EE788: Assignment 2

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October 12, 2022

All parts of the assignment are for an NMOS type transistor.

From the graph given, the following conditions are used in code for the 3 cases:

Case	L (in μm)	t_{ox} (in nm)	V_{DD} (in V)	V_{th} (in V)
1	1	20	5	0.8
2	0.5	10	3.5	0.55
3	0.35	7	3	0.5

- For fixed mobility calculations, $\mu_n = 200 cm^2/V \cdot s$ is used.
- For all the parts below, based on the V_{th} from the graph, the substrate concentration N_A is obtained via interpolation and used in further calculations.
- Width used is $1\mu m$ for all calculations. For a width of $W\mu m$, the results obtained below would merely have to be scaled W times.
- For $I_D - V_D$ characteristics, V_G values of 2.5, 3.5 and 4.5 V are used

The equations used are: Depending on the region of operation, different equations of current are used. Here, $V_{\mathrm{D,sat}} = (V_{GS} - V_{th})/m$

Linear region ($V_{GS} \geq V_{th}$ and $V_{DS} < V_{\mathrm{D,sat}}$):

$$I_D = \mu C_{ox} \left(\frac{W}{L}\right) \left(V_{GS} - V_{th} - \frac{mV_{DS}}{2}\right) V_{DS} \tag{1}$$

Saturation region ($V_{GS} \geq V_{th}$ and $V_{DS} \geq V_{\mathrm{D,sat}}$):

$$I_D = \mu C_{ox} \left(\frac{W}{L}\right) \frac{(V_{GS} - V_{th})^2}{2m} \tag{2}$$

Here, V_{GS} values are well above V_{th} so we need not look at subthreshold characteristics.

Constant Mobility I-V characteristics

Here, μ used in equations 1 and 2 is taken as a fixed value of $200 cm^2/V \cdot s$

Vertical field induced mobility degradation I-V characteristics

$$|Q_I| = C_{ox}\left(V_{GS} - V_{th}\right) \tag{3}$$

$$|Q_D| = C_{ox}\left(V_{th} - V_{FB} - 2\phi_B\right) \tag{4}$$

$$|E_{eff}| = \frac{1}{\epsilon_{Si}}\left(|Q_D| + \frac{1}{2}|Q_I|\right) \tag{5}$$

$$|\mu_{eff}| = A \cdot (E_{eff})^{-n} \tag{6}$$

For calculation here, the values of A and n used are 1 and 0.3 respectively.

Once, μ_{eff} is obtained, this is used in equations 1 and 2 to get the desired curves.

Observations

For all 3 cases, the current is around an order of magnitude lower for the mobility degraded case in comparison to the constant mobility current.

Plots

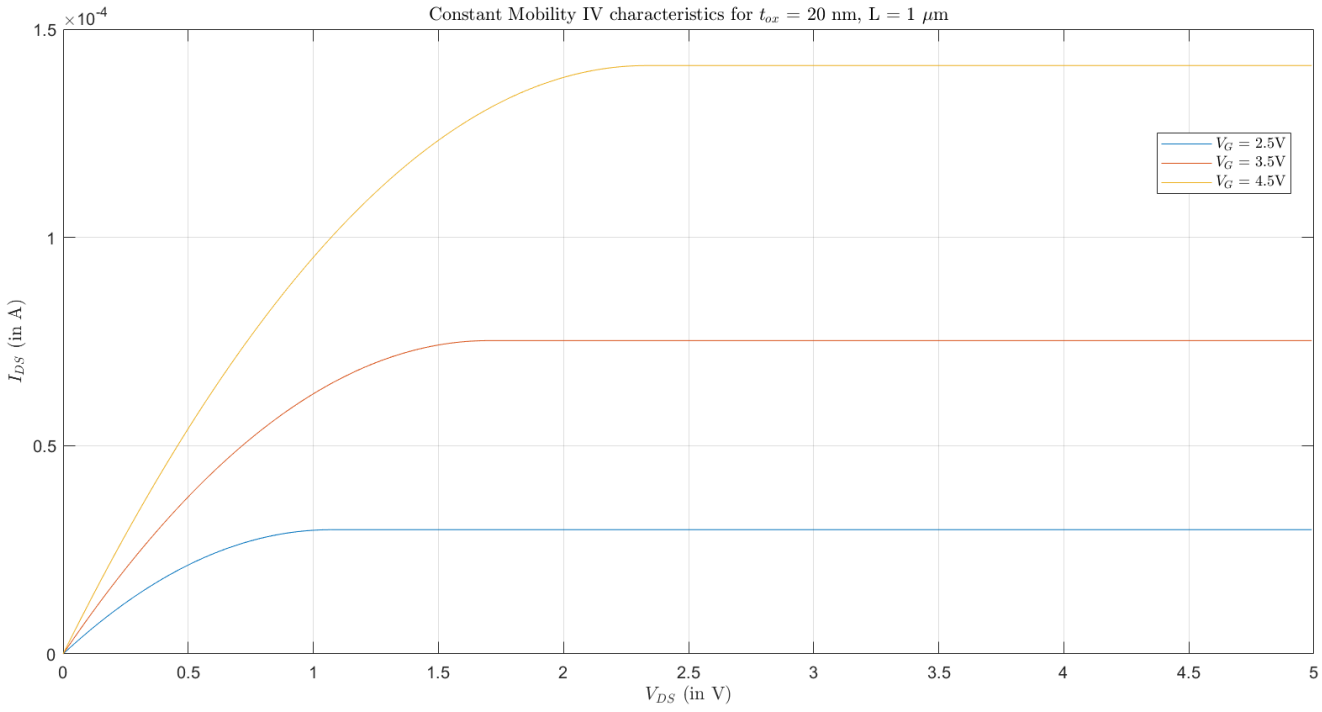

Figure 1: Case 1: $I_D - V_D$ characteristics for Piecewise model with constant mobility

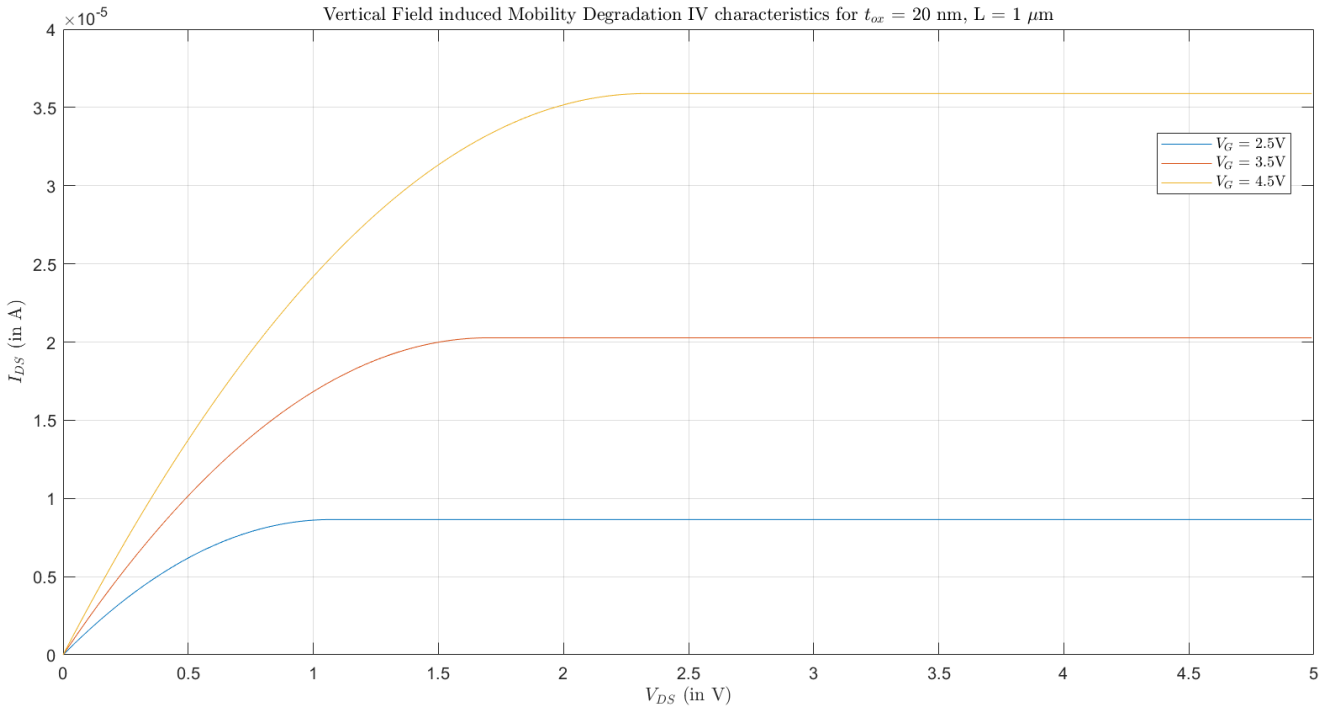

Figure 2: Case 1: $I_D - V_D$ characteristics for Piecewise model with vertical field induced mobility degradation

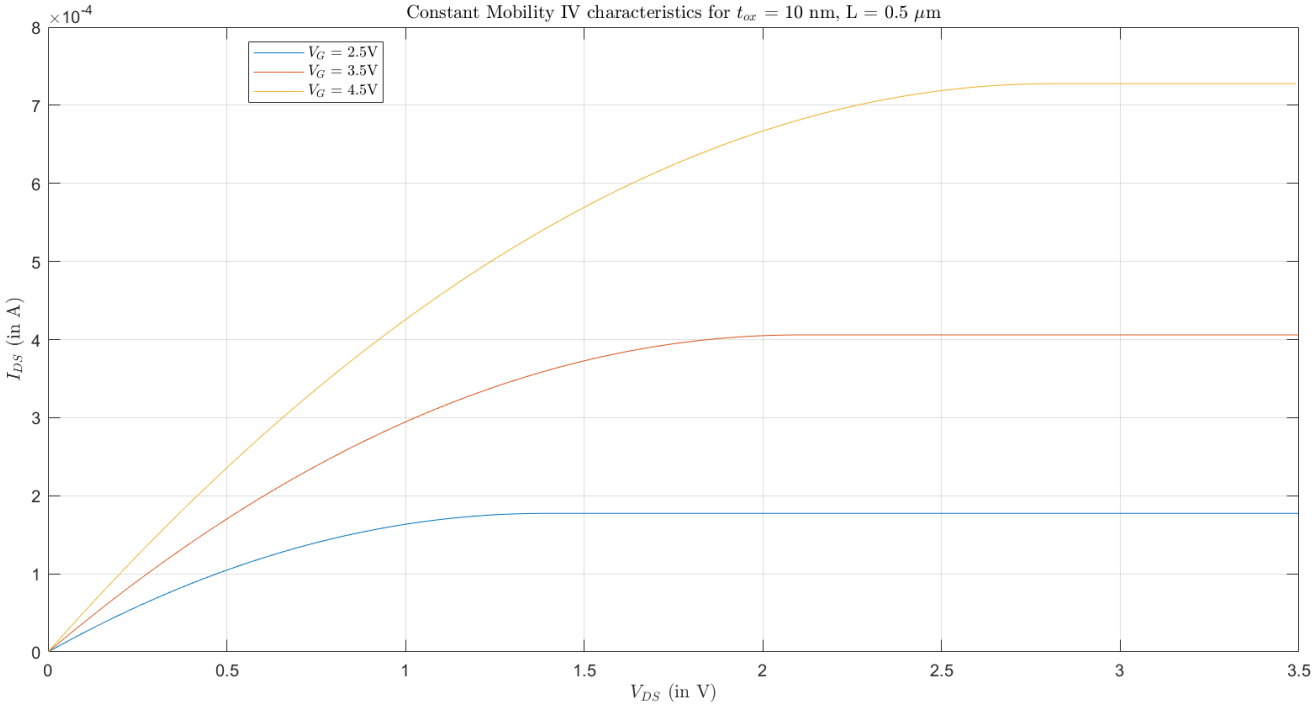

Figure 3: Case 2: $I_D - V_D$ characteristics for Piecewise model with constant mobility

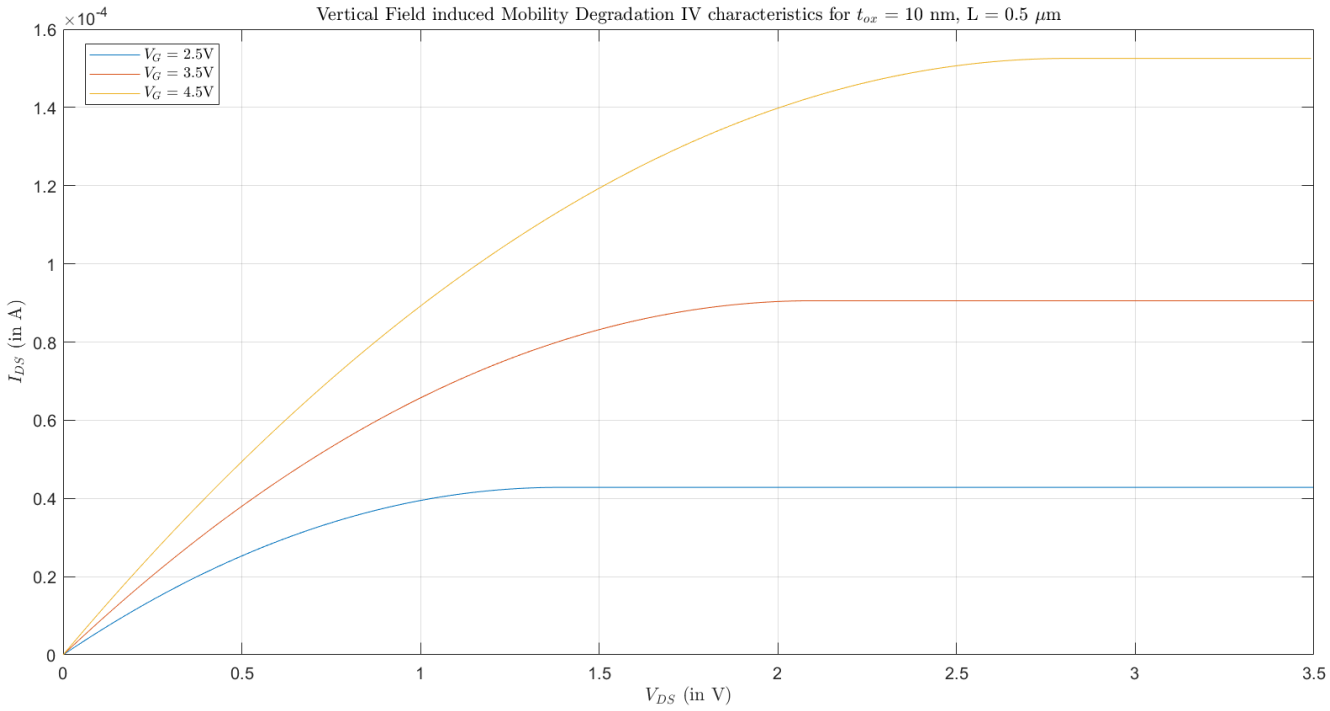

Figure 4: Case 2: $I_D - V_D$ characteristics for Piecewise model with vertical field induced mobility degradation

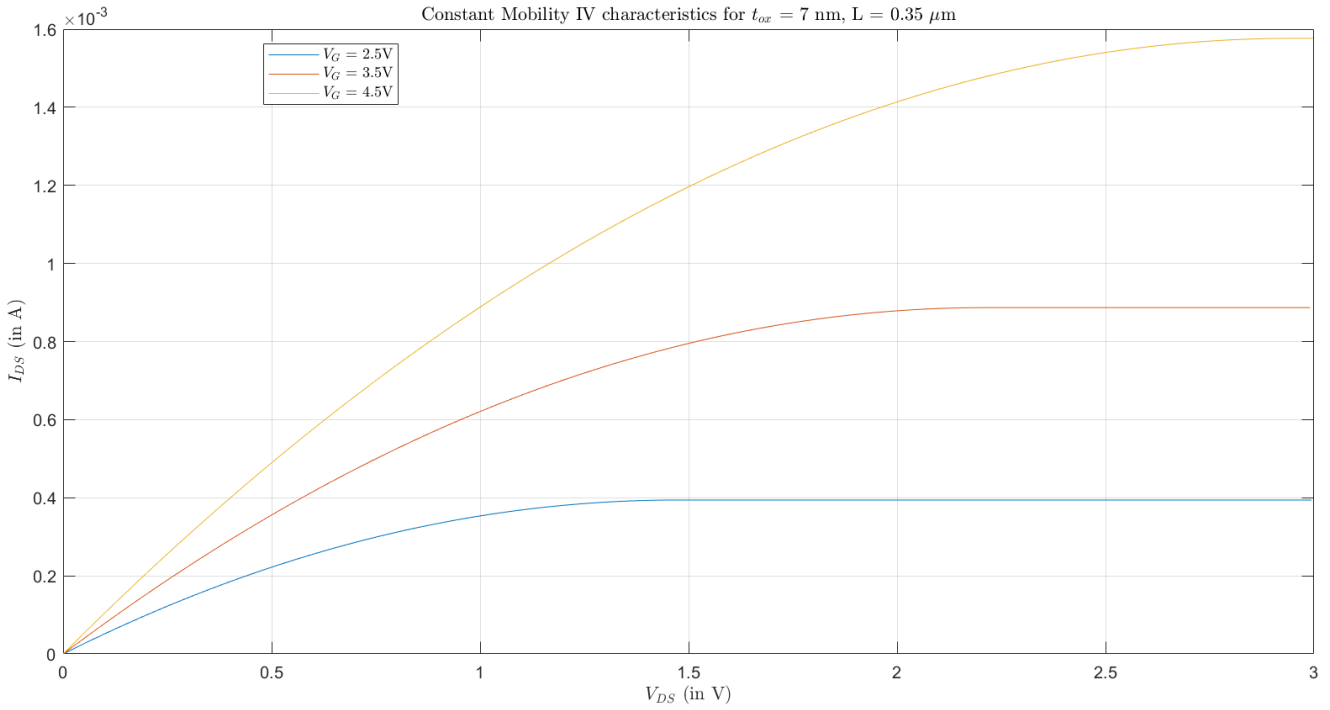

Figure 5: Case 3: $I_D - V_D$ characteristics for Piecewise model with constant mobility

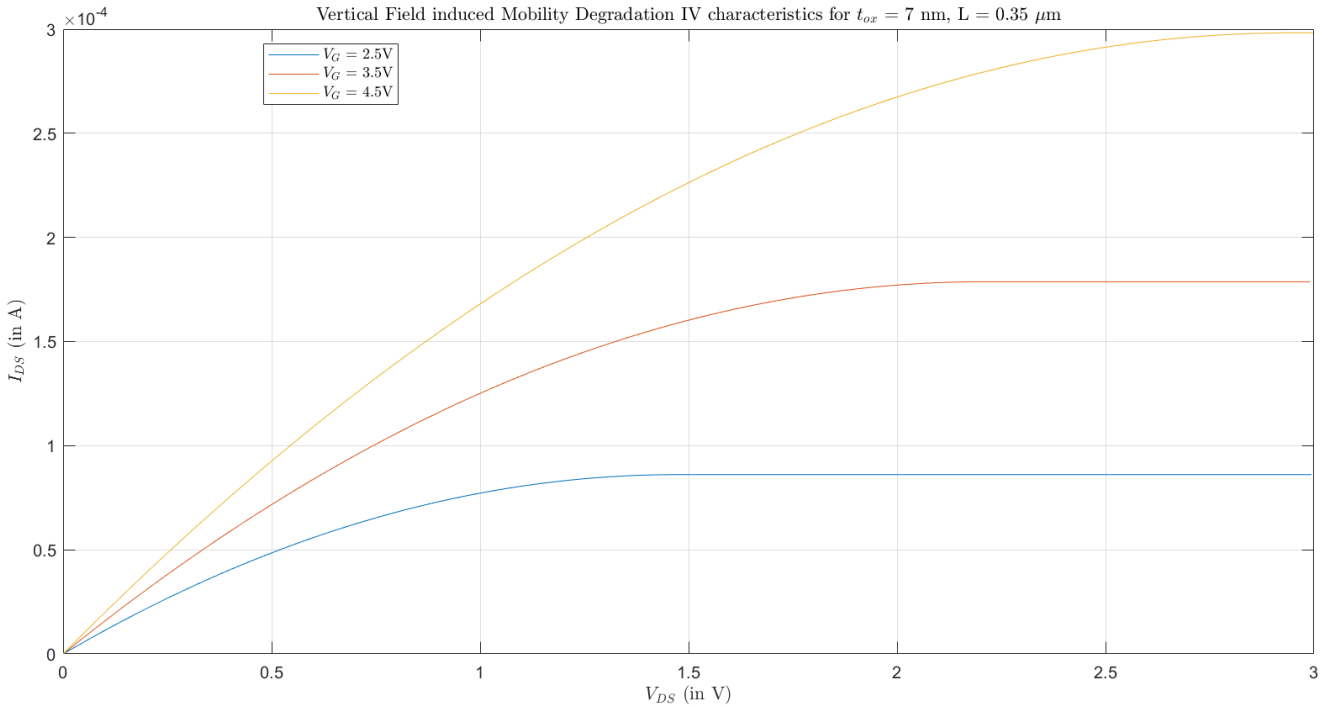

Figure 6: Case 3: $I_D - V_D$ characteristics for Piecewise model with vertical field induced mobility degradation

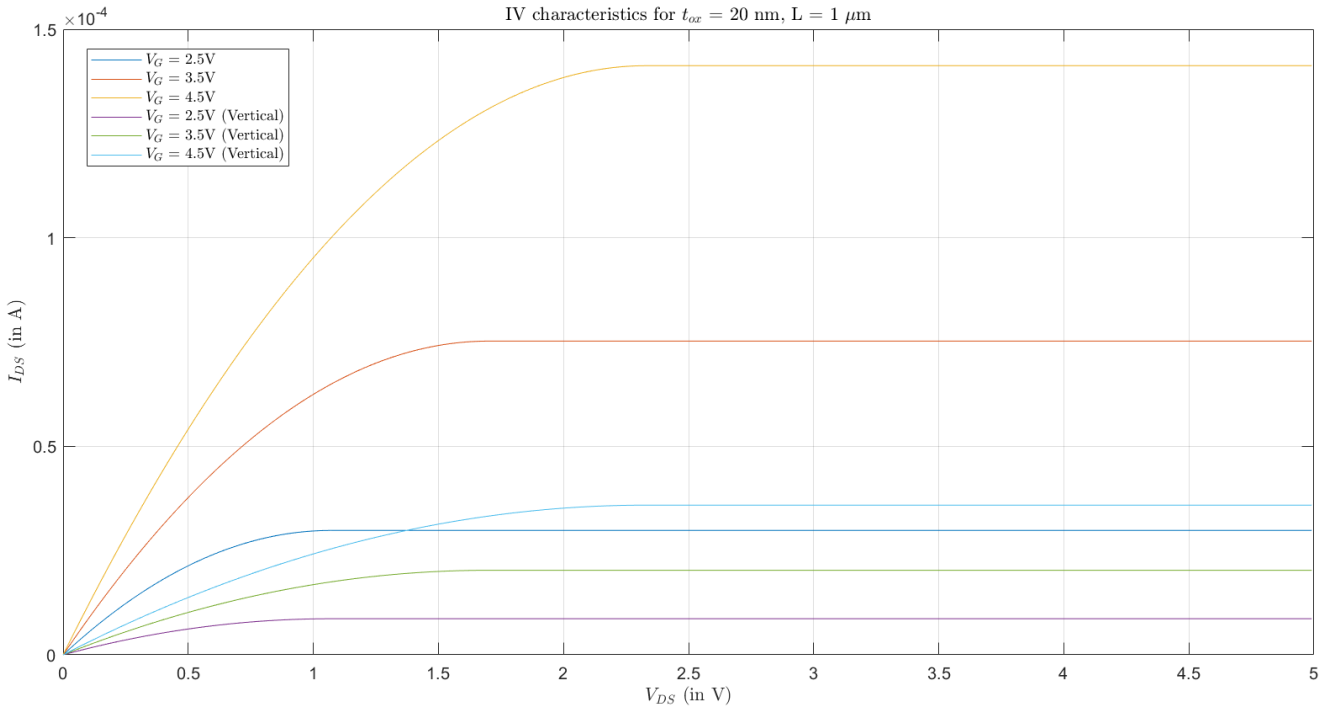

Figure 7: Case 1: $I_D - V_D$ characteristics for Piecewise model with all plots superimposed

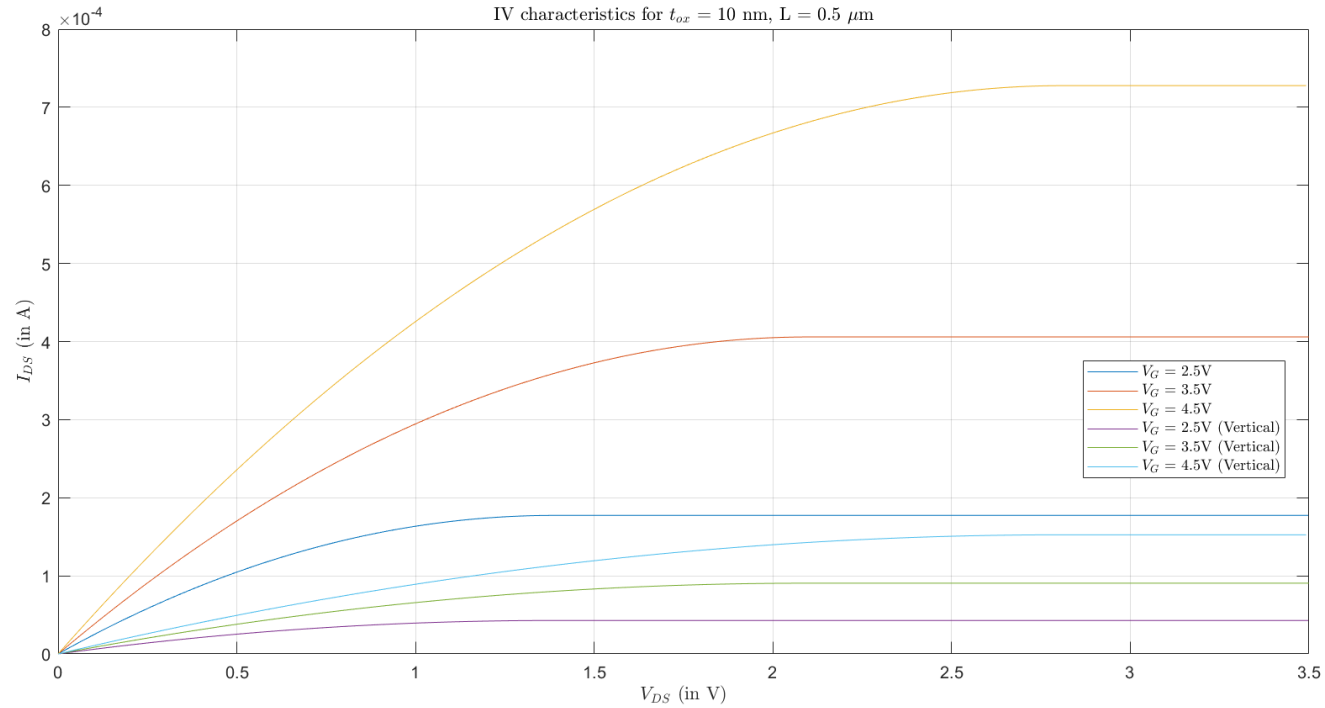

Figure 8: Case 2: $I_D - V_D$ characteristics for Piecewise model with all plots superimposed

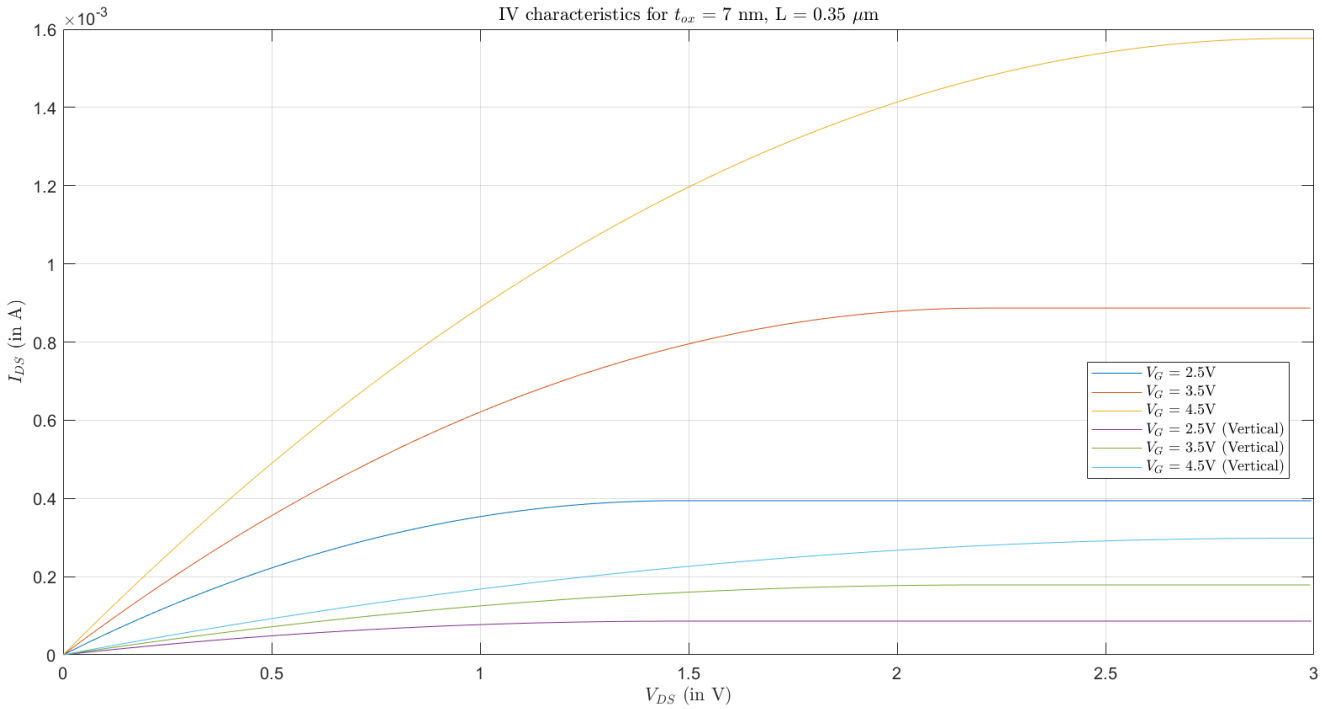

Figure 9: Case 3: $I_D - V_D$ characteristics for Piecewise model with all plots superimposed