Calculation of Output Resistance for MOSFET in the Saturation Region

Problem Setup and Definitions

For a MOSFET, the output resistance r_o in the saturation region is defined by:

$$r_o = \frac{1}{\frac{\partial I_D}{\partial V_{DS}}} \tag{1}$$

where r_o is the reciprocal of the slope of the I_D vs. V_{DS} curve in the saturation region. In this region, the drain current I_D becomes nearly constant as the drain-to-source voltage V_{DS} increases.

Given Data:

- Gate-to-source voltage: $V_{GS} = 3.5\,\text{V}$
- Measured data points for I_D vs. V_{DS} in the table below:

V_{DS} (V)	I_D (mA)
1.85	2.05
2.05	2.07
2.25	2.08
2.45	2.08
⋮	⋮
5.0	2.12

The goal is to calculate r_o based on the data in the saturation region, identified as the point where I_D stabilizes with increasing V_{DS}.

Step-by-Step Calculation of r_o

Step 1: Identify the Saturation Region

The saturation region begins at approximately $V_{DS} = 1.85\,\text{V}$, where I_D becomes almost constant with increasing V_{DS}. This is shown by the values:

V_{DS} (V)	I_D (mA)
3.05	2.09
5.0	2.12

Thus, we select these points within the saturation region for calculating the slope $\frac{\Delta I_D}{\Delta V_{DS}}$.

Step 2: Calculate ΔI_D and ΔV_{DS}

Using Point 1 ($V_{DS} = 3.05\,\text{V}$, $I_D = 2.09\,\text{mA}$) and Point 2 ($V_{DS} = 5.0\,\text{V}$, $I_D = 2.12\,\text{mA}$):

$$\Delta I_D = 2.12\,\text{mA} - 2.09\,\text{mA} = 0.03\,\text{mA}$$

$$\Delta V_{DS} = 5.0\,\text{V} - 3.05\,\text{V} = 1.95\,\text{V}$$

Step 3: Calculate the Slope $\frac{\Delta I_D}{\Delta V_{DS}}$

The slope in the saturation region is:

$$\frac{\Delta I_D}{\Delta V_{DS}} = \frac{0.03\,\text{mA}}{1.95\,\text{V}} = 0.0154\,\text{mA/V}$$

Step 4: Compute Output Resistance r_o

The output resistance r_o is the reciprocal of this slope:

$$r_o = \frac{1}{\frac{\Delta I_D}{\Delta V_{DS}}} = \frac{1}{0.0154\,\text{mA/V}} = \frac{1}{0.0000154\,\text{A/V}} \tag{2}$$

$$r_o \approx 64935\,\Omega \approx 64.9\,\text{k}\Omega$$

Conclusion

The calculated output resistance r_o in the saturation region for $V_{GS} = 3.5\,\text{V}$ is approximately:

$$r_o \approx 64.9\,\text{k}\Omega$$

This result was obtained by identifying the saturation region, selecting stable data points within that region, calculating the slope, and applying the reciprocal relationship to find r_o.