Transfer Characteristics of a MOSFET

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Abstract

This document presents a detailed analysis of the transfer characteristics of a MOSFET in both the linear and saturation regions. The goal is to estimate the threshold voltage (V_T) and transconductance (g_m) based on the measured drain current (I_D) at varying gate-to-source voltages (V_{GS}).

1 Introduction

The performance of a MOSFET is often characterized by its transfer characteristics, which describe how the drain current (I_D) varies with the gate-to-source voltage (V_{GS}). In this experiment, we will analyze the device in two different regions: the linear region and the saturation region.

2 Part I: Transfer Characteristics (Linear Region)

2.1 Experiment Setup

To analyze the linear characteristics of the MOSFET, the device is biased with a constant drain-to-source voltage (V_{DS}) of 200 mV:

$$V_{DS} = 200\,\text{mV} = 0.2\,\text{V}$$

We will vary the gate-to-source voltage (V_{GS}) from 0 to 3 V and measure the corresponding drain current (I_D).

2.2 Assumed Data

The following table summarizes the assumed values for I_D at different V_{GS}:

V_{GS} (V)	I_D (mA)
0.0	0.0
0.5	0.05
1.0	0.2
1.5	0.5
2.0	1.0
2.5	1.8
3.0	2.5

2.3 Plotting I_D vs. V_{GS}

The next step involves plotting the drain current I_D against the gate-to-source voltage V_{GS}. This plot will help identify the threshold voltage (V_T) and the transconductance (g_m).

2.4 Estimating Threshold Voltage (V_T)

The threshold voltage is defined as the gate voltage at which the MOSFET begins to conduct significantly. From the data, we observe:

- At $V_{GS} = 0.5\,\text{V}$, I_D begins to increase from zero.

Thus, we estimate the threshold voltage:

$$V_T \approx 0.5\,\text{V}$$

2.5 Calculating Transconductance (g_m

Transconductance is defined as the change in drain current with respect to the change in gate-to-source voltage, mathematically expressed as:

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

To calculate g_m, we select two points in the linear region: - Point 1: $(1.0\,\text{V}, 0.2\,\text{mA})$ - Point 2: $(2.0\,\text{V}, 1.0\,\text{mA})$

Calculating ΔI_D and ΔV_{GS}:

$$\Delta I_D = 1.0\,\text{mA} - 0.2\,\text{mA} = 0.8\,\text{mA}$$

$$\Delta V_{GS} = 2.0\,\text{V} - 1.0\,\text{V} = 1.0\,\text{V}$$

Now, substituting these values into the formula for g_m:

$$g_m = \frac{0.8\,\text{mA}}{1.0\,\text{V}} = 0.8\,\text{mS}$$

2.6 Summary for Part I

- Threshold Voltage: $V_T \approx 0.5\,\text{V}$
- Transconductance: $g_m \approx 0.8\,\text{mS}$

3 Part II: Transfer Characteristics (Saturation Region)

3.1 Experiment Setup

To analyze the saturation characteristics of the MOSFET, the device is biased with a constant drain-to-source voltage (V_{DS}) of 3 V:

$$V_{DS} = 3\,\text{V}$$

Again, we will vary V_{GS} from 0 to 3 V.

3.2 Assumed Data

The following table summarizes the assumed values for I_D at different V_{GS}:

V_{GS} (V)	I_D (mA)
0.0	0.0
0.5	0.0
1.0	0.0
1.5	0.1
2.0	0.5
2.5	1.5
3.0	2.5

3.3 Plotting I_D vs. V_{GS}

Similar to Part I, we will plot the drain current I_D against the gate-to-source voltage V_{GS} to observe the saturation characteristics.

3.4 Estimating Threshold Voltage (V_T)

From the saturation region data: - The threshold voltage is estimated at the point where I_D begins to increase significantly. We find that at $V_{GS} \approx 1.5\,\text{V}$, I_D starts to rise noticeably.

Thus, we estimate:

$$V_T \approx 1.5\,\text{V}$$

3.5 Calculating Transconductance (g_m)

In the saturation region, transconductance can be defined as:

$$g_m = \frac{2I_D}{V_{GS} - V_T}$$

Using a point like $(2.5\,\text{V}, 1.5\,\text{mA})$:

$$g_m = \frac{2 \times 1.5\,\text{mA}}{2.5\,\text{V} - 1.5\,\text{V}} = \frac{3.0\,\text{mA}}{1.0\,\text{V}} = 3.0\,\text{mS}$$

3.6 Summary for Part II

- Threshold Voltage: $V_T \approx 1.5\,\mathrm{V}$
- Transconductance: $g_m \approx 3.0\,\mathrm{mS}$

4 Conclusion

In this experiment, we analyzed the transfer characteristics of a MOSFET in both the linear and saturation regions. The estimated threshold voltages and transconductance values were as follows:

- **Part I (Linear Region)**:
  - Threshold Voltage: $V_T \approx 0.5\,\mathrm{V}$
  - Transconductance: $g_m \approx 0.8\,\mathrm{mS}$
- **Part II (Saturation Region)**:
  - Threshold Voltage: $V_T \approx 1.5\,\mathrm{V}$
  - Transconductance: $g_m \approx 3.0\,\mathrm{mS}$

This comprehensive approach ensures a detailed understanding of the device's characteristics under different operational conditions.