

# EE788: Assignment 3

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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 $\mu m$ )	$t_{ox}$ (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,  $\mu_n = 200cm^2/V \cdot s$  is used.
- For effect of lateral field on mobility,  $v_{sat} = 10^7 cm/s$  is taken
- 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,  $V_{D,sat} = (V_{GS} - V_{th})/m$

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

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

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

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

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

## Constant Mobility I-V characteristics

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

## Vertical field induced mobility degradation I-V characteristics

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

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

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

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

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

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

## Vertical and Lateral field induced mobility degradation I-V characteristics

$$|\mu_{eff}| = \frac{\mu_{vert}}{1 + \frac{\mu_{vert} V_{DS}}{v_{sat} L}} \quad (7)$$

Here, we substitute  $\mu_{vert}$  from equation 6, and use  $\mu_{eff}$  from 7 to calculate current.

## Observations

For all 3 cases, the current is around an order of magnitude lower for the vertical mobility degraded case in comparison to the constant mobility current, and the current with both lateral and vertical field effects is even lower.

## Plots

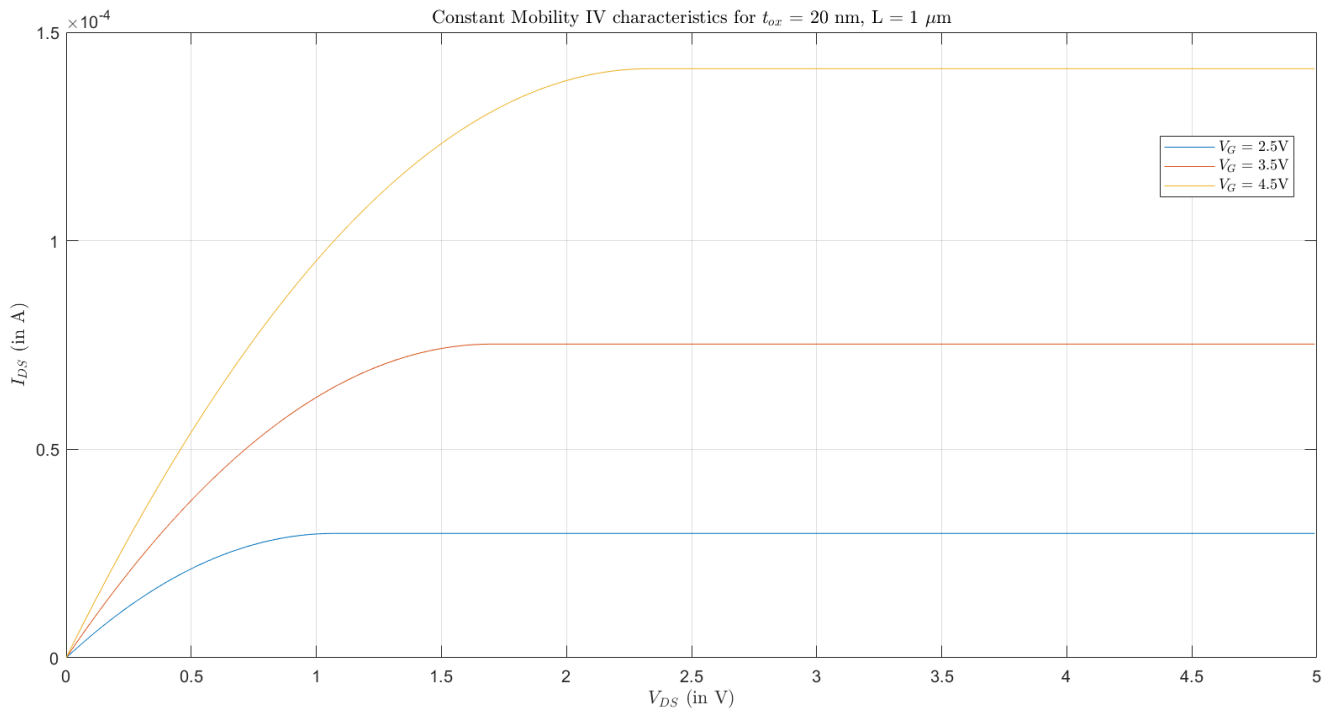


Figure 1: Case 1:  $I_D - V_D$  characteristics for Piecewise model with constant mobility

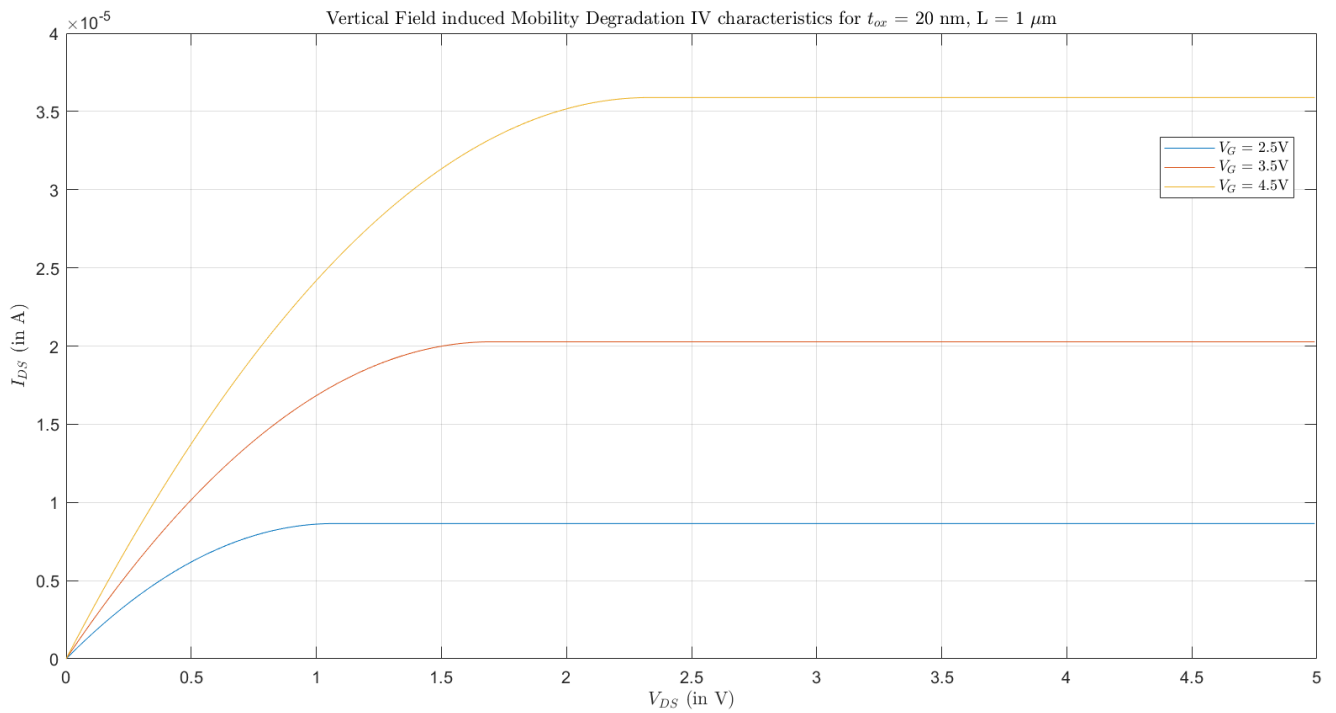


Figure 2: Case 1:  $I_D - V_D$  characteristics for Piecewise model with vertical field induced mobility degradation

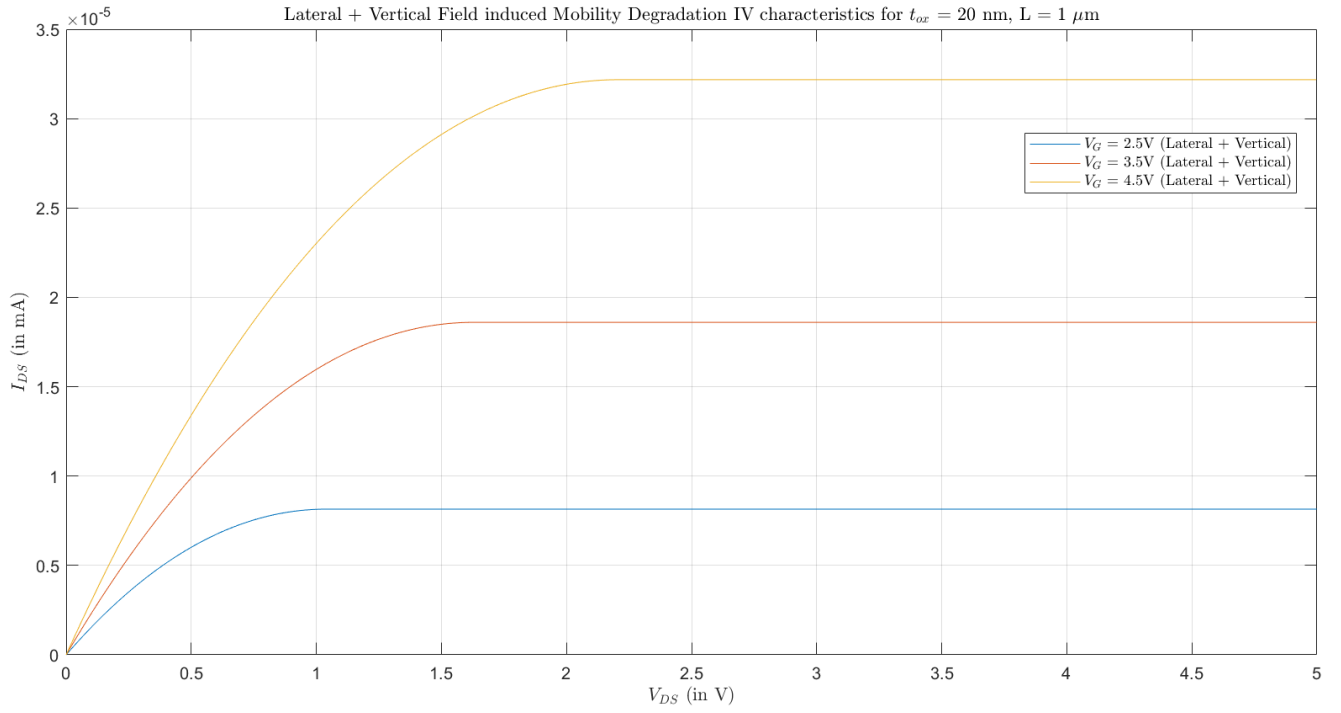


Figure 3: Case 1:  $I_D - V_D$  characteristics for Piecewise model with both lateral and vertical fields induced mobility degradation

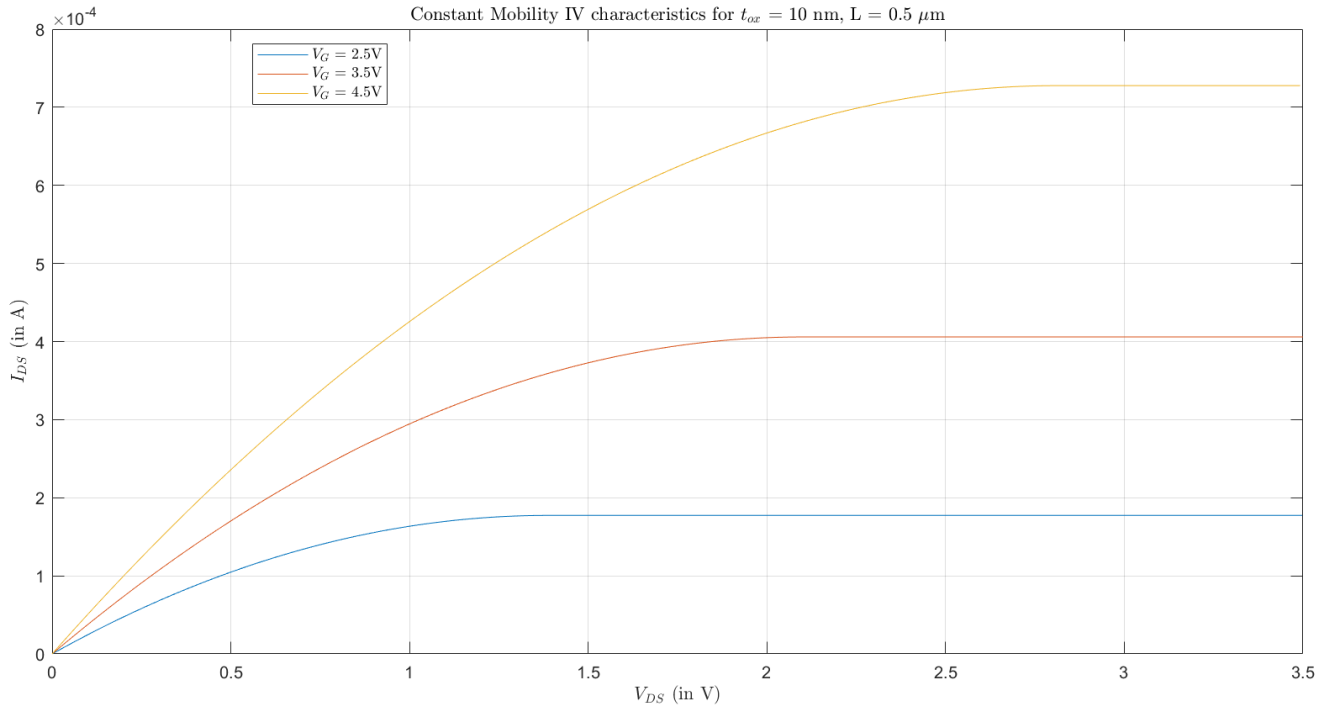


Figure 4: Case 2:  $I_D - V_D$  characteristics for Piecewise model with constant mobility

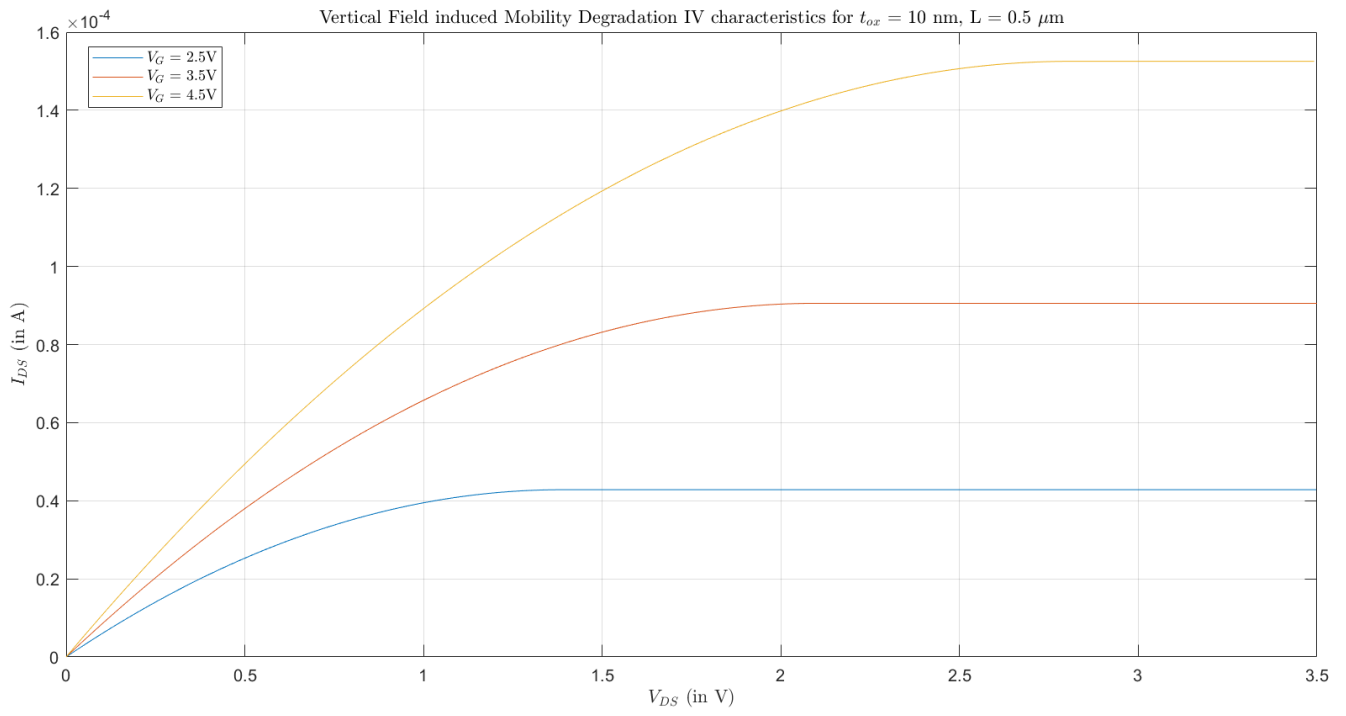


Figure 5: Case 2:  $I_D - V_D$  characteristics for Piecewise model with vertical field induced mobility degradation

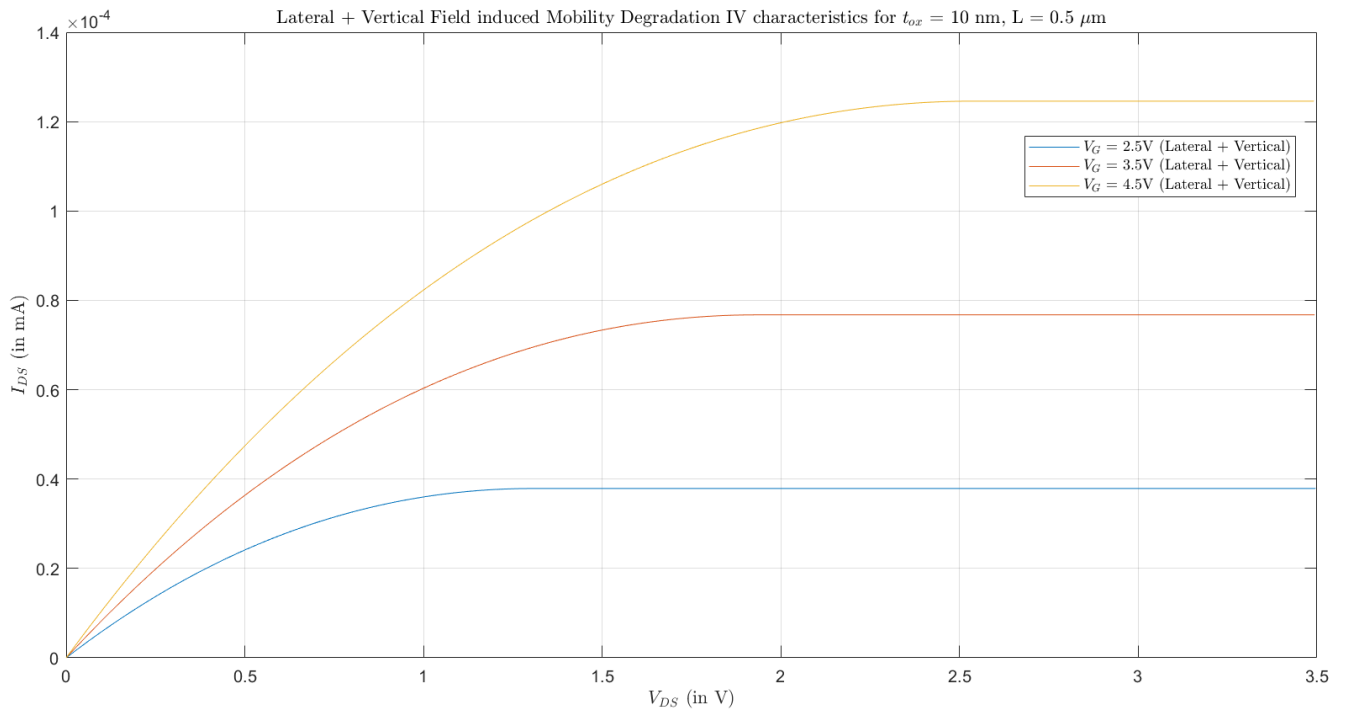


Figure 6: Case 2:  $I_D - V_D$  characteristics for Piecewise model with both lateral and vertical fields induced mobility degradation

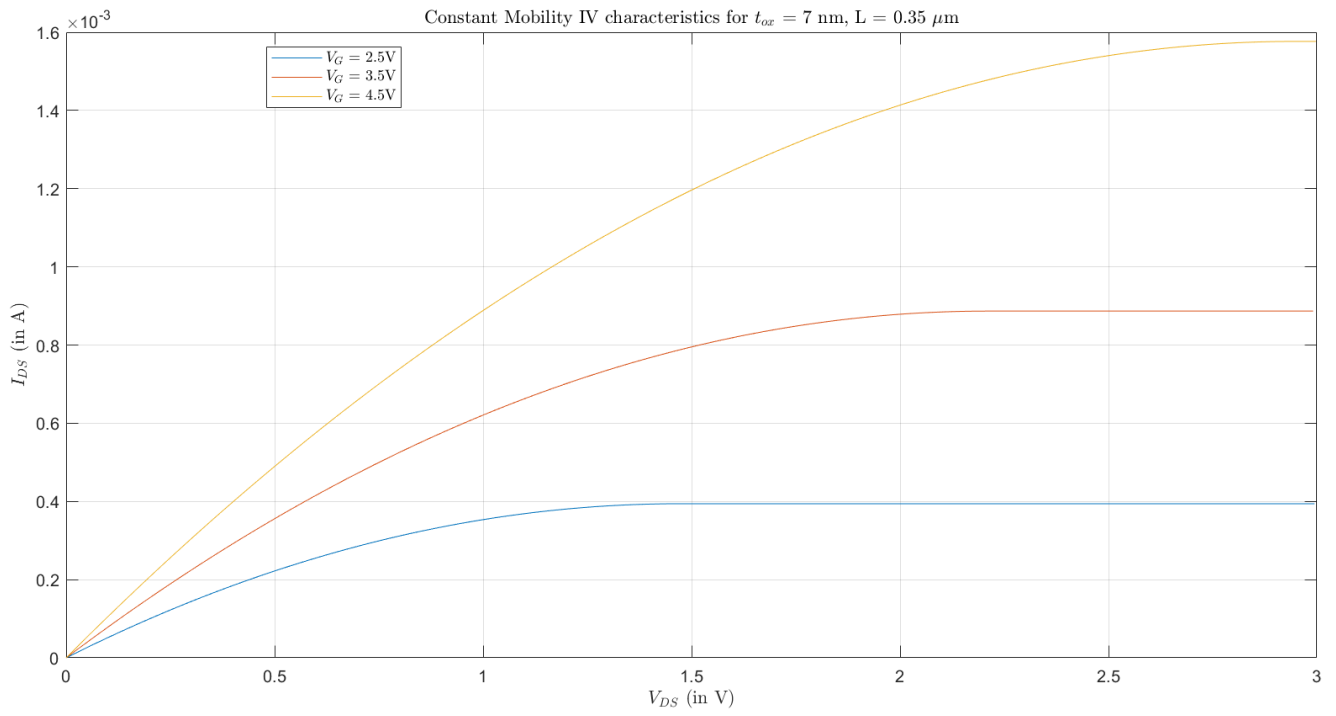


Figure 7: Case 3:  $I_D - V_D$  characteristics for Piecewise model with constant mobility

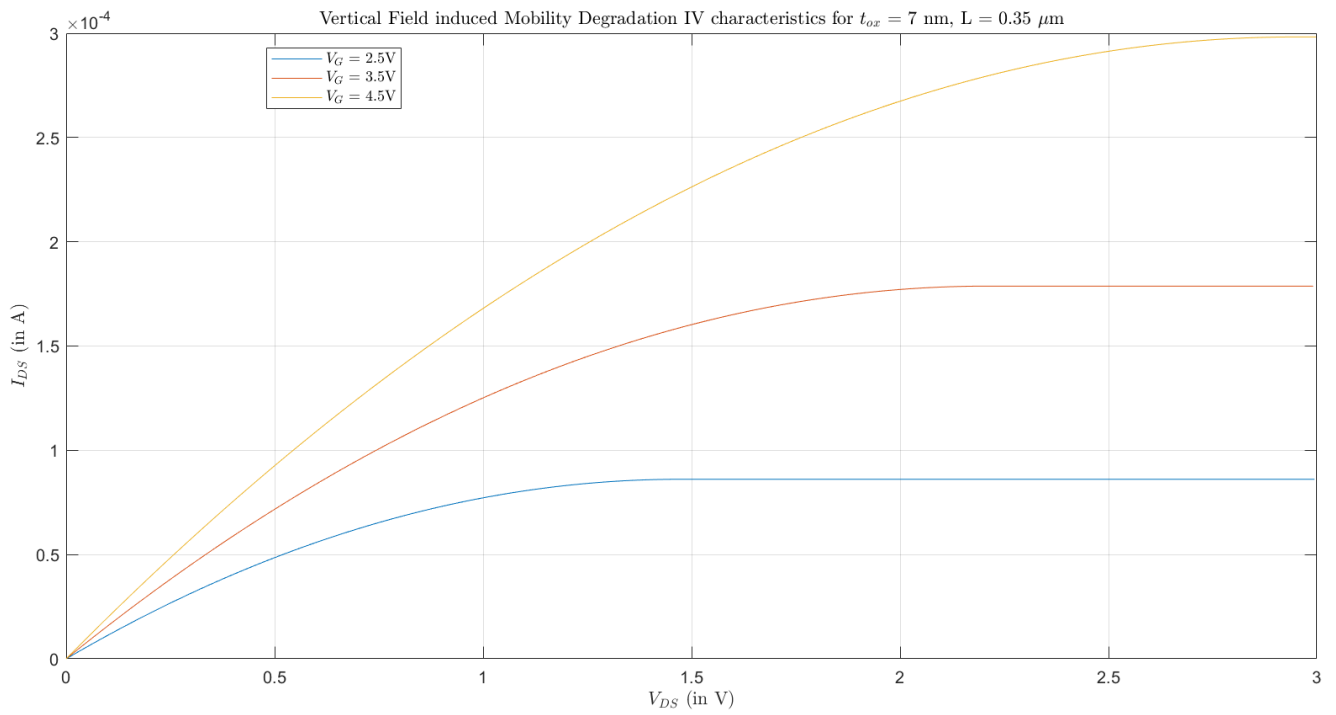


Figure 8: Case 3:  $I_D - V_D$  characteristics for Piecewise model with vertical field induced mobility degradation

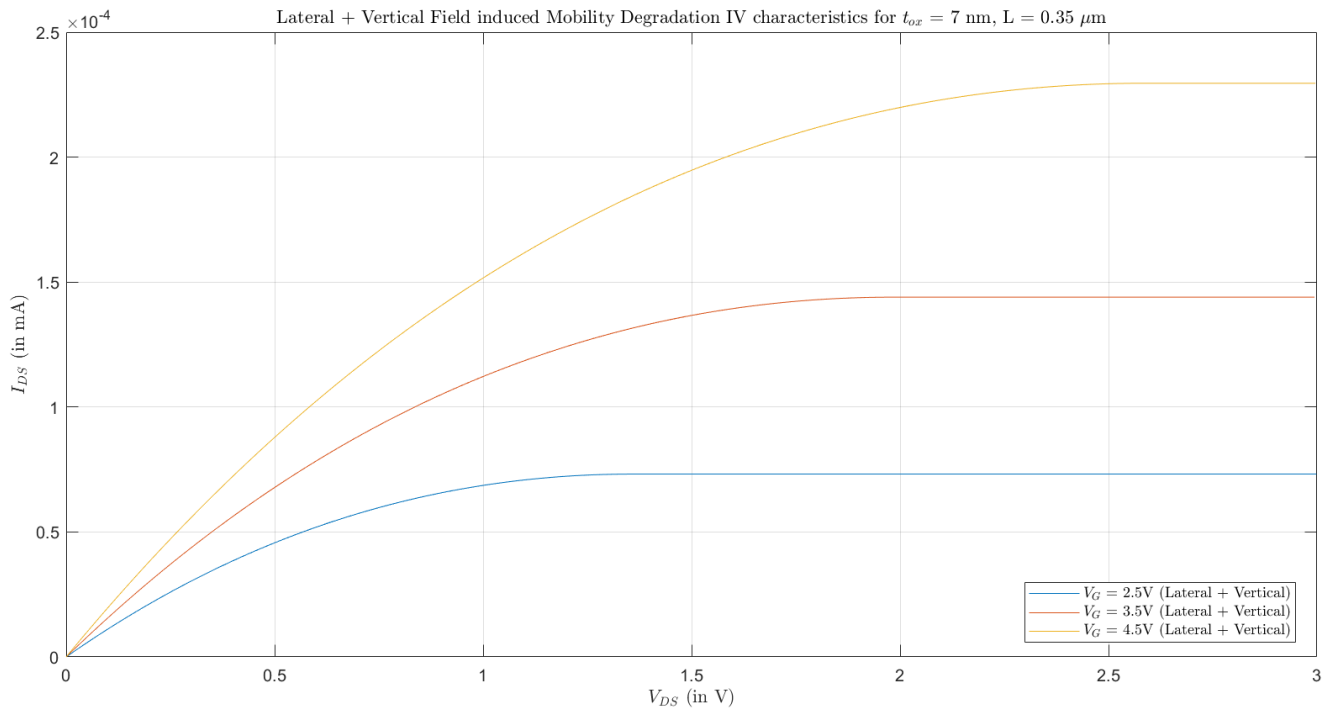


Figure 9: Case 3:  $I_D - V_D$  characteristics for Piecewise model with both lateral and vertical fields induced mobility degradation

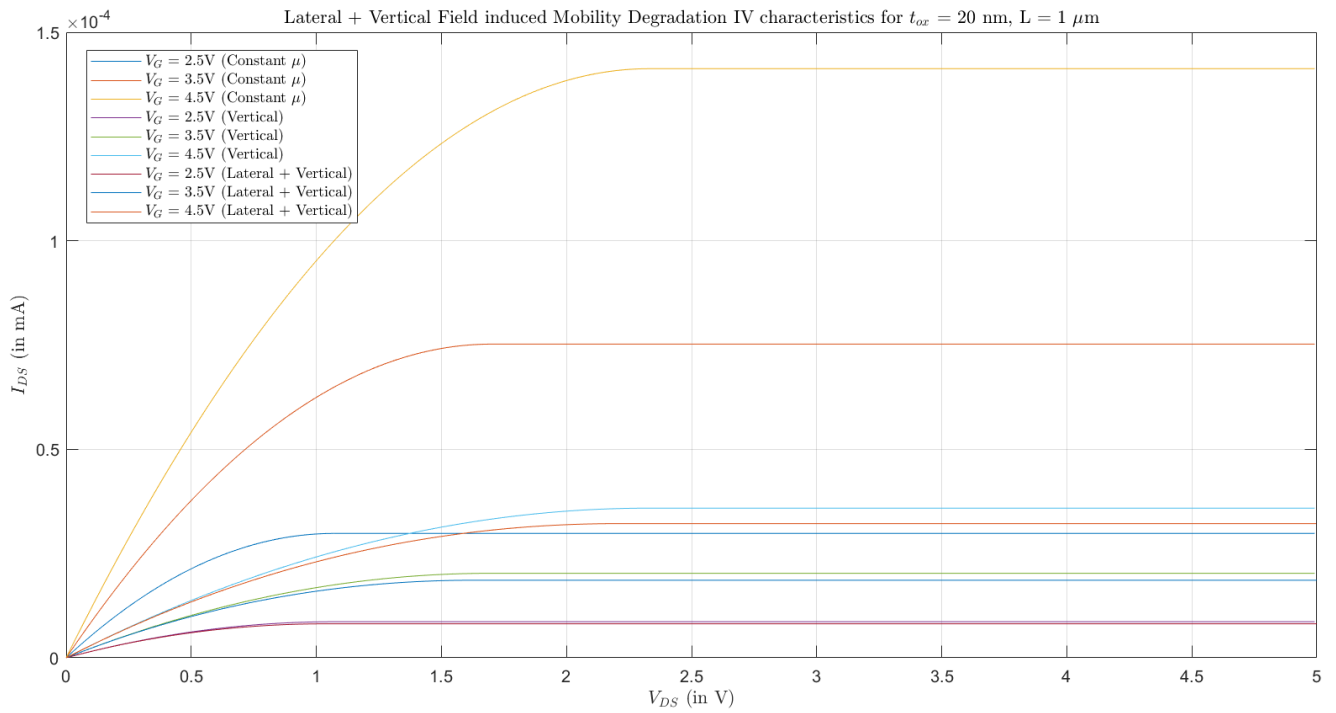


Figure 10: Case 1:  $I_D - V_D$  characteristics for Piecewise model with all plots superimposed

