EE236: Experiment No. 5
PMOS I/V Characteristics and Applications

Mayur Ware, 19D070070

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1 Overview of the experiment

1.1 Aim of the experiment

Aim of this experiment is to analyze the I-V characteristics of PMOS in linear region and saturation region by varying V_{GS} and V_{DS}.
To find the parameters of PMOS such as Threshold Voltage (V_T), Transconductance (g_m) and Body Effect Coefficient (γ).

1.2 Methods

Firstly, I read and understood the background material to understand the working and functionality of PMOS. Then, I wrote the ngs[pice netlsit to plot the I_D vs V_{DS} characteristics of PMOS by varying V_{GS} from -2.5V to -4V in steps of -0.5V and V_{DS} from 0 V to -5 V
After that, I modified the netlist to plot I_D vs V_{GS} characteristics of PMOS in linear and saturation region to find Threshold Voltage (V_T), Transconductance (g_m). Finally, I modified the netlist again to analyze the Body Bias Effect on PMOS and calculated the Body Effect Coefficient (γ) by varying V_{SB}.

2 Design

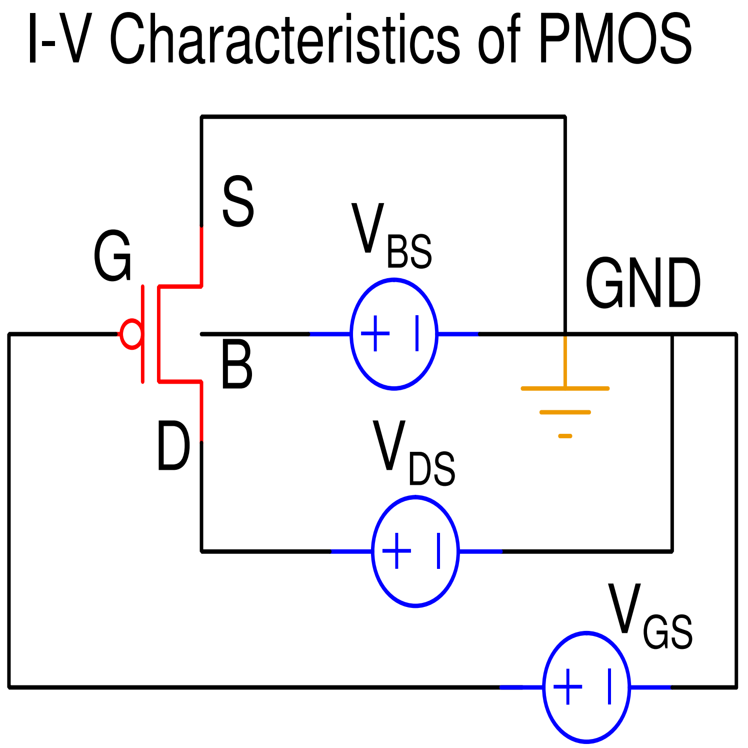

Fig 1. : I-V Characteristics of PMOS

The circuit in Fig. 1 is for the I-V characteristics simulation of PMOS. I did DC analysis for V_{DS} varied from -5V to 0V. Also, I varied V_{GS} from -2.5V to -4V in steps of -0.5V.
Then, I calculated R_{DS} in the linear region by plotting the graph and took the rightmost value to get most accurate R_{DS} (in linear region).

$$R_{DS} = \frac{V_{DS}}{I_{DS}} \tag{1}$$

Then, I calculated the early voltage (V_A) using the x-intercept of straight line on the saturation region. And using it, I calculated R_O.

$$V_A = \frac{1}{\lambda} \tag{2}$$

$$R_O = \frac{1}{\lambda I_{D(sat)}} \tag{3}$$

After that, in the I_D vs V_{GS} characteristics in linear region and saturation region, I found Threshold Voltage (V_T) using the point of intersection of the straight line with the x-axis. And I calculated Transconductance (g_m) using the slope of the straight line.

$$g_m = \frac{\delta I_D}{\delta V_{GS}} \tag{4}$$

Finally, I plotted I_D vs V_{GS} characteristics of PMOS by varying values of V_{SB} as 0V, -1V, -2V, -3V and -4V. Then, I calculated the value of Threshold Voltage (V_T) in all cases to plot V_T vs V_{SB} graph to find the value of Body Effect Coefficient (γ) using the given equation.

$$V_T = V_{T0} + \gamma(\sqrt{\Phi_s + V_{BS}} - \sqrt{\Phi_s}) \tag{5}$$

3 Simulation results

3.1 Code snippets

3.1.1 I_D-V_{DS} Characteristics of PMOS :

```
Mayur Ware | 19D070070
*EE236 | Lab 5 | Part 1
*I-V Characteristics of PMOS
.include pmos.txt ;Including PMOS model file
*Netlist
M1 D G GND GND ALD1107 ;Defining the PMOS Model Drain, Gate, Source,
Body
Vd D GND dc 0
*Vg G GND dc -4
*Vg G GND dc -3.5
*Vg G GND dc -3
Vg G GND dc -2.5
*DC Analysis
.dc Vd -5 0 0.1
.control
run
set color0 = white
set color1 = black
```

```
*set color2 = red
*set color2 = blue
*set color2 = yellow
set color2 = green
set xbrushwidth = 2
plot I(Vd) vs V(D) ;Id vs Vds plot
plot abs((V(D))/(I(Vd))) ;R_DS plot
.endc
.end
```

3.1.2 I_D-V_{GS} Characteristics of PMOS :

```
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*EE236 | Lab 5 | Part 2
*Id-Vgs Characteristics of PMOS
.include pmos.txt ;Including PMOS model file
*Netlist
M1 D G GND GND ALD1107 ;Defining the PMOS Model Drain, Gate, Source,
Body
*Vd D GND dc -200m
Vd D GND dc -5
Vg G GND dc 0
*DC Analysis
.dc Vg -5 0 0.01
.control
run
set color0 = white
set color1 = black
set color2 = blue
set color3 = red
set xbrushwidth = 2
plot I(Vd) vs V(G) ;Id vs Vgs plot
plot sqrt(I(Vd)) vs V(G) ;sqrt(Id) vs Vgs plot
.endc
.end
```

3.1.3 Effect of Body Bias :

```
Mayur Ware | 19D070070
*EE236 | Lab 5 | Part 3
*Id-Vgs Characteristics of PMOS
.include pmos.txt ;Including PMOS model file
```

```
*Netlist
M1 D G GND B ALD1107 ;Defining the PMOS Model Drain, Gate, Source,
Body
Vd D GND dc -200m
Vg G GND dc 0
*Vb B GND dc 0
*Vb B GND dc 1
*Vb B GND dc 2
*Vb B GND dc 3
Vb B GND dc 4
*DC Analysis
.dc Vg -5 0 0.01
.control
run
set color0 = white
set color1 = black
*set color2 = red
*set color2 = blue
*set color2 = yellow
*set color2 = green
set color2 = violet
set xbrushwidth = 2
plot I(Vd) vs V(G) ;Id vs Vgs plot
.endc
.end
```

3.2 Simulation results

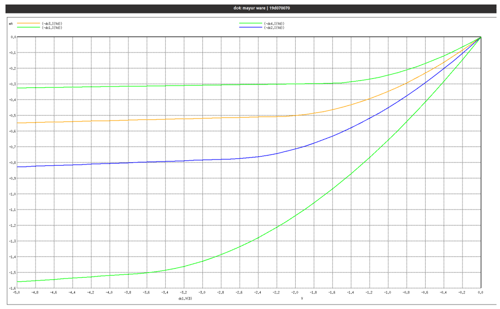


Fig. 2 : Id-Vds Characteristics of PMOS

For lower values of V_{DS}, PMOS is in the saturation mode. Whereas, after a certain value, PMOS is going into the linear region. Red, Blue, Yellow and Green curves are for V_{DS} values -4V, -3.5V, -3V and -2.5V respectively.

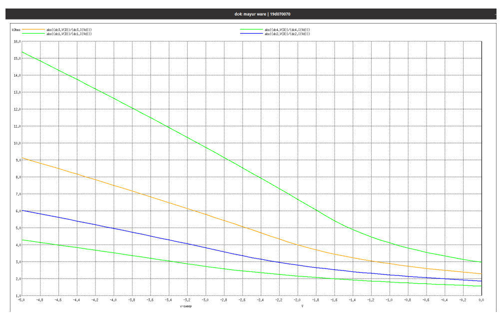
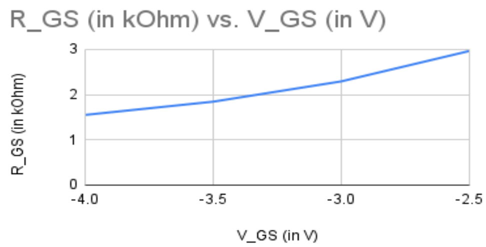
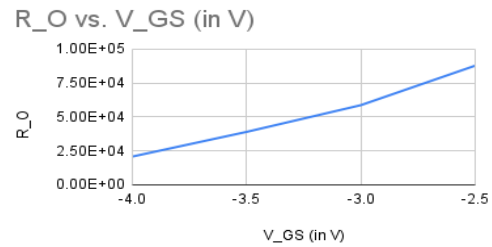


Fig. 3 : R_{DS} of PMOS

For lower values of V_{DS}, R_{DS} is decreasing linearly and then it is saturating at a value. The leftmost point of this graph would be the best value of R_{DS}. Red, Blue, Yellow and Green curves are for V_{DS} values -4V, -3.5V, -3V and -2.5V respectively.

V_{GS} (in V)	R_{GS} (in kΩ)	$I_{D(sat)}$	R_O (in kΩ)
-4	1.551	1.55mA	20.8
-3.5	1.844	0.82mA	39.0
-3	2.293	0.55mA	58.7
-2.5	2.965	0.32mA	87.8





Lighted Id-Vds Characteristics of PMOS

Fig. 4 : R_{GS} vs V_{GS}

Fig. 5 : R_O vs V_{GS}

It can be seen in Fig. 4 and Fig. 5 that both R_{GS} and R_O increase with increase in V_{GS}.

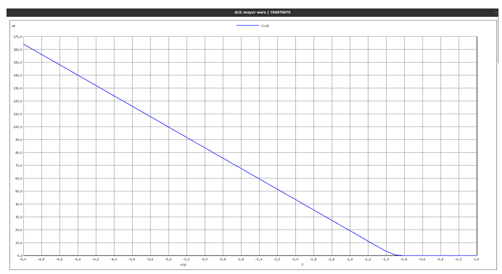
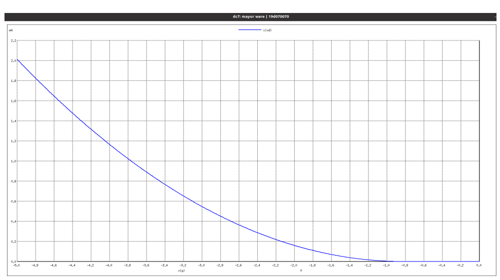
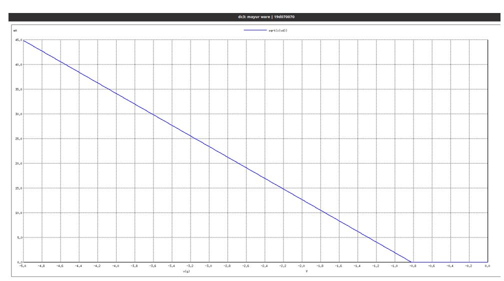


Fig. 6 :Id vs Vgs Characteristics in linear mode of PMOS

Graph is a straight line with negative slope and Id is decreasing with increase in V_{GS}.
Threshold Voltage (V_T) = -0.82V and Transconductance (g_m) = 4.2E-05.





Saturation mode of PMOS

Fig. 7 : I_D vs V_GS

Fig. 8 : $\sqrt{I_D}$ vs V_GS

I_D vs V_GS curve is parabolic. Whereas, $\sqrt{I_D}$ vs V_GS curve is a straight line with negative slope. Both decrease with increase in V_{GS}.
Threshold Voltage (V_T) = -0.82V and Transconductance (g_m) = 6.96E-05 and K = 0.228 mV/A^2

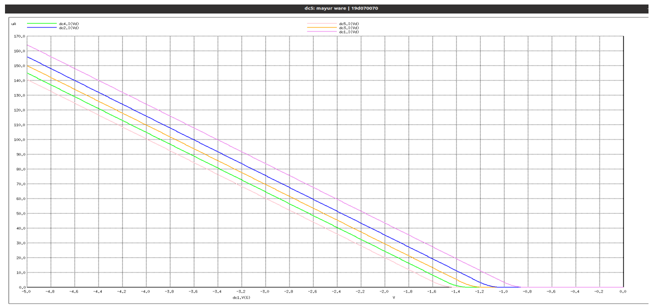


Fig. 9 :I_D vs V_{GS} Characteristics of PMOS varying V_{SB}

I_D vs V_{GS} Characteristics of PMOS varying V_{SB} are straight lines with negative slopes. Curves shift to left with decrease in V_{SB}.

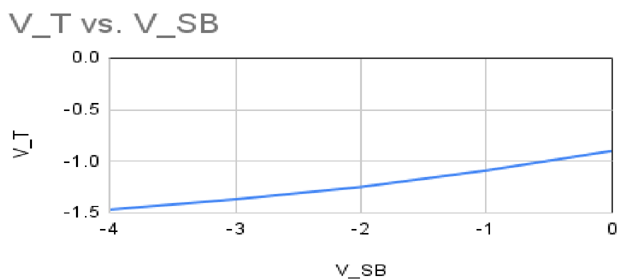


Fig. 10 :V_T vs V_{SB}

V_T increases with increase in V_{SB}. Using this graph and given equation, the value of Body Effect Coefficient (γ) comes out to be -0.465.

4 Experimental results

This section is not applicable for this experiment.

5 Experiment completion status

I have completed all sections as well as exercises in this lab.

6 Questions for reflection

This section is not applicable for this experiment.