

report

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1 MOSFET Model

1.1 Constants

$$n_i = 10^{10}/cm^3 \quad (1)$$

$$\epsilon_{ox} = 3.9 \times 8.854 \times 10^{-14} F/cm \quad (2)$$

$$\epsilon_s = 11.9 \times 8.854 \times 10^{-14} F/cm \quad (3)$$

1.2 Variable Parameters

$$N_A = 10^{15}/cm^3 \quad (4)$$

$$t_{ox} = 2 \times 10^{-5} cm \quad (5)$$

$$V_{FB} = 1.035V \quad (6)$$

$$q = 1.60217663 \times 10^{-19} C \quad (7)$$

$$W = 0.22 \times 10^{-4} cm \quad (8)$$

$$L = 4 \times 10^{-4} cm \quad (9)$$

$$V_{BS} = -10V \quad (10)$$

$$\mu_n = 1340 cm^2/(V.s) \quad (11)$$

1.3 Calculations

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} \quad (12)$$

$$\phi_B = 0.0258 \log(N_A/n_i) \quad (13)$$

$$V_{th} = V_{FB} + 2\phi_B + \frac{\sqrt{2qN_A\epsilon_s 2\phi_B}}{C_{ox}} V \quad (14)$$

$$\gamma = \frac{\sqrt{2 \times \epsilon_s q N_A}}{C_{ox}} \quad (15)$$

$$\alpha = 1 + \gamma / (2\sqrt{2\phi_B - V_{BS}}) \quad (16)$$

1.4 Level-3 Model

$$V_{DSat} = (V_{GS} - V_{th})/\alpha \quad (17)$$

$$I_{DS} = \begin{cases} \frac{\mu_n C_{ox} W}{2L} (V_{GS} - V_{th}) \left[2V_{DS} - \frac{V_{DS}^2}{V_{DSat}} \right], & \text{if } V_{DS} \leq V_{DSat} \\ \frac{\mu_n C_{ox} W}{2L} (V_{GS} - V_{th}) V_{DSat}, & \text{if } V_{DS} \geq V_{DSat} \end{cases} \quad (18)$$

1.5 Simulations

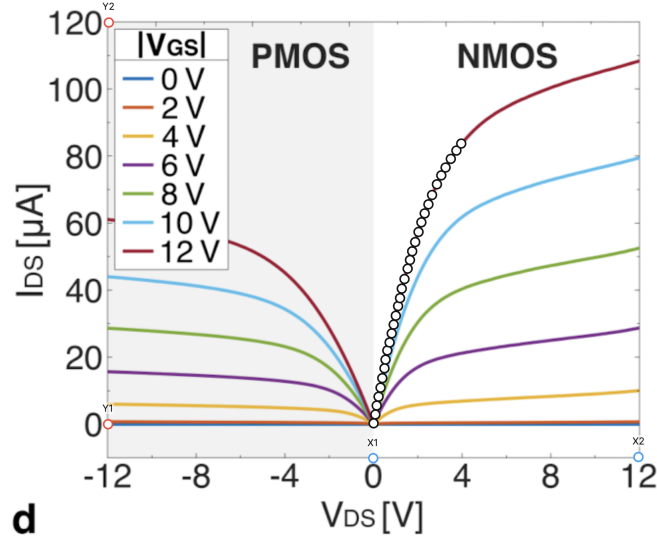
$$V_{DSeff} = V_{DS} - \frac{1}{2} (V_{DS} - V_{DSat} + \sqrt{(V_{DS} - V_{DSat})^2 + \Delta^2}) \quad (19)$$

$$V_{DSeff} = \begin{cases} V_{DS}, & \text{if } V_{DS} \leq V_{DSat} \\ V_{DSat}, & \text{if } V_{DS} \geq V_{DSat} \end{cases} \quad (20)$$

$$I_{DS} = \frac{\mu_n C_{ox} W}{2L} (V_{GS} - V_{th}) \left(2V_{DSeff} - \frac{V_{DSeff}^2}{V_{DSat}} \right) \quad (21)$$

1.6 Plot-digitizer

Plot digitizer app is used to digitize the plot given in the paper and the data obtained is used to calculate the gain factor.



$$I_{DS}(2.05V) = 57.44\mu A$$

$$I_{DS}(0.01V) = 00.28\mu A$$

In equation 21 if we assume linearity with V_{DS} and neglecting the term $\frac{V_{DS}^2}{2V_{DSat}}$ the gain factor is given by the equation 22.

$$\mu C_{ox} \frac{W}{L} = \frac{1}{V_{GS} - V_{th}} \times \frac{I_{DS}(2.05V) - I_{DS}(0.01V)}{2.05 - 0.01} \quad (22)$$

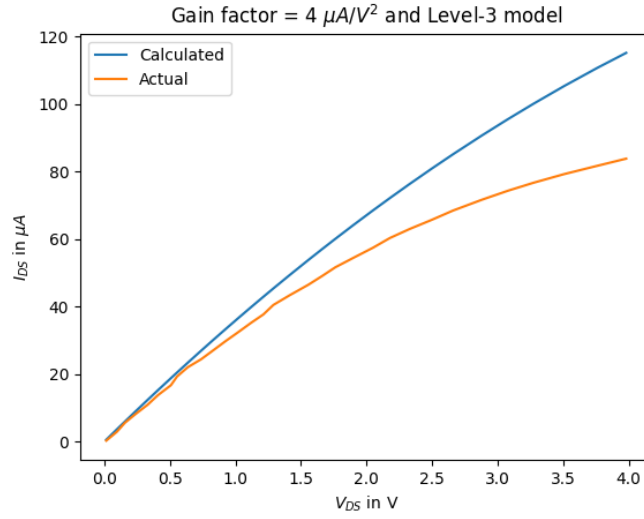
$$\mu C_{ox} \frac{W}{L} = \frac{1}{12 - 2.45} \times \frac{57.44 - 00.28}{2.05 - 0.01} \mu A/V^2 \quad (23)$$

$$\mu C_{ox} \frac{W}{L} = 2.93 \mu A/V^2 \quad (24)$$

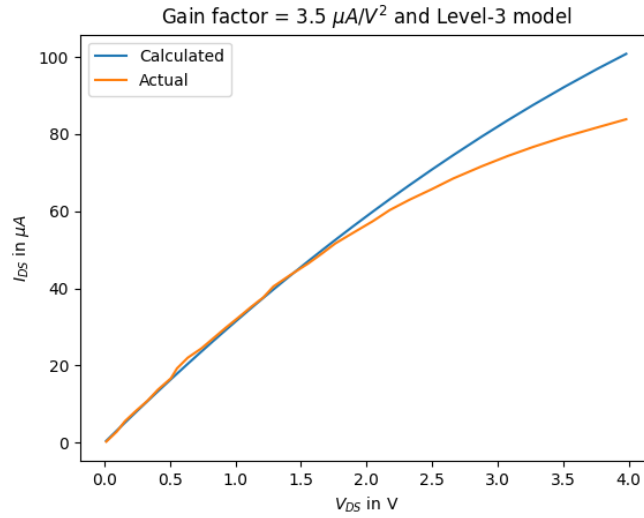
The gain factor given in the reference is $4\mu A/V^2$ the difference may be due to the fact that the Current through channel is not a linear function of V_{DS} .

1.7 Comparing acquired data with level-3 model

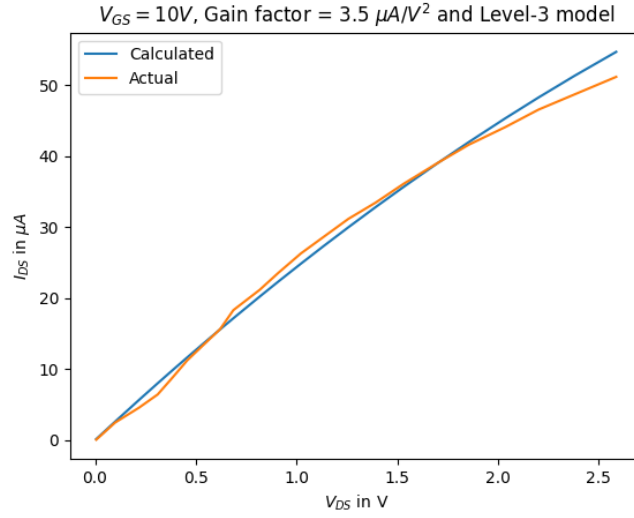
The Drain current (I_{DS}) is calculated using the level-3 model given by equation 21, the gain factor is fixed at the value $4\mu A/V^2$ as described in the paper. The comparison of calculated drain current and acquired drain current is shown in figure (1.7).



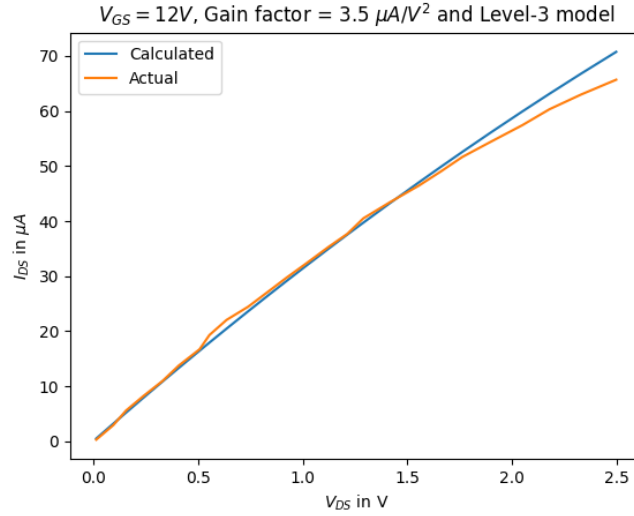
If the gain factor is reduced to $3.5\mu A/V^2$ the Comparison graph is as shown below in figure (1.7).



The plot of $V_{GS} = 10V$ is digitized and compared with the model with gain factor = 3.5 V the comparison is shown in figure (1.7). The range of V_{DS} considered is $0V \rightarrow 2.5V$ because the plot is linear in that region.



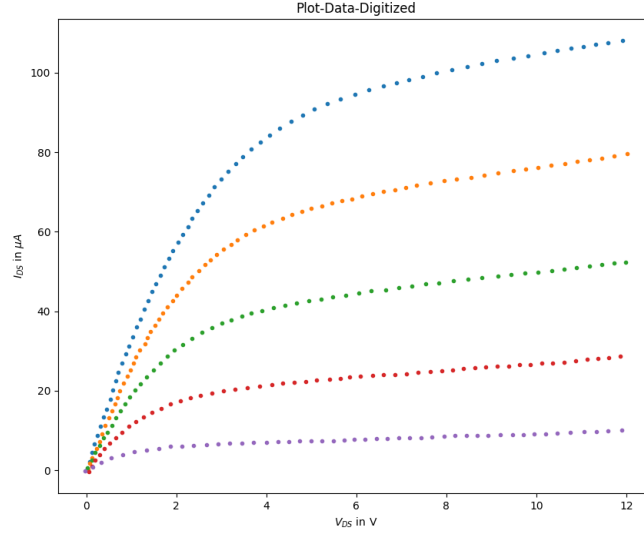
The comparison of Calculated and acquired data for $V_{GS} = 12V$ and for V_{DS} in range of $0V \rightarrow 2.5V$ is shown in figure (1.7).



1.8 Four MOS-CAPs in parallel

1.9 Model

The data from the plot is extracted for the gate voltage values of 4V, 6V, 8V, 10V, 12V and plotted in figure 1.9.



Since, there is a small slope in saturation region the previous model is modified and the new modified model contains a new parameter λ . The new model is given by the equation 25.

$$I_{DS} = \text{gain} \times \alpha \left(V_{DSeff} V_{DSat} - \frac{V_{DSeff}^2}{2} \right) (1 + \lambda V_{DS}) \quad (25)$$

where,

$$\alpha = \text{Level - 3 model Parameter} \quad (26)$$

$$\text{Gain} = \frac{\mu C_{ox} W}{L} \quad (27)$$

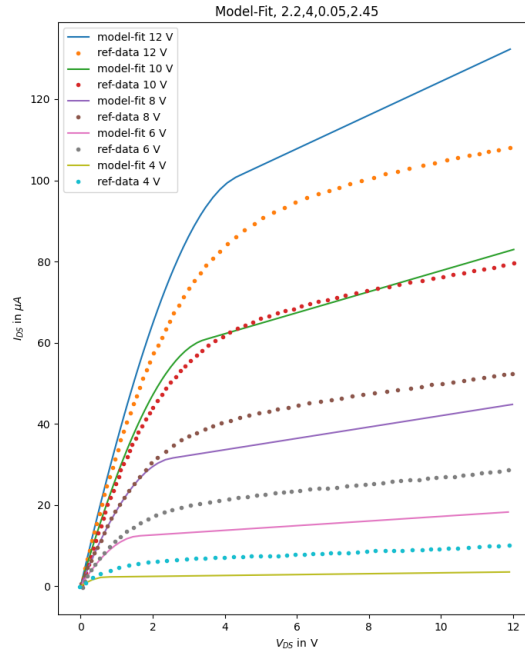
$$V_{DSat} = \frac{V_{GS} - V_{th}}{\alpha} \quad (28)$$

$$(29)$$

1.10 Fit - 1

Variable parameters to fit the model for different values of V_{GS} and V_{DS} .

- $\alpha = 2.2$
- $\text{gain} = 4$
- $\lambda = 0.05$
- $V_{th} = 2.45$

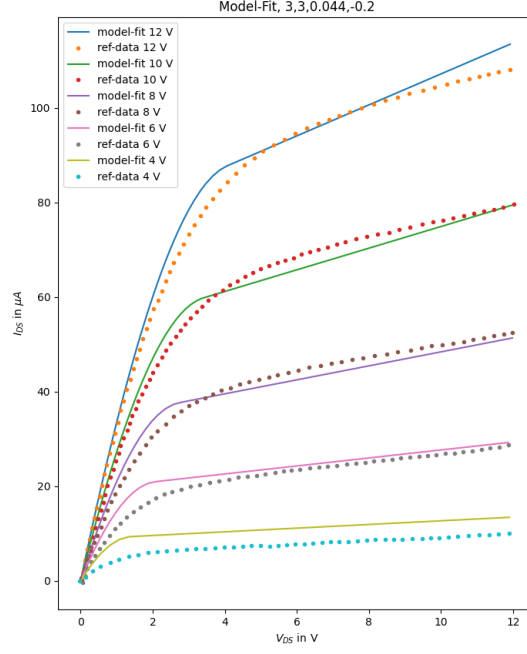


1.11 Fit - 2

Variable parameters to fit the model for different values of V_{GS} and V_{DS} .

- $\alpha = 3$
- $\text{gain} = 3$
- $\lambda = 0.044$
- $V_{th} = -0.2$

With the parameters set the model is fit and shown in the figure 1.11.



1.11.1 Analysis of the Fit

$$V_{DS} < V_{DSat}$$

$$I_{DS} = \text{gain} \times \left[(V_{DS}(V_{GS} - V_{th})) - \frac{(V_{GS} - V_{th})^2}{2\alpha} \right] (1 + \lambda V_{DS}) \quad (30)$$

$$V_{DS} \geq V_{DSat}$$

$$I_{DS} = \text{gain} \times \frac{(V_{GS} - V_{th})^2}{2\alpha} (1 + \lambda V_{DS}) \quad (31)$$