SB} = 0.750$ V



Schematic diagram for NMOS with $V_{SB} = 0.750$ V



DC Analysis Graph for $V_{SB} = 0.750$ V

Threshold voltage, $\mathbf{V_T = 328}$ **Mv**

The results are tabulated as following

V_{SB}	V_T
0 V	238 mV
250 mV	271 mV
500 mV	301 mV
750 mV	328 mV

We know,

$V_{TH} = V_{T0} + \gamma \sqrt{(|-2\varphi_F + V_{SB}|)} - \sqrt{(|-2\varphi_F|)}$

V_{TH} = Threshold Voltage

V_{T0} = Threshold voltage for V_{SB} = 0V

φ_F = Fermi potential for substrate

γ = Body effect coefficient

When V_{SB} is increased $|-2\varphi_F + V_{SB}|$ is increased and $\gamma \sqrt{(|-2\varphi_F + V_{SB}|)} - \sqrt{(|-2\varphi_F|)}$ is increased. This makes V_{T0} to increase. We can say that the body effect comes into action when V_{SB} is provided. The V_{SB} opposes the gate voltage. The gate must be provided a higher voltage than V_{T0} so that the MOSFET goes past the cutoff region and turns on. This body effect can be observed in both short channel and long channel MOSFETs.

SHORT CHANNEL n-MOSFET

A short channel n-MOSFET with following dimensions is placed in cellview.

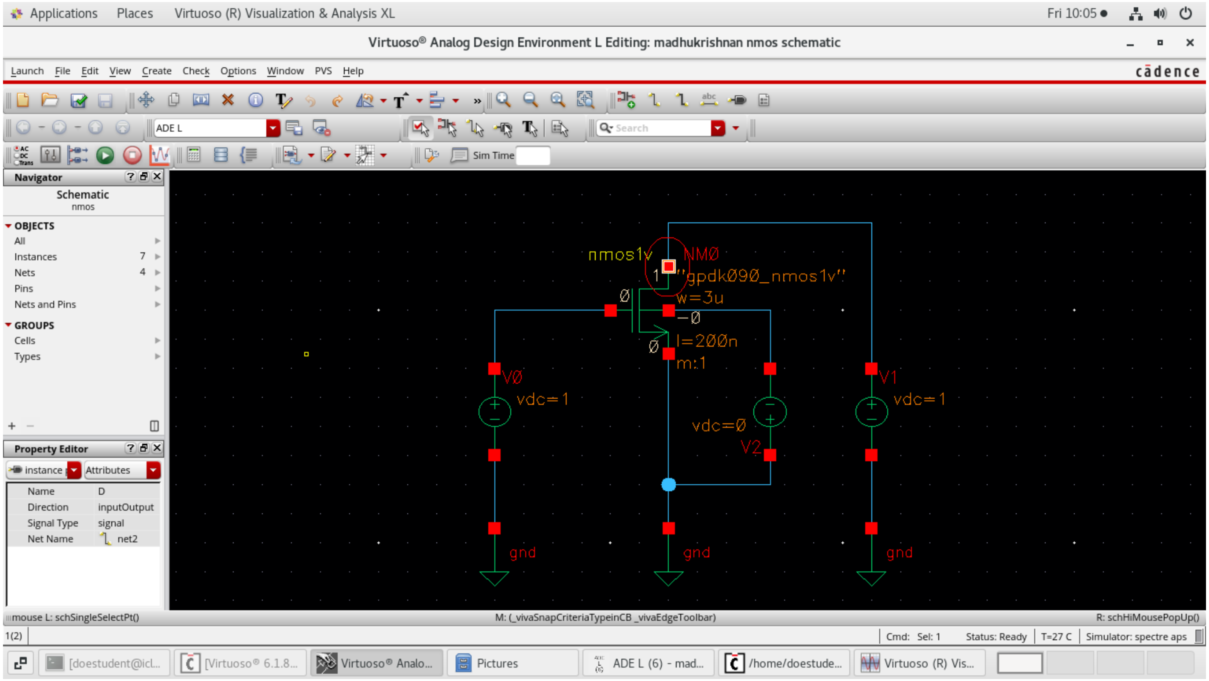
Length, 200 nm

Width, W = 1 + (Roll Number/5) = 1 + (10/5) = 3μm

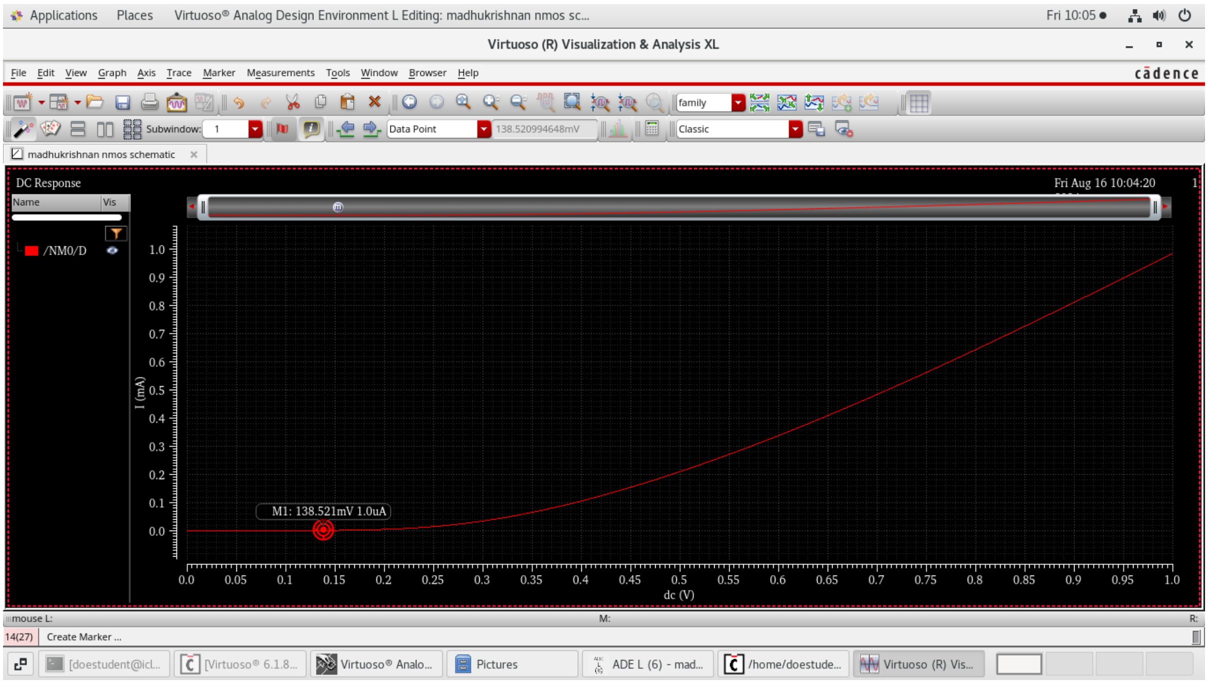
W/L = 15

V_{DD} = 1 V is connected to the MOSFET.

V_{SB} = 0 V



Schematic diagram

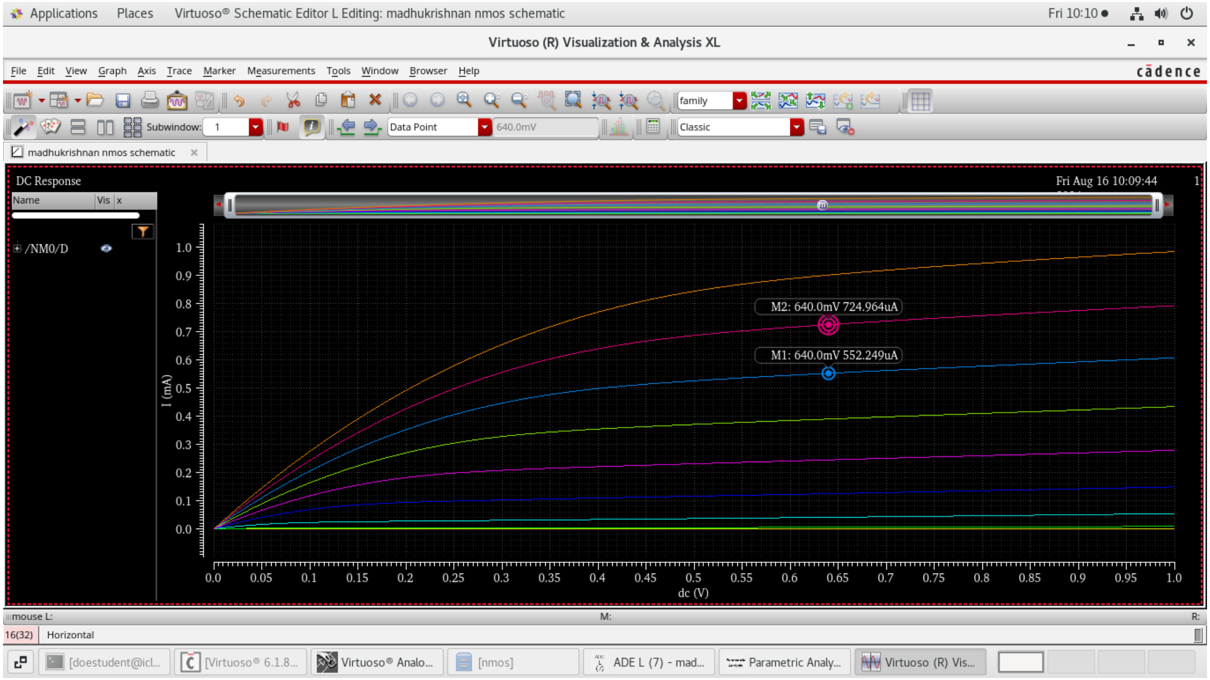


I_{DS} vs V_{DS} for V_{GS} = 1V

V_{T0} = 139 mV

EXTRACTION OF PARAMETERS

Parametric analysis is done for varying V_{GS} to extract parameters. The graph is plotted.



Parametric analysis graph

The following equation is used to find $I_{D\,SAT}$ and $\mu_n C_{ox}$

$I_{D\,SAT} = \mu_n C_{ox} (W/L) ([V_{GS} - V_T] V_{D\,SAT} - (V_{D\,SAT})^2/2)$ ________________________________[2]

2 Points M1 and M2 with different V_{GS} is taken

For M1

$V_{GS} = 777.8$ mV

$I_{D\,SAT} = 552.249$ µA

For M2

$V_{GS} = 888.9$ mV

$I_{D\,SAT} = 724.964$ µA

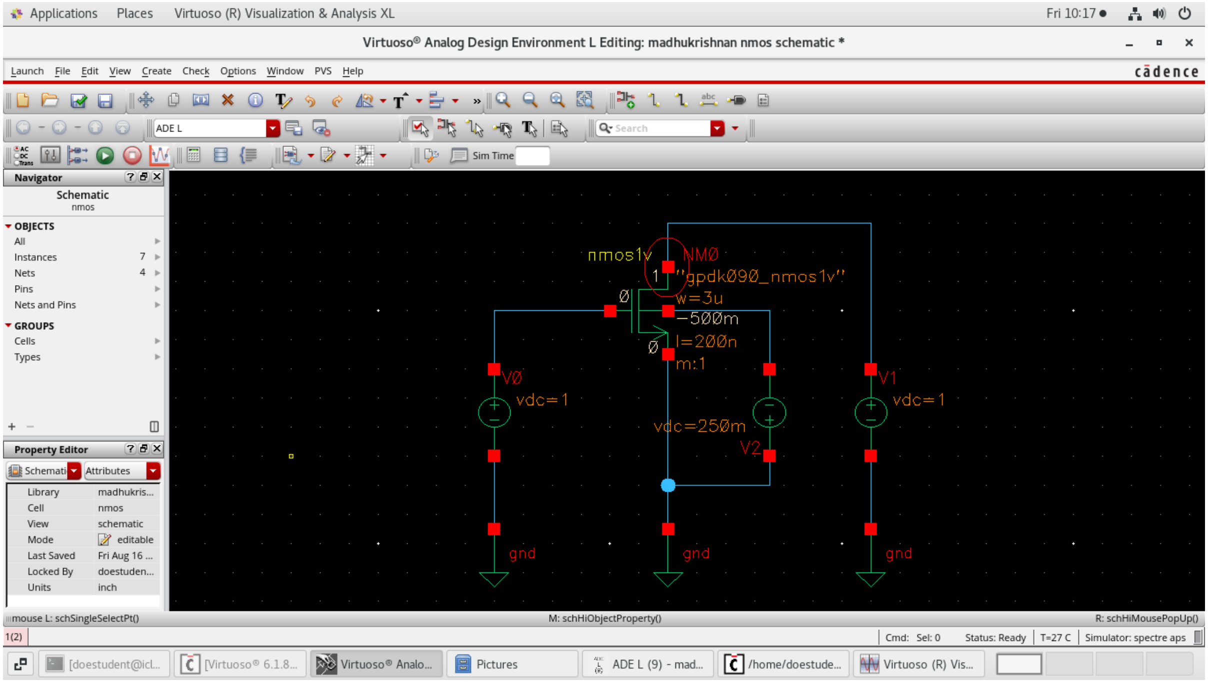
The above values are substituted in equation [2] and $V_{D\,SAT}$ is found. This is then substituted along with parameters of M1 to find $\mu_n C_{ox}$

$V_{D\,SAT} = 0.56796\ V^{-1}$

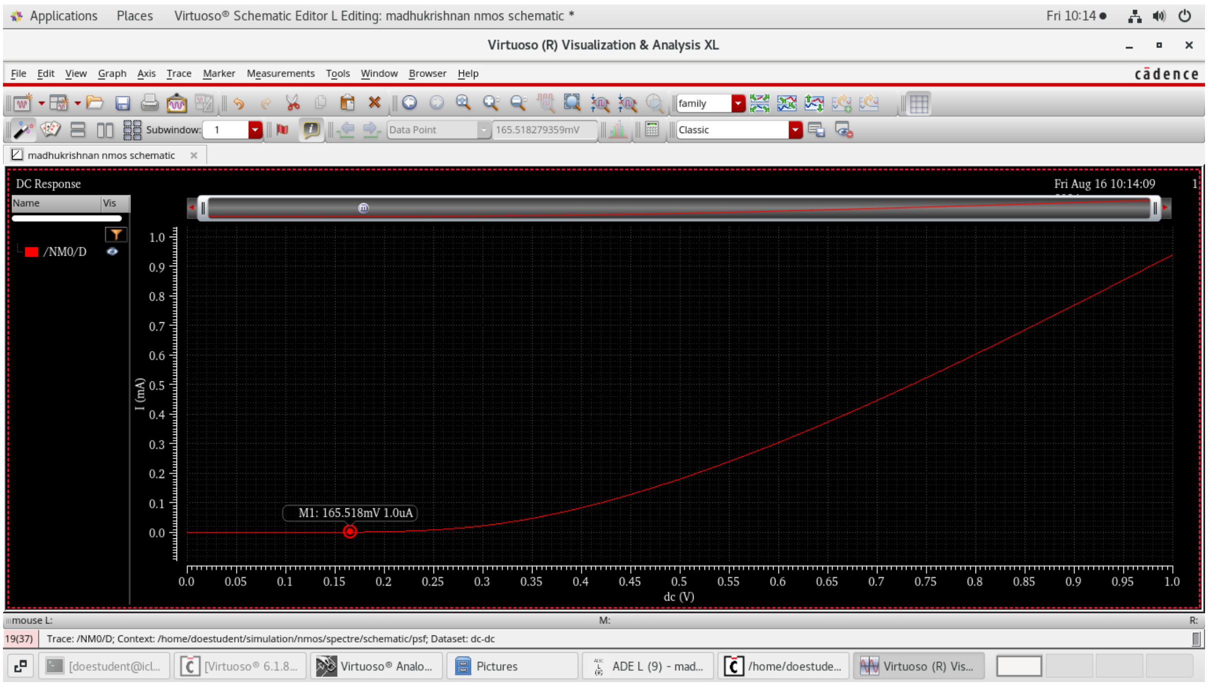
$\mu_n C_{ox} = 182.691\ \mu A/V^2$

V_{GS} is varied and V_T is noted using DC analysis of I_{DS} vs V_{DS}.

For V_{GS} = 0.250 V

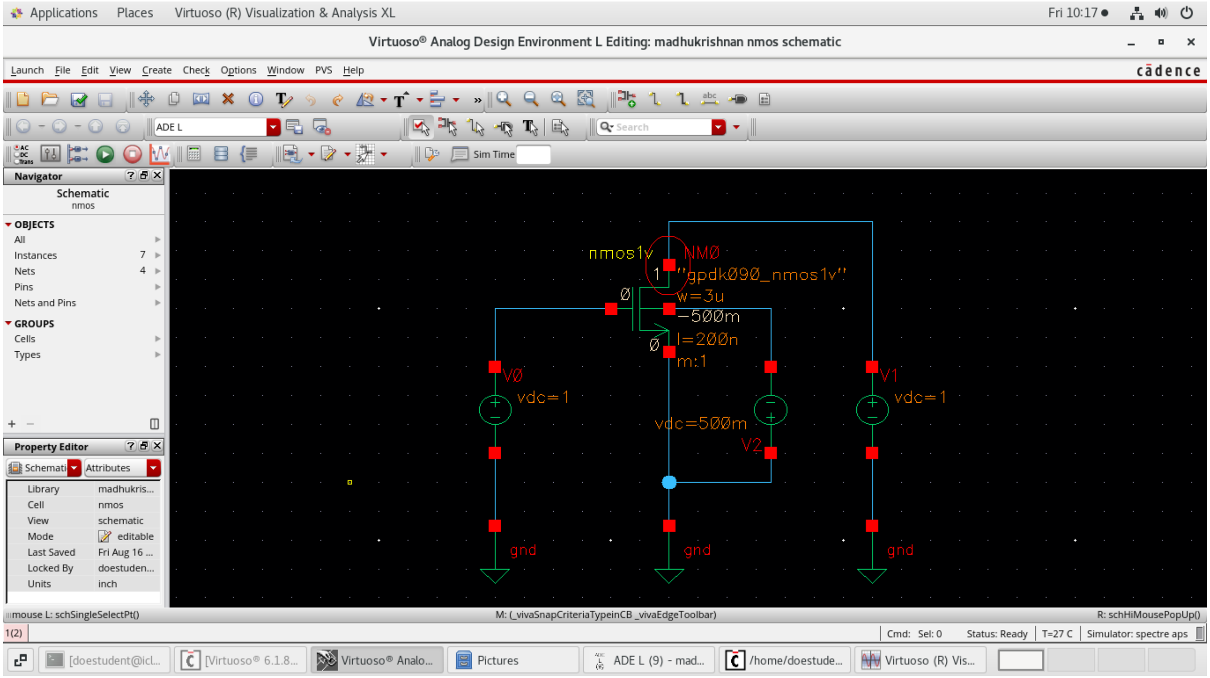


Schematic diagram

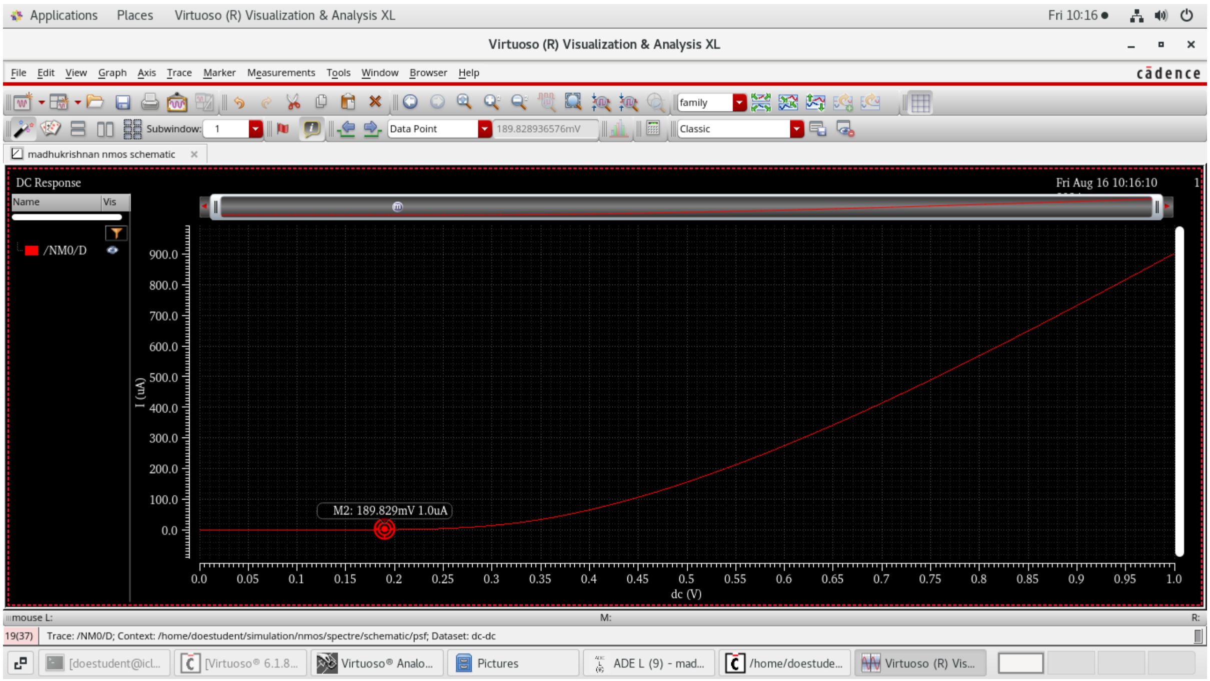


DC Analysis graph

For V_{GS} = 0.500 V

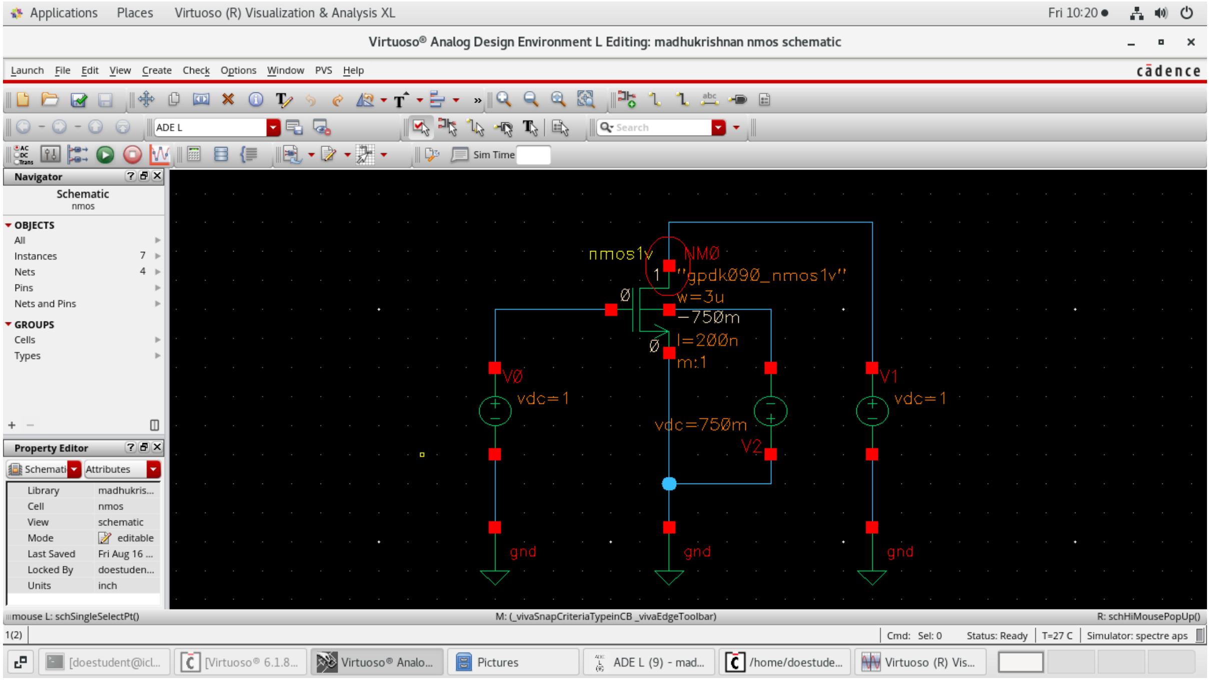


Schematic diagram

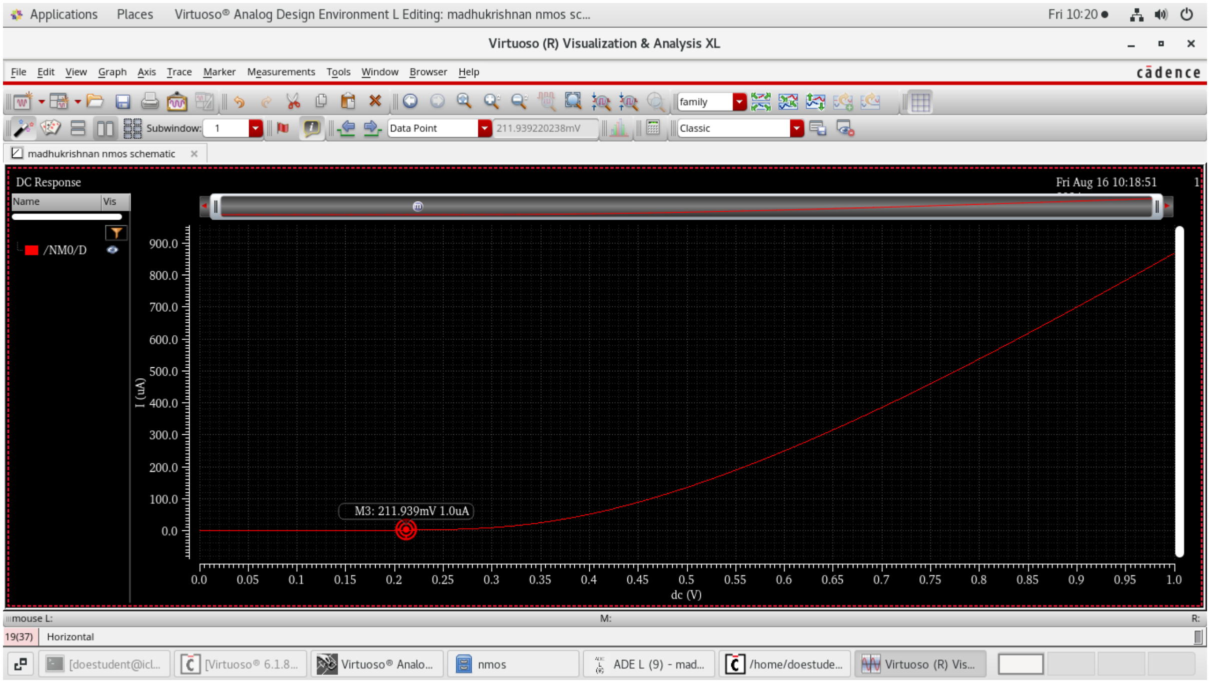


DC Analysis graph

For V_{GS} = 0.750 V



Schematic diagram



DC Analysis graph

The results are tabulated

V_{SB}	V_T
0 V	139 mV
250 mV	166 mV
500 mV	190 mV
750 mV	212 mV

A short channel n-MOSFET with following dimensions is placed in cellview.

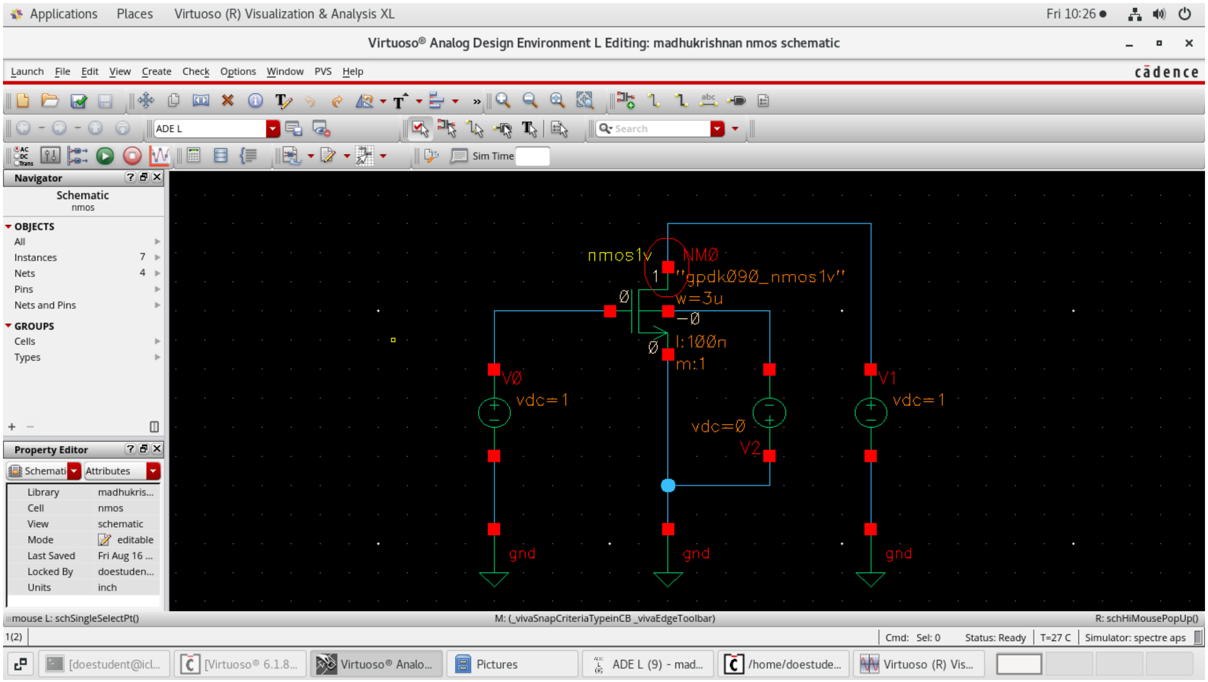
Length, 100 nm

Width, W = 1 + (Roll Number/5) = 1 + (10/5) = 3µm

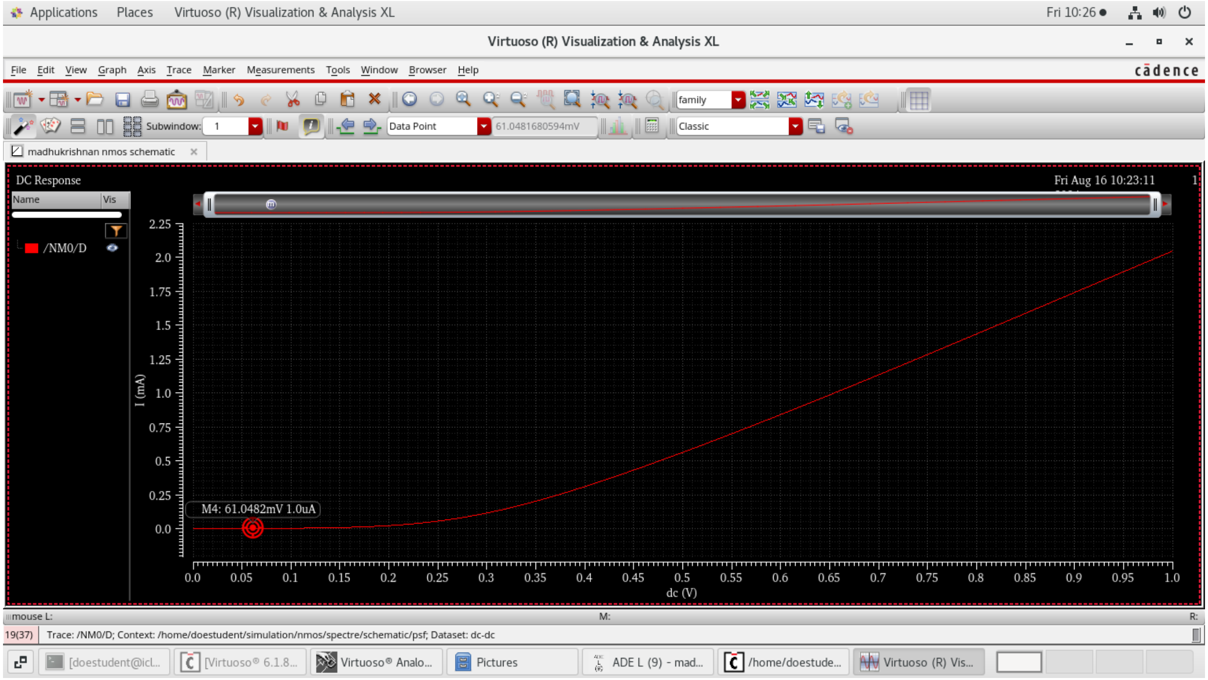
W/L = 30

V_{DD} = 1 V is connected to the MOSFET.

V_{SB} = 0 V



Schematic diagram



I_{DS} vs V_{DS} for V_{GS} = 1V

V_{T0} = 62 mV

EXTRACTION OF PARAMETERS

Parametric analysis is done for varying V_{GS} to extract parameters. The graph is plotted.

Parametric analysis graph

The following equation is used to find $I_{D\,SAT}$ and $\mu_n C_{ox}$

$$I_{D\,SAT} = \mu_n C_{ox} (W/L) \left([V_{GS} - V_T] V_{D\,SAT} - (V_{D\,SAT})^2/2 \right) \qquad [3]$$

2 Points M1 and M2 with different V_{GS} is taken

For M1

$V_{GS} = 777.8$ mV

$I_{D\,SAT} = 1.16296$ mA

For M2

$V_{GS} = 888.9$ mV

$I_{D\,SAT} = 1.49589$ mA

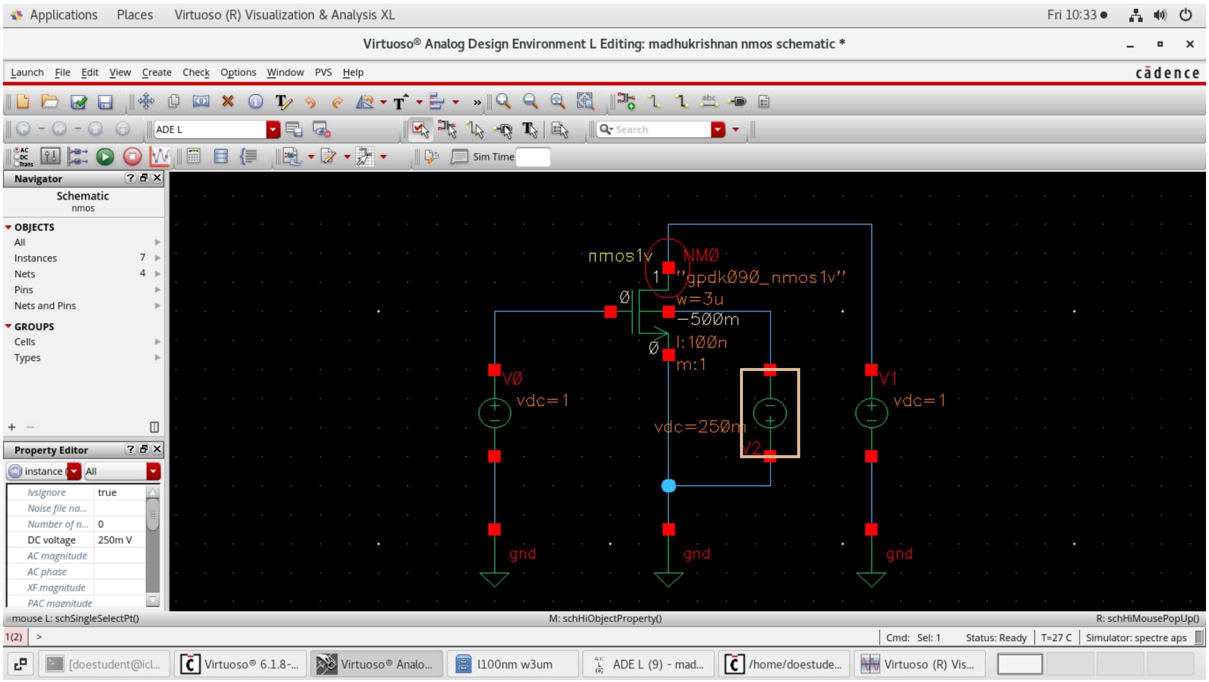
The above values are substituted in equation [3] and $V_{D\,SAT}$ is found. This is then substituted along with parameters of M1 to find $\mu_n C_{ox}$

$V_{D\,SAT} = 0.60582\ V^{-1}$

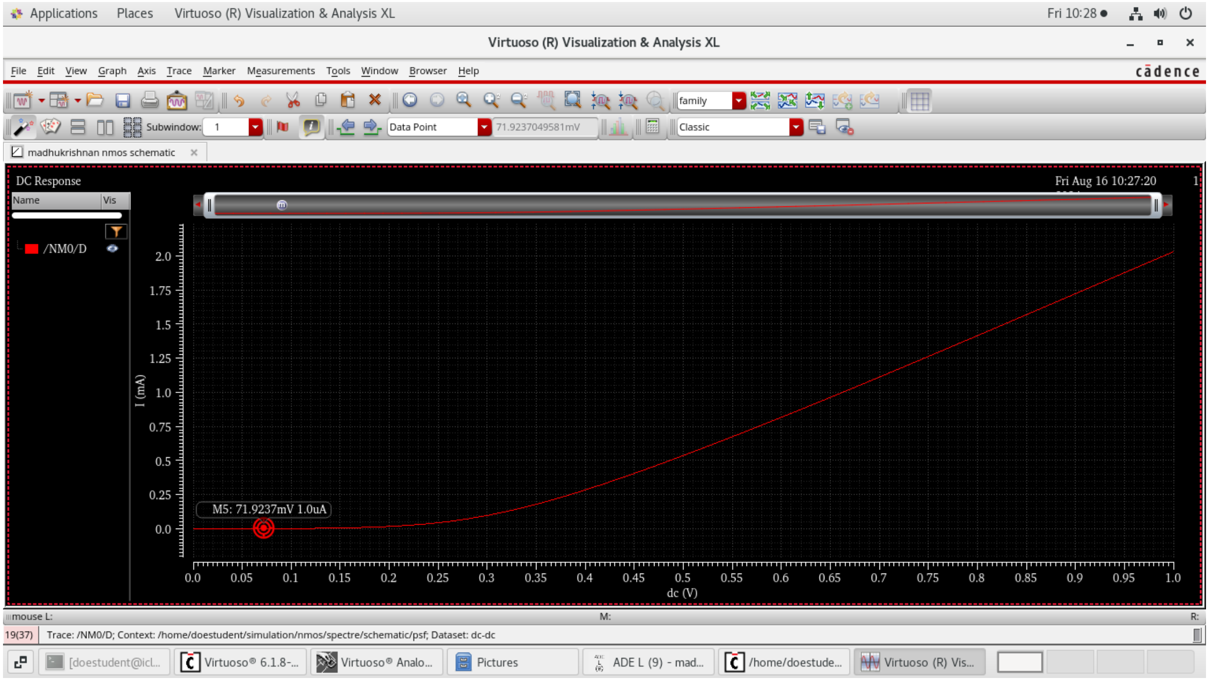
$\mu_n C_{ox} = 154.976\ \mu A/V^2$

V_{GS} is varied and V_T is noted using DC analysis of I_{DS} vs V_{DS}.

For $V_{GS} = 0.250$ V

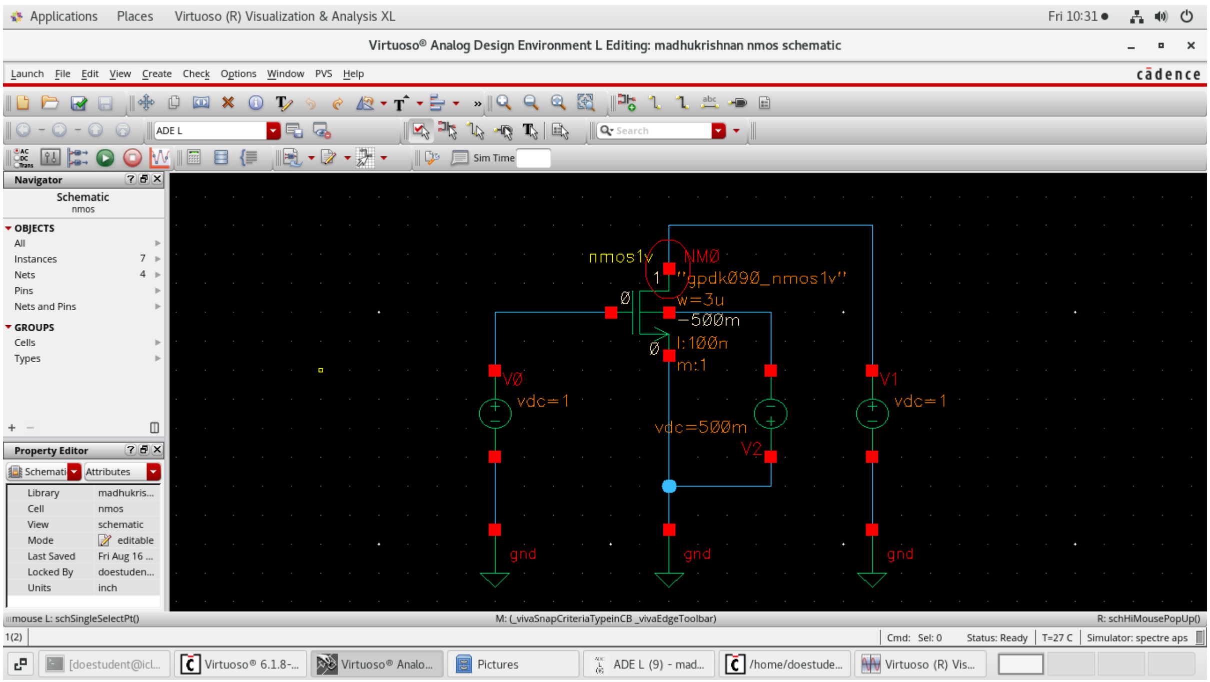


Schematic diagram

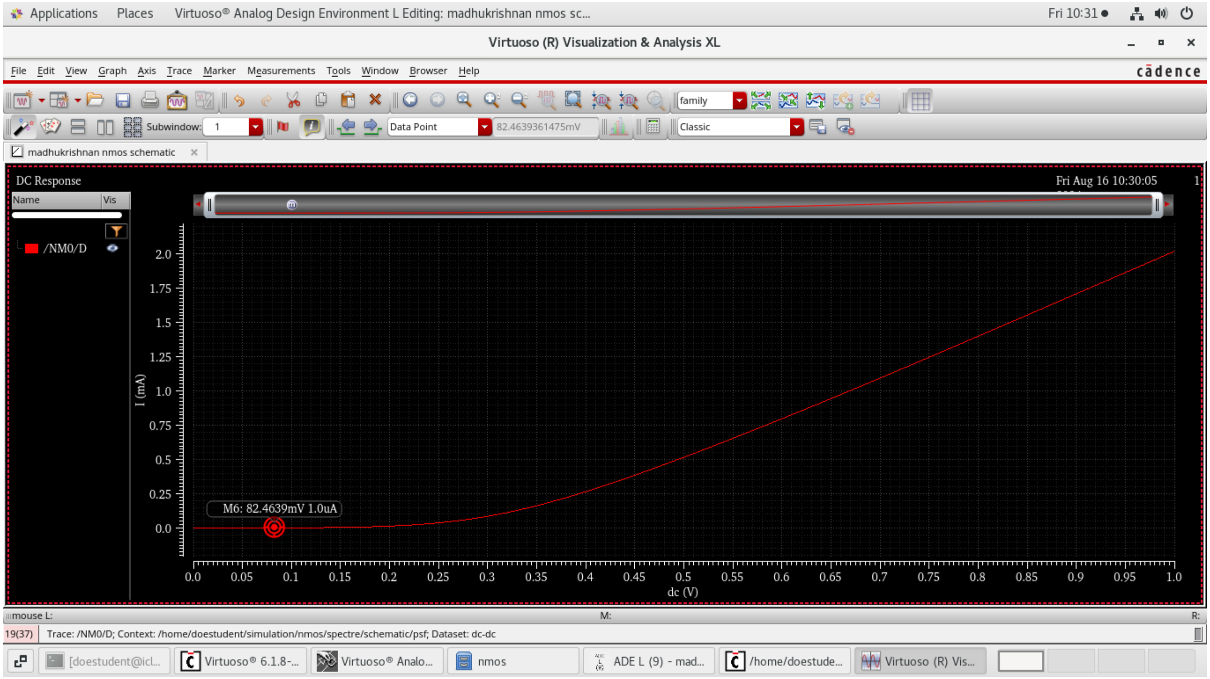


DC Analysis graph

For $V_{GS} = 0.500$ V

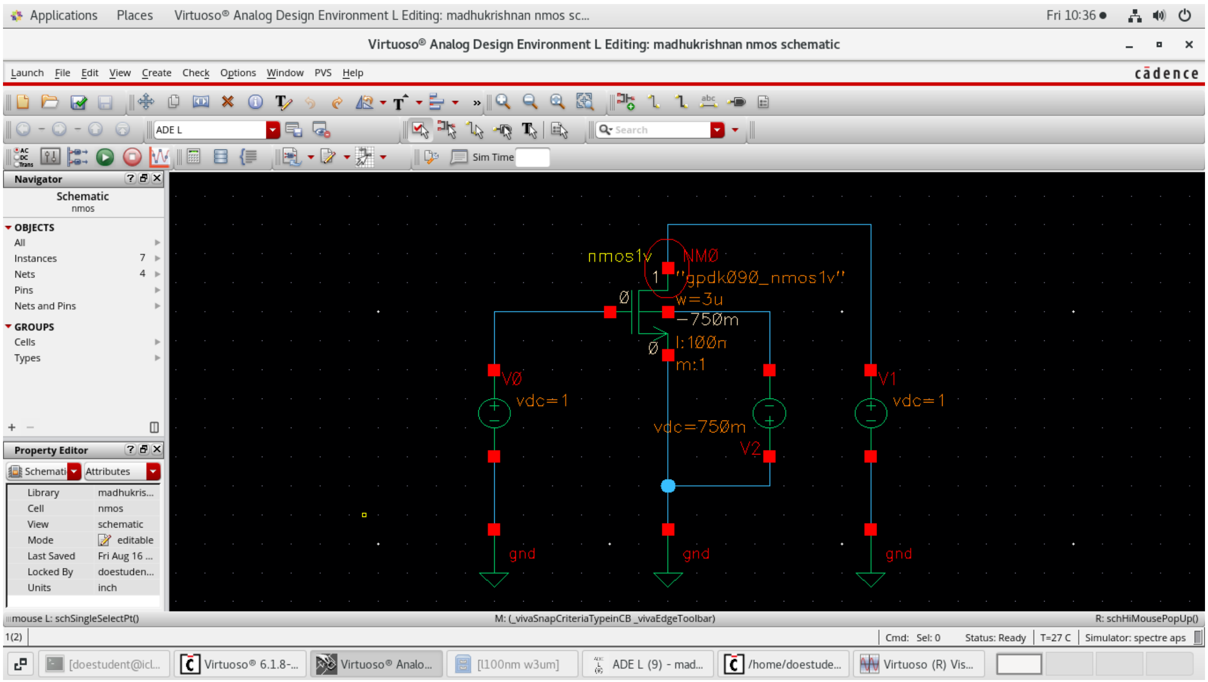


Schematic diagram

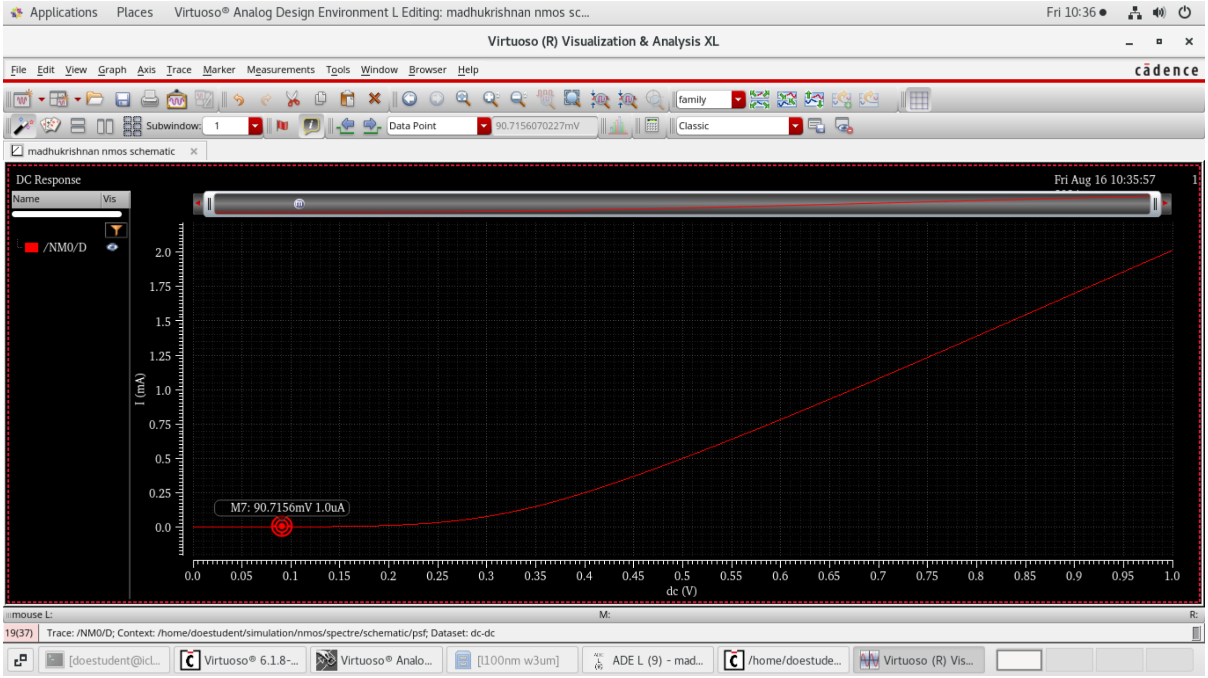


DC Analysis graph

For V_{GS} = 0.750 V



Schematic diagram



DC Analysis graph

The results are tabulated

V_{SB}	V_T
0 V	62 mV
250 mV	72 mV
500 mV	85 mV
750 mV	91 mV

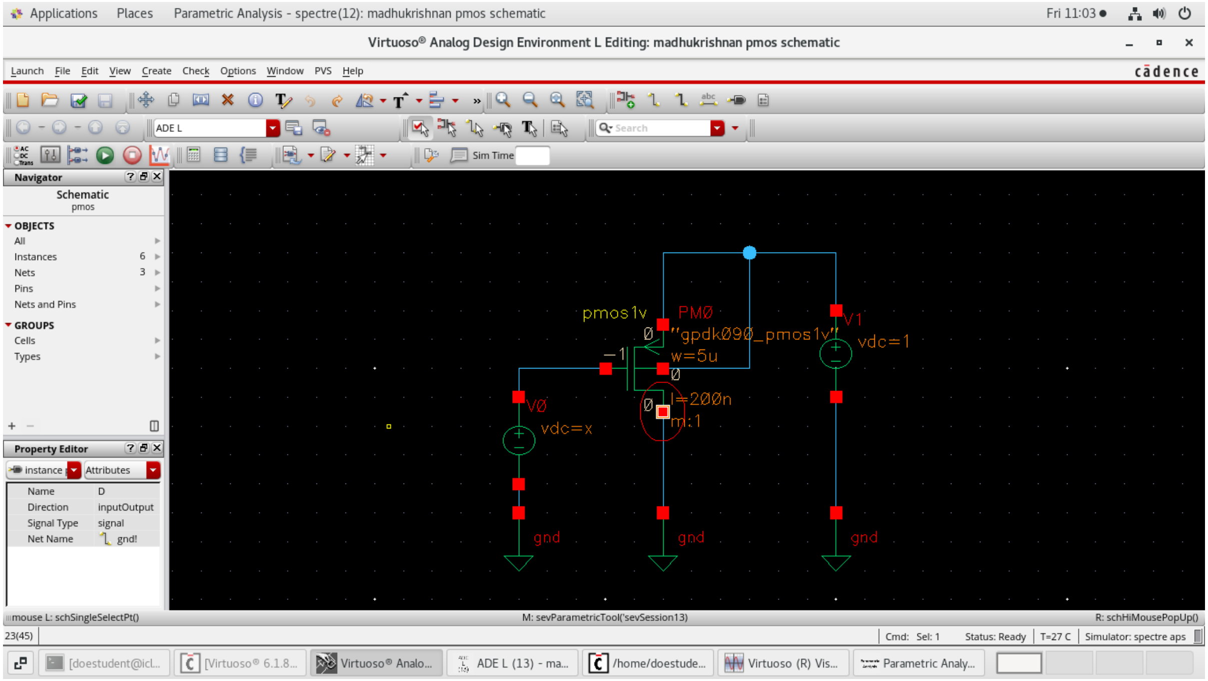
The threshold voltage is found to be reduced for equal V_{GS} and reduced length. The $V_{D\ SAT}$ is observed to be higher for 100nm MOSFET. The body effect can be seen in both 100nm and 200nm MOSFET.

p-MOSFET

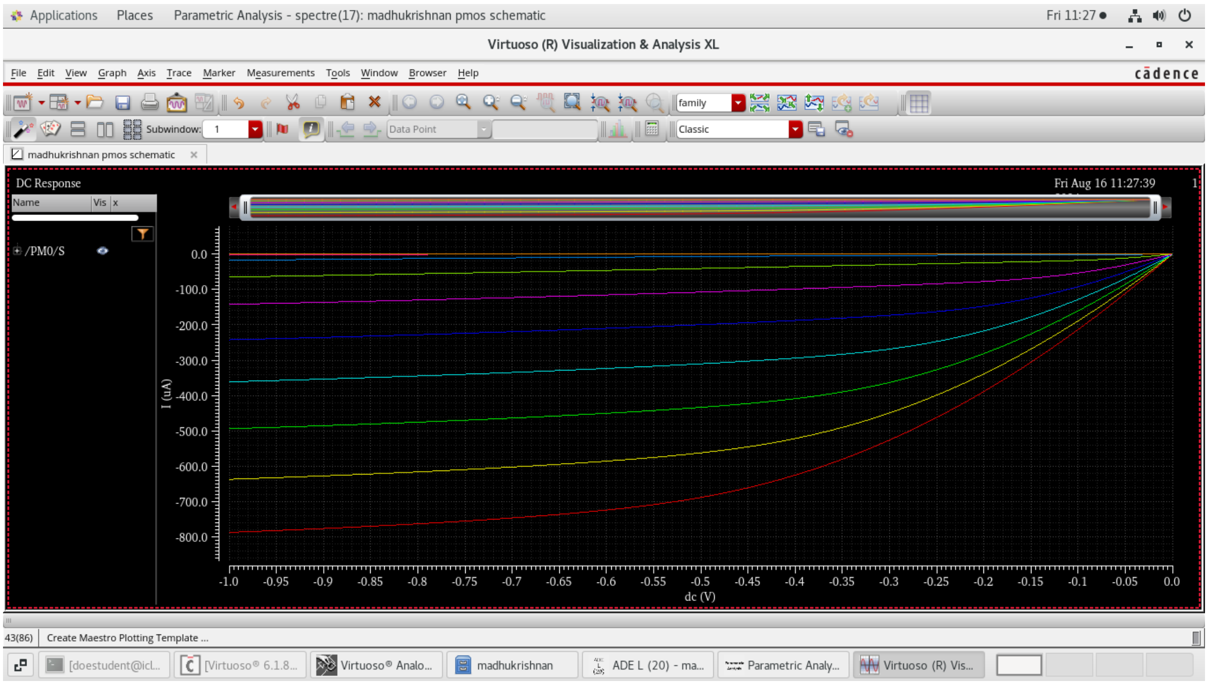
A p-MOSFET having following dimension is placed in cellview.

L = 200 nm

W = 3 µm



Schematic diagram



Parametric analysis graph

Parametric analysis is performed for V_{DS} vs I_{DS} with varying V_{GS}