Electronic Devices and Characterization Lab
Experiment 9

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1 Aim of the Experiment

1. Obtain output and transfer characteristics of an N-channel enhancement type MOSFET (NMOS).
2. Measure the trans-conductance and output resistance from the obtained characteristics.
3. Investigate the effect of body bias on the characteristics of the NMOS.

2 Experimental Setup

The components used in the experiment are:

- CD4007 IC (containing NMOS transistors)
- Potentiometers ($1\,\mathrm{k}\Omega$) $\times 2$
- Breadboard and connecting wires
- DC Power Supply

3 Transfer Characteristics (Linear Region)

- Biased the NMOS in the linear region by setting $V_{DS} = 200\,\mathrm{mV}$.
- Vared V_{GS} from $0\,\mathrm{V}$ to $3\,\mathrm{V}$, and measure the drain current I_D.
- Plotted the I_D vs V_{GS} characteristics to determine the threshold voltage V_T and the trans-conductance g_m.
- Applied linear regression on the points obtained. **Got the V_T = 1341.037326 and g_m = slope = 0.000264985882726968 A/V**

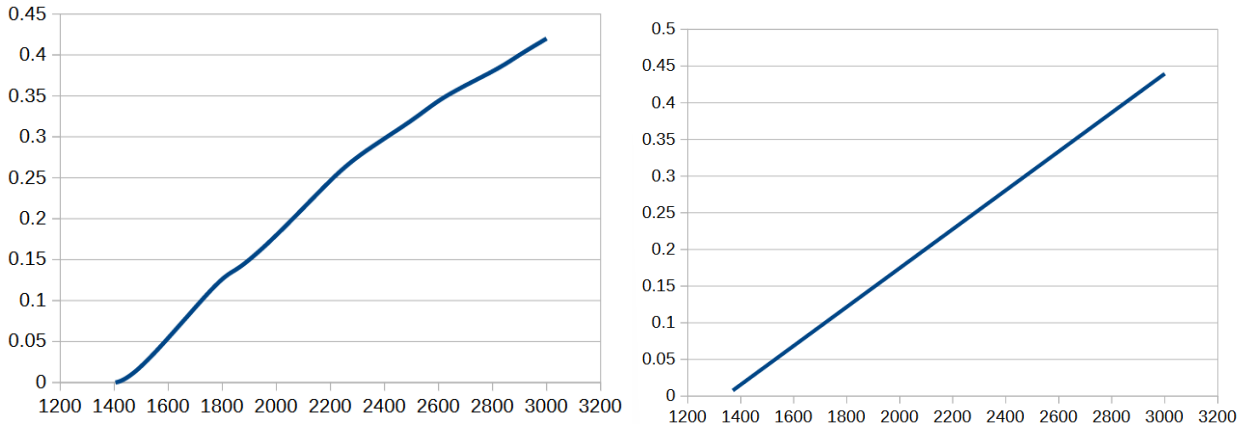

Figure 1: Transfer Characteristics in the Linear Region (a) (Plot of I_D vs V_{GS}) (b) After applying regression

4 Transfer Characteristics (Saturation Region)

- Biased the NMOS in the saturation region by setting $V_{DS} = 3\,\text{V}$.
- Varied V_{GS} from $0\,\text{V}$ to $3\,\text{V}$ and measure I_D.
- Plotted the I_D vs V_{GS} characteristics to determine V_T and g_m in the saturation region.
- **The VT = 238.24073130864 and gm = 0.000688848938017342**

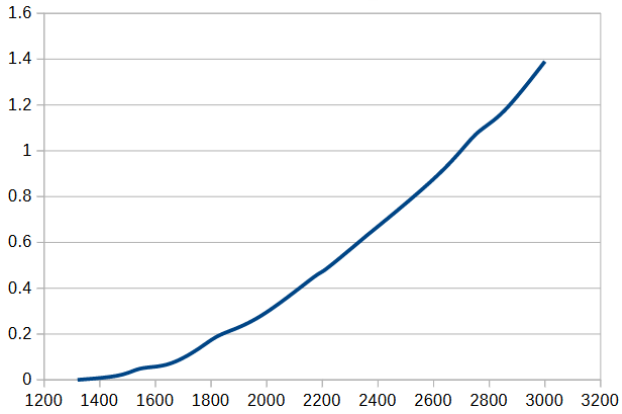

Figure 2: Saturation Region

5 Drain Characteristics

- Measure I_D vs V_{DS} by varying V_{DS} from $0\,\text{V}$ to $5\,\text{V}$ for different values of $V_{GS} = 1.5V, 2.5V, 3.5V$.

- Plot the drain characteristics for all three V_{GS} values.
- We get the r_o for V_{GS} as 15.4185022026432 kΩ

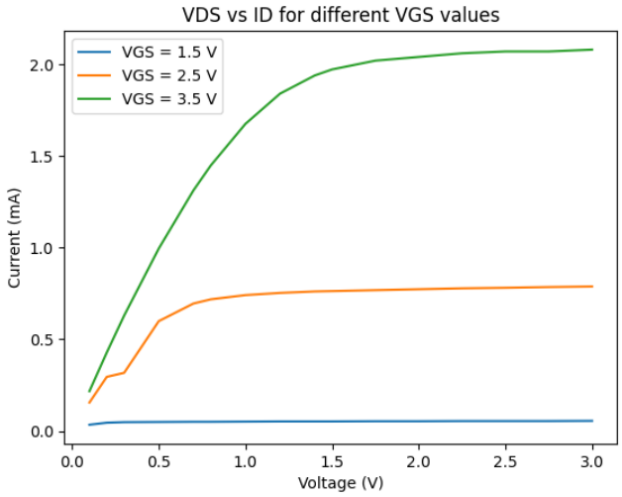

Figure 3: Drain Characteristics for V_{GS} = 1.5V, 2.5V, 3.5V

6 Body Effect

- Bias the NMOS in the linear region with $V_{DS} = 200\,\text{mV}$.
- Vary $V_{SB} = 0V, 1V, 2V, 3V$ and measure the I_D vs V_{GS} characteristics.

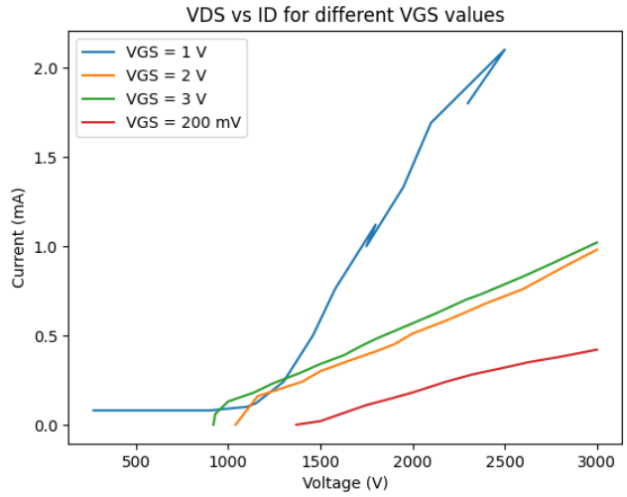

Figure 4: I_D vs V_{GS} characteristics body effect

7 Formulae

7.1 Body Effect Equation

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

7.2 Trans-conductance

The trans-conductance is defined as:

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_{\text{const } V_{DS}}$$

7.3 Output Resistance

The output resistance is:

$$r_o = \left. \frac{\partial V_{DS}}{\partial I_D} \right|_{\text{const } V_{GS}}$$

7.4 Calculations for the body effect

V_{SB} (V)	V_T
0.2	1500
1.0	1200
2.0	1100
3.0	900

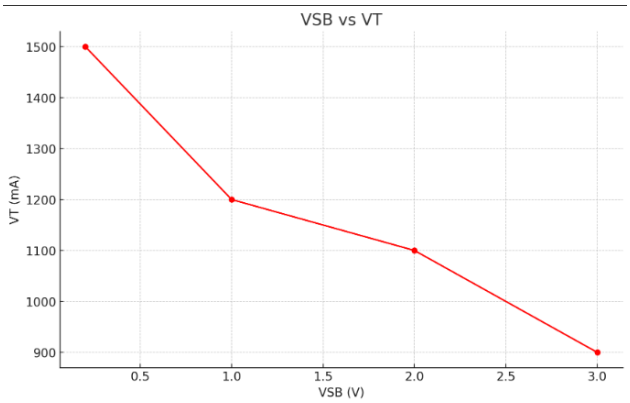

Figure 5: VT vs VSB

The formula for calculating the threshold voltage considering the body effect is:

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

Where:

- V_T: Threshold voltage with body bias.
- V_{T0}: Threshold voltage when $V_{SB} = 0$.
- γ: Body effect coefficient (to be calculated).
- $\phi_s = 0.9\,V$: Surface potential.
- V_{SB}: Source-to-body voltage.

Calculations:

For $V_{SB} = 0.2\,V$, $V_T = 1500\,mA$:

$$\gamma = \frac{1500 - 0.6}{0.1001} \approx 14933.8$$

For $V_{SB} = 1.0\,V$, $V_T = 1200\,mA$:

$$\gamma = \frac{1200 - 0.6}{0.4297} \approx 2793.3$$

For $V_{SB} = 2.0\,V$, $V_T = 1100\,mA$:

$$\gamma = \frac{1100 - 0.6}{0.7533} \approx 1461.4$$

For $V_{SB} = 3.0\,V$, $V_T = 900\,mA$:

$$\gamma = \frac{900 - 0.6}{1.0263} \approx 877.5$$

8 Conclusion

The experiment successfully demonstrated the I-V characteristics of an NMOS transistor in both the linear and saturation regions. We also investigated the body bias effect and measured trans-conductance and output resistance.