EE 236: Experiment No. 5
PMOS I-V Characteristics and Applications

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1 Overview of the experiment

1.1 Aim of the experiment

The following were the aims of the experiment:

- To measure transfer characteristics of PMOS transistor.
- To analyse the effect of body bias on the characteristics of a PMOS transistor.

1.2 Methods

The method overview includes constructing circuit netlists according to the standard circuit, simulating them using *dc* analysis and calculating required parameters for all parts. The first plot required us to plot $I_D - V_{DS}$ characteristics, and calculate r_{DS}, Early Voltage (V_0), and r_0. The second and third plots required us to plot $I_D - V_{GS}$ characteristics, and find V_T, g_m and k.

2 Design

2.1 Part 1

The netlist according to the following circuit diagram was made which included a PMOS transistor and voltage sources.

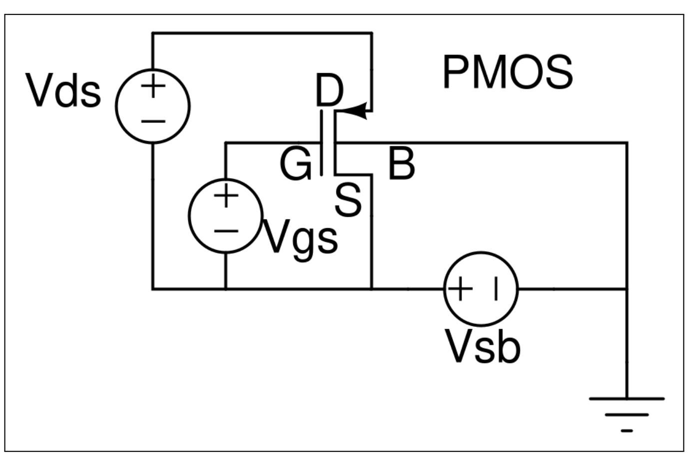


Figure 1: The I-V Characterization Circuit

DC analysis was performed by varying V_{DS} from 0V to -5V in steps of -0.001V and V_{GS} from -2.5V to -4V in steps of -0.5V to obtain the I-V characteristic plots. R_{DS} in the linear region was found using:

$$R_{DS} = \frac{\Delta V_{DS}}{\Delta I_{DS}}$$

V_0 was found as the x-intercept of the equation in the saturation region:

$$y = mx + c$$

R_0 in the saturation region was found using:

$$R_0 = \frac{\Delta V_{DS}}{\Delta I_{DS}}$$

2.2 Part 2

I_D was plotted against V_{GS}, first keeping $V_{DS} = -200mV$ (linear) and then $V_{DS} = -5V$ (saturation). V_T and g_m were found from the plot.

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$

Then, k was found from the slope of the $\sqrt{I_D}$ vs V_{GS}.

$$k = 2.\left(\frac{\Delta\sqrt{I_D}}{\Delta V_{GS}}\right)^2$$

2.3 Part 3

V_{DS} was set to -200mV. DC analysis was performed by varying V_{GS} from 0V to -5V in steps of -0.01V and V_{SB} from 0V to -4V in steps of -V to obtain the I-V characteristic plots. V_T values were obtained from the plot and plotted against V_{SB}. γ was calculated from:

$$V_T = V_{T0} + \gamma.(\sqrt{\phi_s - V_{SB}} - \sqrt{\phi_s})$$

3 Simulation results

3.1 Code snippets

3.1.1 Part 1

```
Vinamra Baghel 190010070 Part 1 Id-Vds Characteristics
.include pmos.txt

*Netlist
M1 d g 0 0 ALD1107
Vg g 0 dc -2.5
Vd d 0 dc 0

*Analysis
.dc Vd 0 -5 -1m Vg -2.5 -4 -0.5

.control
run
let Id1 = I(Vd)[0, 5000]
let Id2 = I(Vd)[5001, 10001]
let Id3 = I(Vd)[10002, 15002]
let Id4 = I(Vd)[15003, 20003]
let Vds1 = V(d)[0, 5000]
let Vds2 = V(d)[5001, 10001]
let Vds3 = V(d)[10002, 15002]
let Vds4 = V(d)[15003, 20003]
plot Id1 vs Vds1 Id2 vs Vds2 Id3 vs Vds3 Id4 vs Vds4

meas dc i11 find Id1 when Vds1 = -1m
meas dc i12 find Id1 when Vds1 = -2m
let rds1 = 1m/(i12-i11)
meas dc i21 find Id2 when Vds2 = -1m
meas dc i22 find Id2 when Vds2 = -2m
let rds2 = 1m/(i22-i21)
meas dc i31 find Id3 when Vds3 = -1m
meas dc i32 find Id3 when Vds3 = -2m
let rds3 = 1m/(i32-i31)
meas dc i41 find Id4 when Vds4 = -1m
meas dc i42 find Id4 when Vds4 = -2m
let rds4 = 1m/(i42-i41)

print rds1 rds2 rds3 rds4

meas dc i511 find Id1 when Vds1 = -4900m
meas dc i512 find Id1 when Vds1 = -5
let Vo1 = (-4900m*i512-(-5)*i511)/(i512-i511)
let ro1 = 100m/(i512-i511)
meas dc i521 find Id2 when Vds2 = -4900m
meas dc i522 find Id2 when Vds2 = -5
let Vo2 = (-4900m*i522-(-5)*i521)/(i522-i521)
```

```
let ro2 = 100m/(i522-i521)
meas dc i531 find Id3 when Vds3 = -4900m
meas dc i532 find Id3 when Vds3 = -5
let Vo3 = (-4900m*i532-(-5)*i531)/(i532-i531)
let ro3 = 100m/(i532-i531)
meas dc i541 find Id4 when Vds4 = -4900m
meas dc i542 find Id4 when Vds4 = -5
let Vo4 = (-4900m*i542-(-5)*i541)/(i542-i541)
let ro4 = 100m/(i542-i541)

print Vo1 Vo2 Vo3 Vo4
print ro1 ro2 ro3 ro4
.endc
.end
```

3.1.2 Part 2

```
Vinamra Baghel 190010070 Part 2 Id-Vgs Characteristics
.include pmos.txt

*Netlist
M1 d g 0 0 ALD1107
Vg g 0 dc -5
Vd d 0 dc -200m

*Analysis
.dc Vg -5 0 0.01

.control
run
let Id = I(Vd)
let Vg = V(g)
plot I(Vd) vs V(g)

meas dc i1 find Id when Vg = -4
meas dc i2 find Id when Vg = -4010m
let gm = (i2-i1)/10m
print gm

let SId = sqrt(Id)
plot SId vs Vg
meas dc si1 find SId when Vg = -4
meas dc si2 find SId when Vg = -4010m
let k = 2*((si2-si1)/10m)^2
print k
.endc
.end
```

3.1.3 Part 3

```
Vinamra Baghel 190010070 Part 3 Id-Vgs Characteristics
.include pmos.txt

*Netlist
M1 d g s b ALD1107
Vgs g s dc -5
Vds d s dc -200m
Vsb s b dc 0
Vb b 0 dc 0

*Analysis
.dc Vgs -5 0 0.01 Vsb 0 -4 -1

.control
run
let Id1 = I(Vds)[0, 500]
let Id2 = I(Vds)[501, 1001]
let Id3 = I(Vds)[1002, 1502]
let Id4 = I(Vds)[1503, 2003]
let Id5 = I(Vds)[2004, 2504]

plot Id1 Id2 Id3 Id4 Id5
.endc
.end
```

3.2 Simulation results

3.2.1 Part 1

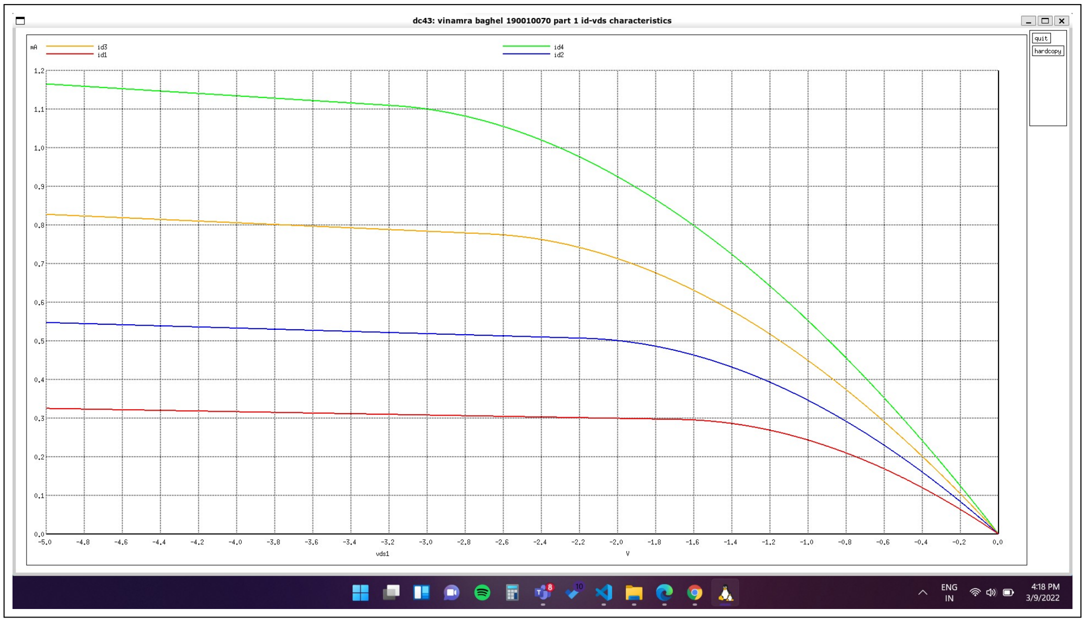
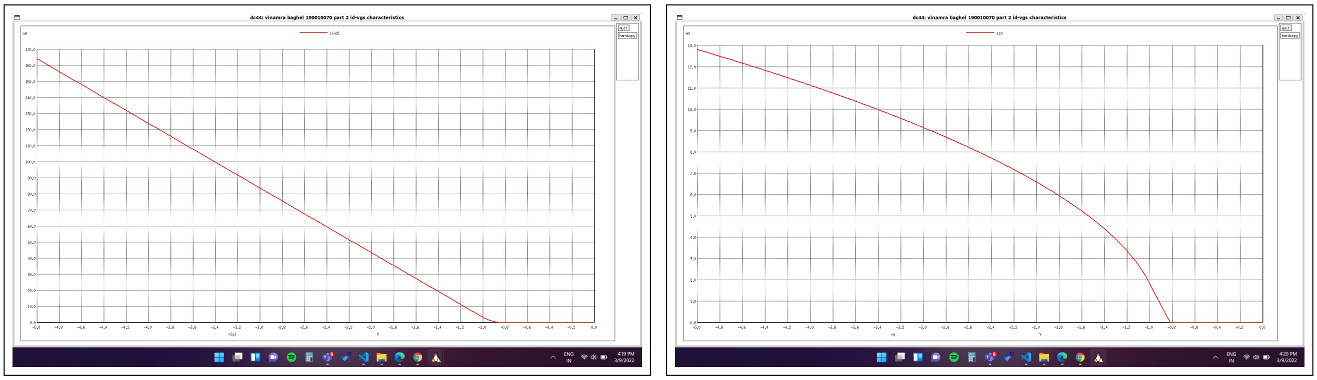


Figure 2: $I_D - V_{DS}$ Characteristics

Shown above were the $I_D - V_{DS}$ characteristics.

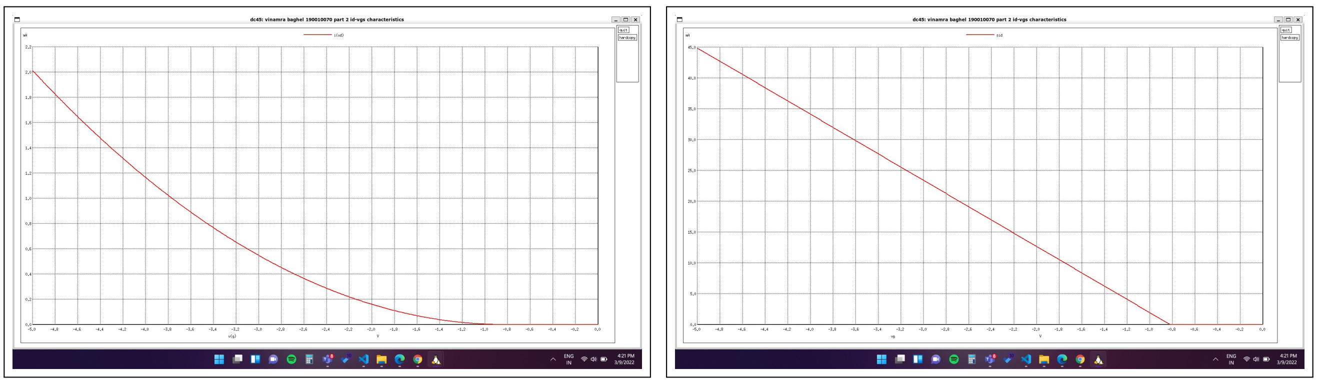
3.2.2 Part 2



(a) $I_D - V_{GS}$

(b) $\sqrt{I_D} - V_{GS}$

Figure 3: $I_D - V_{GS}$ and $\sqrt{I_D} - V_{GS}$ Characteristics for $V_{DS} = -200mV$



(a) $I_D - V_{GS}$

(b) $\sqrt{I_D} - V_{GS}$

Figure 4: $I_D - V_{GS}$ and $\sqrt{I_D} - V_{GS}$ Characteristics for $V_{DS} = -5V$

3.2.3 Part 3

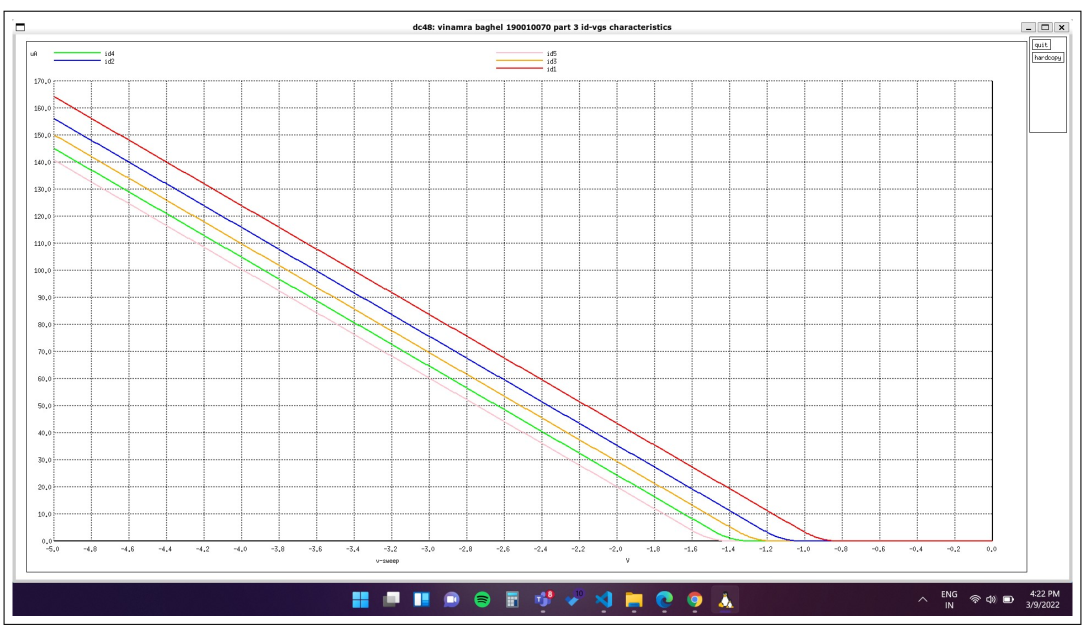


Figure 5: $I_D - V_{GS}$ Characteristics for different V_{SB}

4 Experimental results

Part 1: R_{DS}, V_0 and r_0.

V_{GS} (in V)	R_{DS} (in kΩ)	V_0 (in V)	r_0 (in kΩ)
-2.5	2.979	32.895	116.550
-3	2.295	32.896	69.219
-3.5	1.867	32.894	45.798
-4	1.573	32.897	32.531

Part 2: V_T, g_m and k.
For $V_{DS} = -200mV$,
$V_T = -0.879V$, $g_m = 4.024 \times 10^{-5}\Omega^{-1}$ and $k = 6.523 \times 10^{-6}AV^{-2}$.
For $V_{DS} = -5V$,
$V_T = -1.009V$, $g_m = 7.339 \times 10^{-4}\Omega^{-1}$ and $k = 2.304 \times 10^{-4}AV^{-2}$.

Part 3: The V_Ts for $V_{SB} = \{0, -1, -2, -3, -4\}$ respectively are:
-0.86177, -1.05588, -1.20588, -1.33235, and -1.44118.
The value of *gamma* came out to be **-0.447**.

5 Experiment completion status

I could complete all the parts of the lab. There was no hardware involvement as it was all simulation based. The results were shown to the TA and then submitted.