report

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1 MOSFET Model

1.1 Constants

$$n_i = 10^{10}/cm^3 \tag{1}$$
$$\epsilon_{ox} = 3.9 \times 8.854 \times 10^{-14} F/cm \tag{2}$$
$$\epsilon_s = 11.9 \times 8.854 \times 1e - 14F/cm \tag{3}$$

1.2 Variable Parameters

$$N_A = 10^{15}/cm^3 \tag{4}$$
$$t_{ox} = 2 \times 10^{-5} cm \tag{5}$$
$$V_{FB} = 1.035V \tag{6}$$
$$q = 1.60217663 \times 10^{-19} C \tag{7}$$
$$W = 0.22 \times 10^{-4} cm \tag{8}$$
$$L = 4 \times 10^{-4} cm \tag{9}$$
$$V_{BS} = -10V \tag{10}$$
$$\mu_n = 1340 cm^2/(V.s) \tag{11}$$

1.3 Calculations

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} \tag{12}$$
$$\phi_B = 0.0258 \log(N_A/n_i) \tag{13}$$
$$V_{th} = V_{FB} + 2\phi_B + \frac{\sqrt{2qN_A\epsilon_s 2\phi_B}}{C_{ox}} V \tag{14}$$
$$\gamma = \frac{\sqrt{2 \times \epsilon_s q N_A}}{C_{ox}} \tag{15}$$
$$\alpha = 1 + \gamma/(2\sqrt{2\phi_B - V_{BS}}) \tag{16}$$

1.4 Level-3 Model

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

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

1.5 Simulations

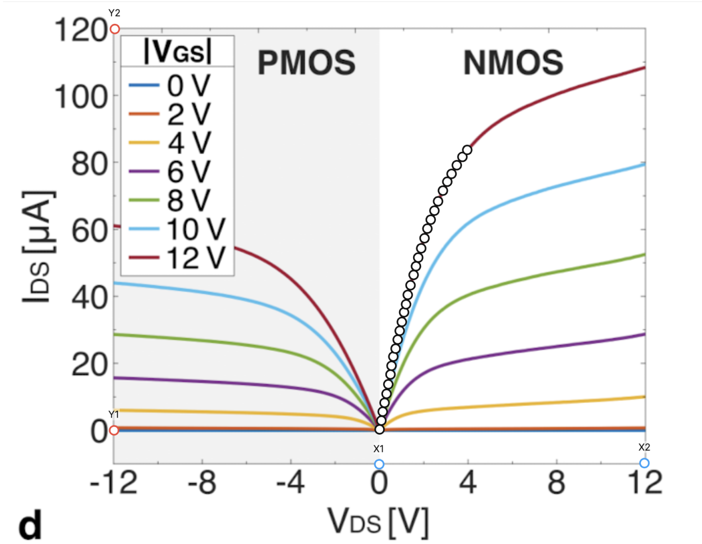
$$V_{DSeff} = V_{DS} - \frac{1}{2}(V_{DS} - V_{DSat} + \sqrt{(V_{DS} - V_{DSat})^2 + \Delta^2}) \tag{19}$$

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

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

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.

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

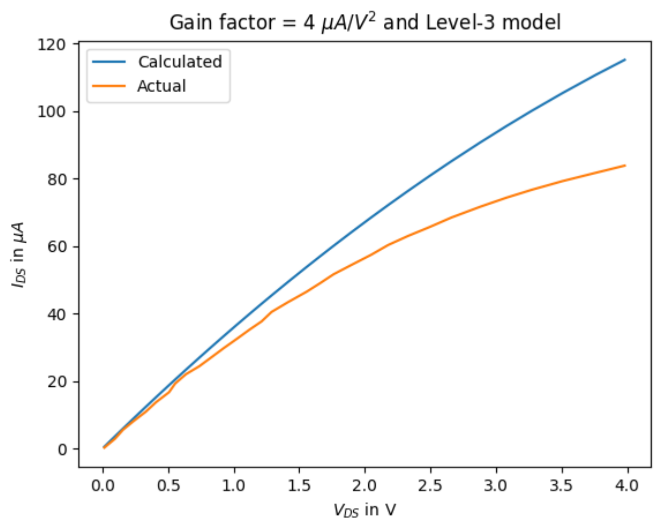
$$\mu C_{ox}\frac{W}{L} = \frac{1}{12 - 2.45} \times \frac{57.44 - 00.28}{2.05 - 0.01}\mu A/V^2 \tag{23}$$

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

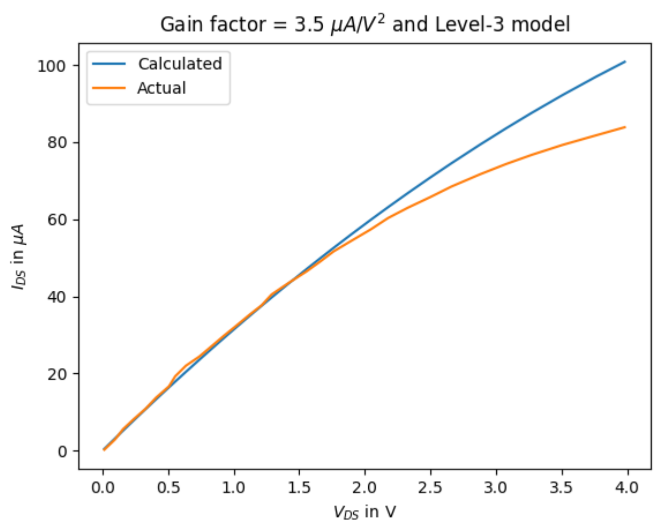
The gain factor given in the reference is $4\mu A/V^2$ the difference may be due to the fact that the Current through channel is not a linear function of V_{DS}.

1.7 Comparing acquired data with level-3 model

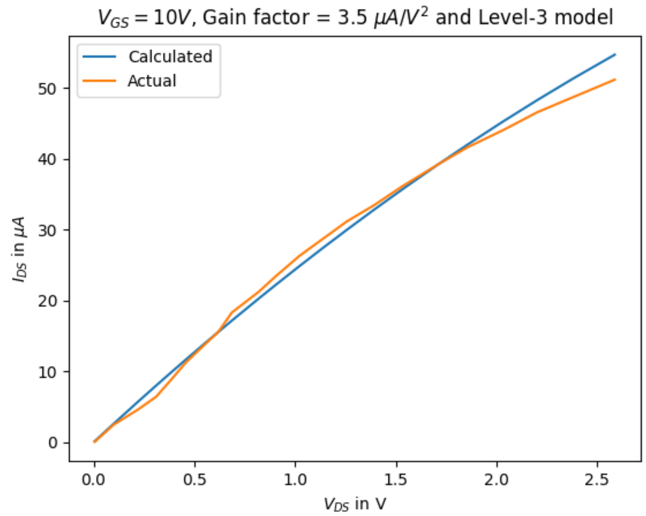
The Drain current (I_{DS}) is calculated using the level-3 model given by equation 21, the gain factor is fixed at the value $4\mu A/V^2$ as described in the paper. The comparison of calculated drain current and acquired drain current is shown in figure (1.7).



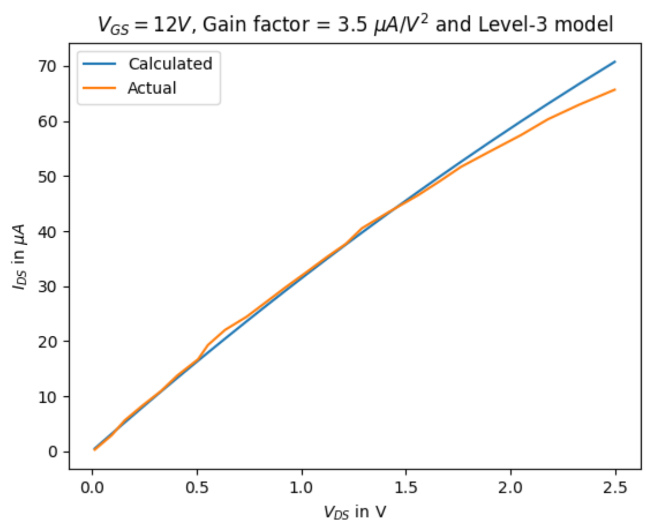
If the gain factor is reduced to $3.5\mu A/V^2$ the Comparison graph is as shown below in figure (1.7).



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.



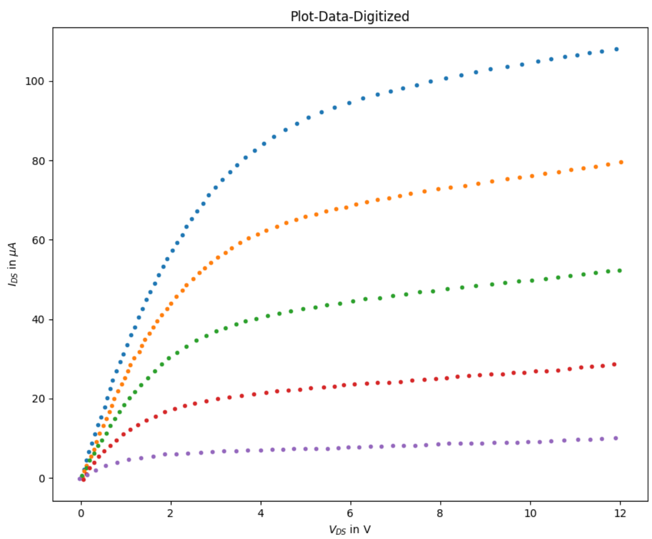
The comparison of Calculated and acquired data for $V_{GS} = 12V$ and for V_{DS} in range of $0V \rightarrow 2.5V$ is shown in figure (1.7).



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.

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

where,

$$\alpha = \text{ Level - 3 model Parameter} \tag{26}$$

$$\text{Gain } = \frac{\mu C_{ox} W}{L} \tag{27}$$

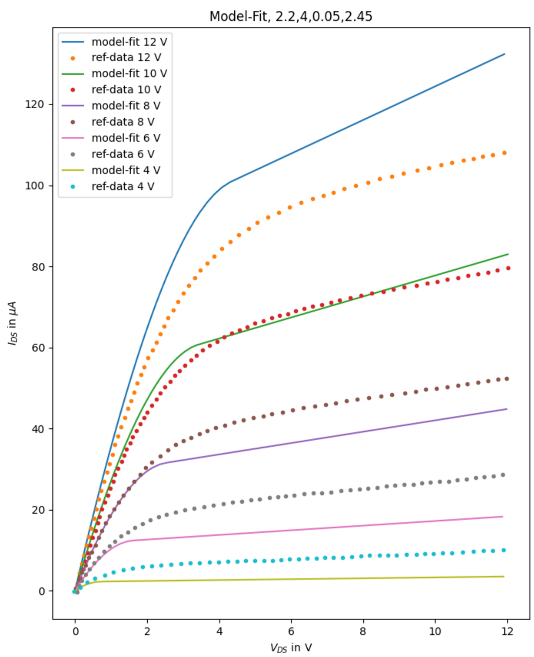
$$V_{DSat} = \frac{V_{GS} - V_{th}}{\alpha} \tag{28}$$

$$\tag{29}$$

1.10 Fit - 1

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

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

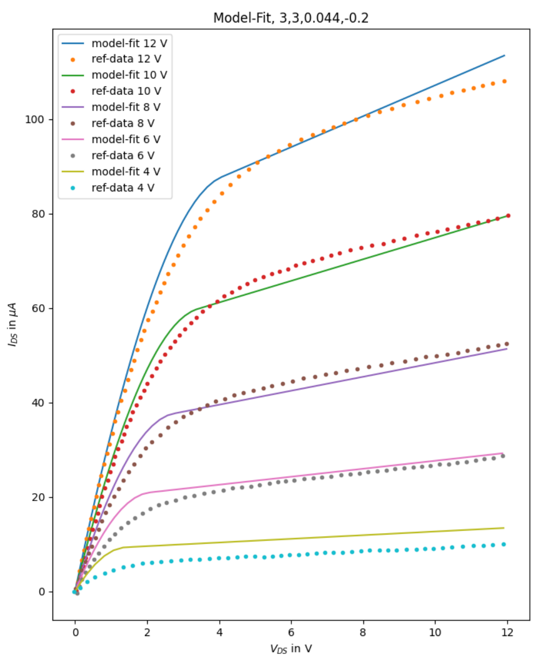


1.11 Fit - 2

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

- $\alpha = 3$
- 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

$V_{DS} < V_{DSat}$

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

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

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

1.12 QUCS simulations

There is some resistance in between source contact pad and source terminal in transistor therefore, we model a resistor in between them and similarly a resistance between drain contact pad drain terminal at transistor. The resistance is calculated as shown in equation (**??**eq:resistance]).

$$R = \frac{\rho L}{A} = \frac{0.085 \times 6}{2 * 0.22 \times 10^{-4}} = 11590\Omega \tag{32}$$

The model used to simulate is as shown in the figure 1.12. I_D is given by equation 33.

$$\boxed{I_D = \alpha * \text{gain} * (V_{DSeff} V_{DSat} - \frac{V_{DSeff}^2}{2})(1 + \lambda V_{DSi})} \tag{33}$$

the equations of V_{DSeff}, V_{DSat} and V_{DSi} are given by equation 34

$$\begin{align} V_{GSi} &= V_{GS} - V_{Si} \tag{34} \\ V_{DSi} &= V_{DS} - V_{Si} \tag{35} \\ V_{DSat} &= (V_{GSi} - V_{th})/\alpha \tag{36} \\ V_{DSeff} &= V_{DSi} - \frac{1}{2}(V_{DSi} - V_{DSat} + \sqrt{(V_{DSi} - V_{DSat})^2 + \Delta^2}) \tag{37} \end{align}$$

The parameters are α, gain, V_{th}, λ