EE236: Lab 9

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Contents

1 N-channel MOSFET I-V Characteristics

1.1 Aim of the Experiment

- To obtain the output and transfer characteristics of an N-channel enhancement MOSFET.
- To measure transconductance and output resistance from the characteristics.
- To investigate the effect of body bias on NMOS characteristics.

1.2 Background Information

The N-channel MOSFET (NMOS) is widely used in both digital and analog circuits. It has four terminals: Gate (G), Drain (D), Source (S), and Body (B). The voltage applied between the gate and source controls the current between the drain and source terminals. The body of an NMOS is typically connected to the ground.
For the NMOS to be in its "ON" state, the gate-source voltage V_{GS} must be greater than the threshold voltage V_T. The following conditions define the operating regions:

- **Linear Region:** $V_{DS} < V_{GS} - V_T$
- **Saturation Region:** $V_{DS} \geq V_{GS} - V_T$

1.2.1 Current Equation

The current through an NMOS in different regions can be represented as:

- **Cut-off Region:** $I_D = 0$
- **Linear Region:** $I_D = \mu_n C_{\text{ox}} \frac{W}{L} V_{DS} \left(V_{GS} - V_T - \frac{V_{DS}}{2}\right)$
- **Saturation Region:** $I_D = \frac{1}{2} \mu_n C_{\text{ox}} \frac{W}{L} \left(V_{GS} - V_T\right)^2 \left(1 + \lambda V_{DS}\right)$

1.3 Experimental Results

1.3.1 Part 1: Transfer Characteristics

The NMOS was biased in both the linear region ($V_{DS} = 0.2\,\text{V}$) and the saturation region ($V_{DS} = 3\,\text{V}$). The gate-source voltage V_{GS} was varied from 0 to 3V and the drain current I_D was measured for both regions.

Data

V_{GS} **(V)**	I_D **(mA)** (Linear) ($V_{ds} = 0.2V$)
0.02	0.02
0.3	0.02
0.6	0.02
0.9	0.13
1.2	0.36
1.5	0.84
1.8	4.54
2.1	7.78
2.4	10.81
2.7	13.53
3.0	15.71

V_{GS} **(V)**	I_D **(mA)** (Saturation) ($V_{ds} = 3V$)
0	0
0.28	0
0.39	0
0.99	0.07
1.07	0.52
1.1	0.92
1.11	1.06
1.13	1.35
1.16	2.04
1.2	3.31
1.23	4.21
1.27	6.7
1.31	9.73

1.32	10.61
1.38	17.08
1.4	21
1.42	24
1.45	29
1.48	35
1.52	45
1.55	51
1.6	62
1.65	73
1.68	83
1.77	110
1.86	134
1.93	153
2.02	174
2.16	210
2.29	240
2.4	263
2.49	284
2.54	294
2.66	316
2.75	332
2.86	347
2.94	363
3	372

Plot

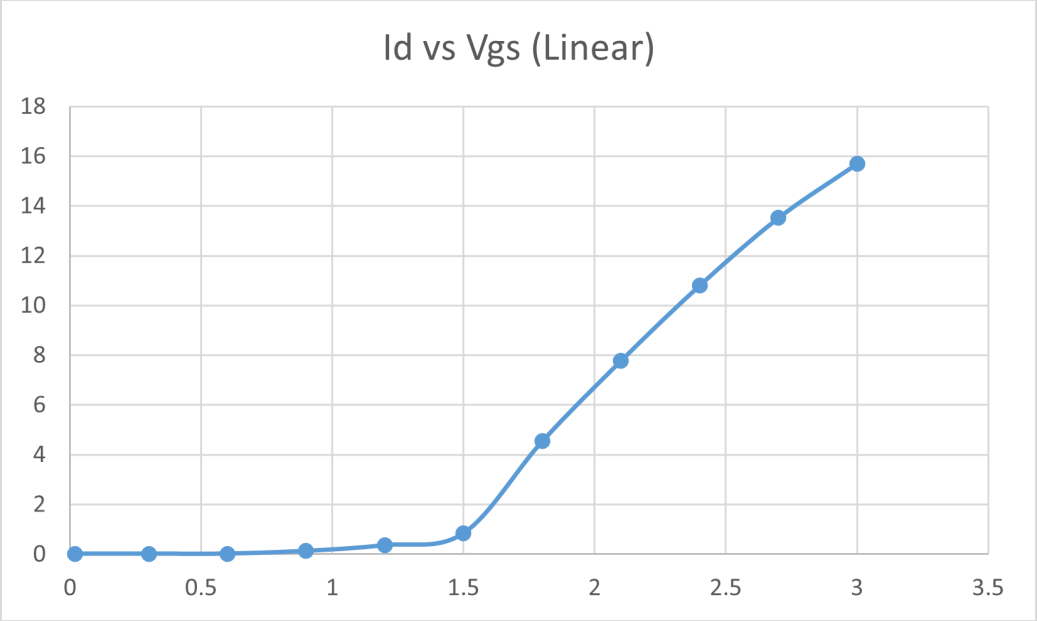

Figure 1: Transfer Characteristics of NMOS (Linear Region)

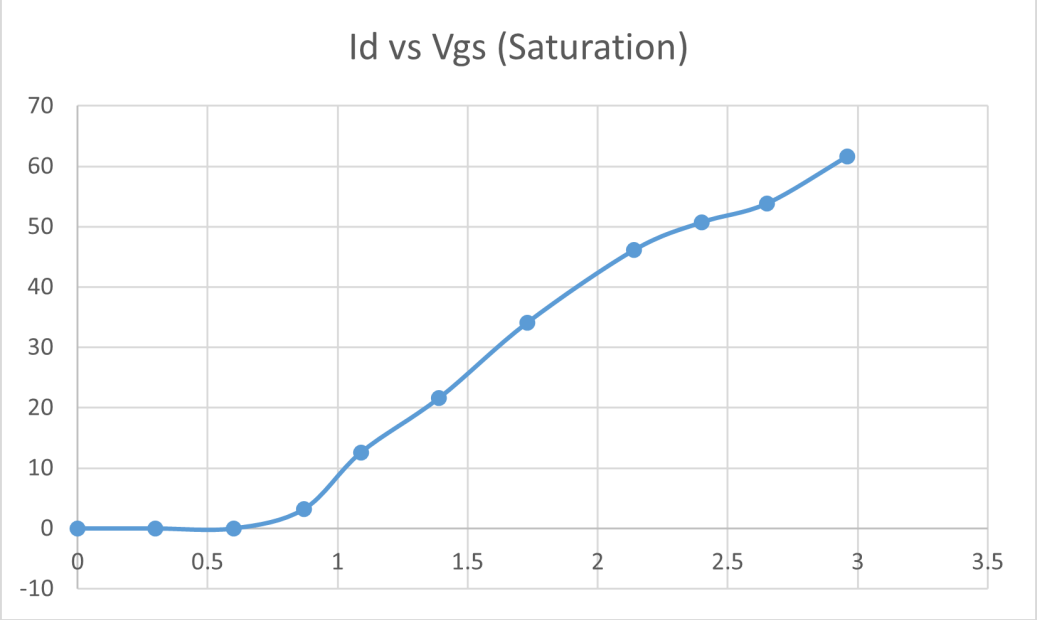

Figure 2: Transfer Characteristics of NMOS (Saturation Region)

1.3.2 Part 2: Drain Characteristics

For the drain characteristics, I_D versus V_{DS} was plotted for three different values of V_{GS} (1.5V, 2.5V, and 3.5V).

Data

V_{DS} **(V)**	I_D **(mA)** ($V_{GS} = 1.5$V)
0	0.0
0.1	0.031
0.2	0.042
0.3	0.045
0.4	0.046
3	0.048
5	0.049

Table 3: Drain Characteristics for $V_{GS} = 1.5V$

V_{DS} **(V)**	I_D **(mA)** ($V_{GS} = 2.5$V)
0	0.0
0.1	0.152
0.2	0.278
0.3	0.387
0.4	0.477
0.5	0.549
0.6	0.601
0.7	0.637
0.8	0.658
0.9	0.671
1.0	0.679
1.1	0.683
1.2	0.687
1.3	0.690
1.4	0.692
2.0	0.701
2.5	0.706
3.0	0.710

3.5	0.717
4.0	0.717
5.0	0.720

Table 4: Drain Characteristics for $V_{GS} = 2.5V$

V_{DS} **(V)**	I_D **(mA)** ($V_{GS} = 3.5$V)
0	0.0
0.1	0.25
0.2	0.49
0.3	0.70
0.4	0.91
0.5	1.10
0.6	1.26
0.7	1.40
0.8	1.53
0.9	1.63
1.0	1.71
1.1	1.78
1.2	1.83
1.3	1.86
1.4	1.89
1.5	1.91
2.0	1.95
2.5	1.97
3.0	1.99
4.0	2.01
5.0	2.02

Table 5: Drain Characteristics for $V_{GS} = 3.5V$

Plot

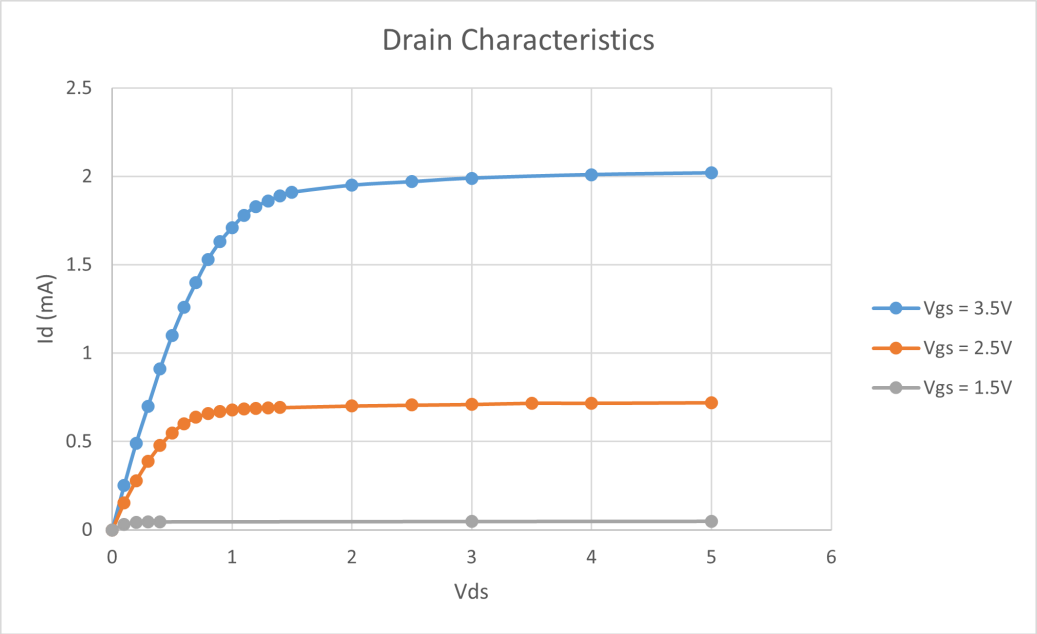

Figure 3: Drain Characteristics of NMOS for various V_{GS} values

1.3.3 Part 3: Body Effect

The body effect was studied by applying body-source voltages $V_{SB} = 1V$, $V_{SB} = 2V$, and $V_{SB} = 3V$, and plotting the V_{GS} vs I_D characteristics.

Data

V_{GS} **(V)**	I_D **(mA)** ($V_{SB} = 1$V)
0	0.0
0.83	0.0
1.36	0.0
2.38	0.04
2.61	0.08
2.81	0.13
2.94	0.17
3.09	0.21

Table 6: Body Effect for $V_{SB} = 1V$

V_{GS} **(V)**	I_D **(mA)** ($V_{SB} = 2$V)
0	0.0
1.26	0.0
2.32	0.0
3.20	0.04
3.45	0.09
3.69	0.15
3.88	0.21
4.10	0.26

Table 7: Body Effect for $V_{SB} = 2V$

V_{GS} **(V)**	I_D **(mA)** ($V_{SB} = 3$V)
0	0.0
1.26	0.0
3.50	0.0
4.00	0.05

4.28	0.13
4.42	0.17
4.70	0.24
5.00	0.30

Table 8: Body Effect for $V_{SB} = 3V$

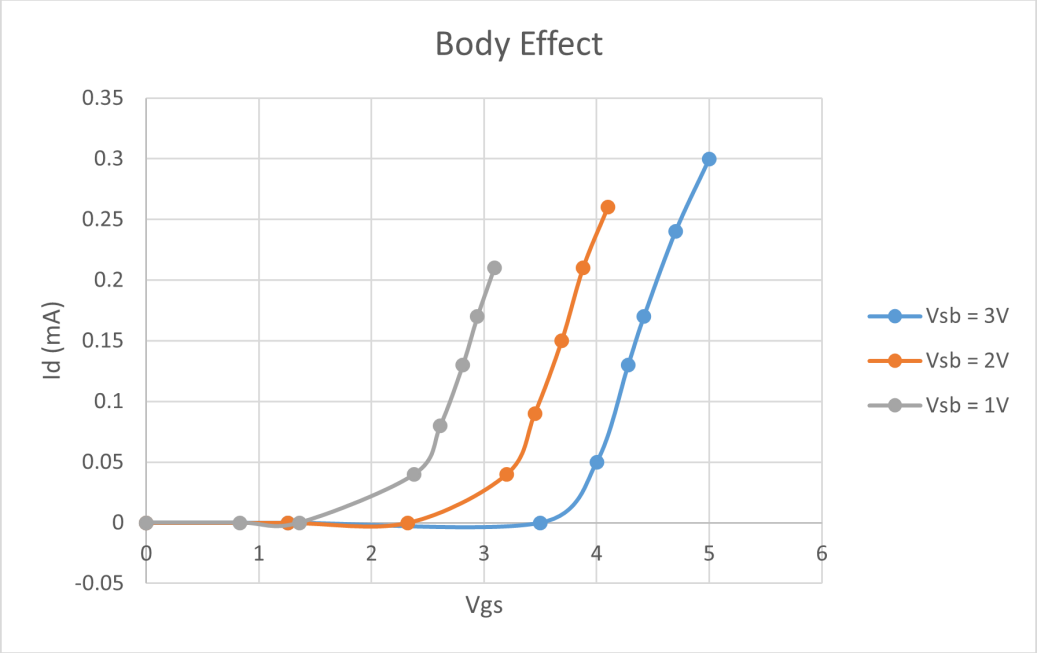

Figure 4: Body Effect on NMOS Characteristics

Plot

1.3.4 Calculations:

Parameter	Value
g_m (mS) (Linear)	0.21
g_m (mS) (Saturation)	1.05
V_T (V) (Linear)	1.4
V_T (V) (Saturation)	1.5
r_o	25kΩ
V_T (V) ($V_{SB} = 1V$)	1.27
V_T (V) ($V_{SB} = 2V$)	2.31
V_T (V) ($V_{SB} = 3V$)	3.48
V_{T0} (V)	0.65
γ	2.15

Table 9: Calculated Parameters

1.4 Conclusions and Inferences

The experiment successfully characterized the NMOS I-V characteristics in both the linear and saturation regions. Transconductance and output resistance were extracted. The body effect was also observed, and the body effect coefficient was calculated from the measured data.

1.5 Experiment Completion Status

Completed the complete experiment in the lab