Current-Voltage Relation

- For $V_{GS} > V_{TN}$ and ***small*** V_{DS}:

$$I_D = k_N \left(V_{GT} V_{DS} - V_{DS}^2 / 2 \right)$$

$V_{GT} = V_{GS} - V_{TN} =$ ***Gate overdrive***

$$k_N = \left(W/L \right) k'_N$$

$=$ ***Device transconductance parameter***

$W/L =$ ***Aspect ratio***

$$k'_N = \mu_n C'_{ox}$$

$$= \textbf{\textit{Process transconductance parameter}}$$

μ_n = ***Channel electron mobility***

- For ***small*** V_{DS}, the V_{DS}^2 term can be ***neglected***
  - ➢ I_D changes ***linearly*** with V_{DS}
    - ***Linear*** (or ***Non-Saturation***) Region
- As $V_{DS}\uparrow$, the ***restraining*** effect of V_{DS}^2 term$\uparrow$
  - ➢ ***Rate of increase*** of I_D with V_{DS} ***slows down***

- For ***inversion channel*** to exist at the ***D end***, ***V_{GD} must be > V_{TN}***
  - ***V_{DS} must be < V_{GT}***
- When ***V_{DS} = V_{GT}***, the ***channel*** is said to be ***pinched-off*** at the ***D end***, and ***I_D does not increase any more***
- This value of V_{DS} is known as the ***drain-to-source saturation voltage*** $V_{DS,sat}$
  - $V_{DS,sat} = V_{GT}$

- For $V_{DS} > V_{DS,sat}$, the ***mode of operation*** is known as ***saturation***
- ***Drain current in saturation***:

$$I_D = \frac{k_N}{2} V_{GT}^2$$

  - ***Obtained from the non-saturation I_D expression by substituting $V_{DS} = V_{GT}$***
  - ***Note that I_D is independent of V_{DS}***
- ***Above equations are valid for $V_{GT} > 3V_T$***

(~ ***80 mV at room temperature***)

The Complete LEVEL 0 Model

$$I_D = k_N\left(V_{GT}V_{DS} - V_{DS}^2/2\right)$$

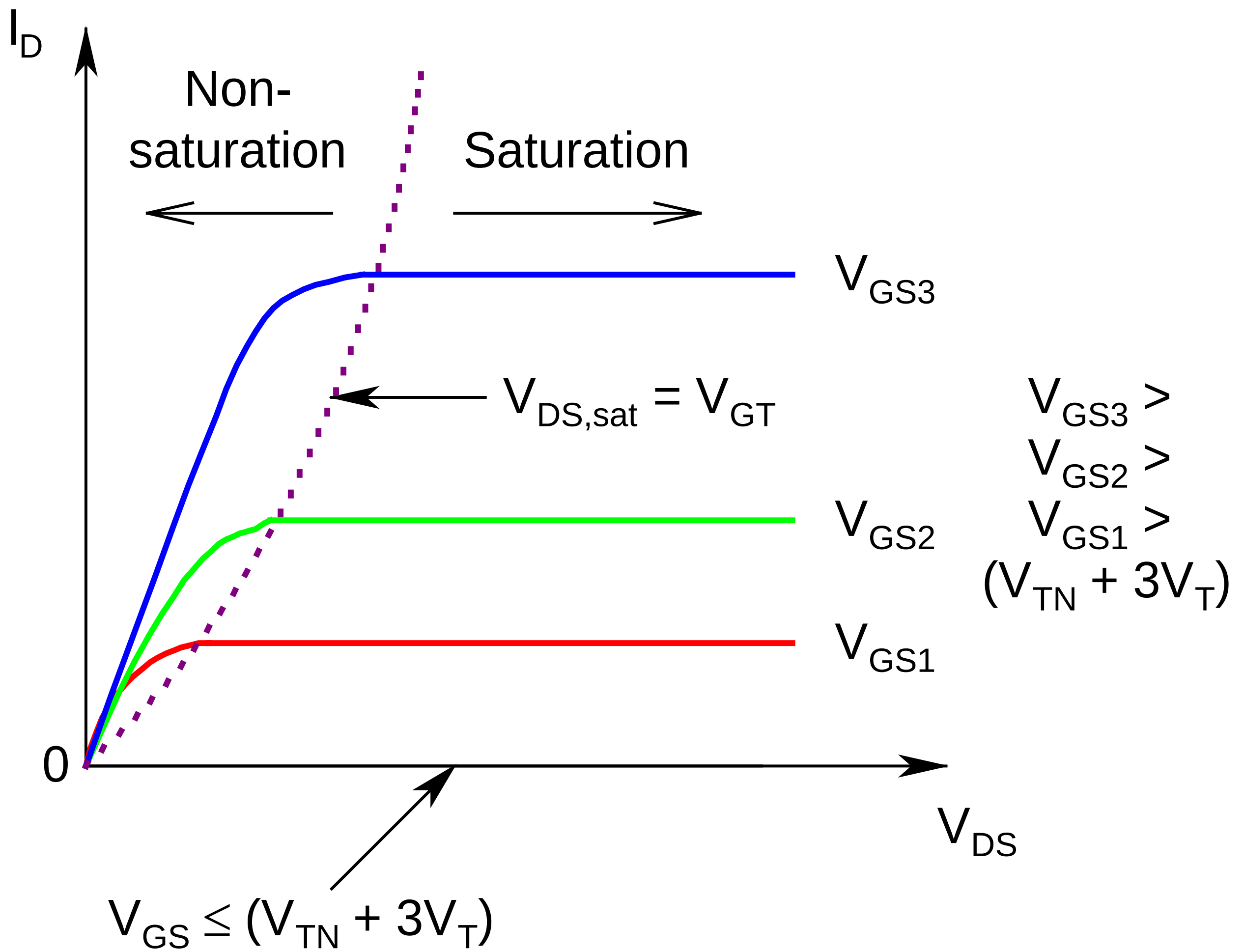
$$\left(\textbf{\textit{linear region}}\ \text{-}\ V_{GT} > 3V_T, V_{DS} < V_{GT}\right)$$

$$= \left(k_N/2\right)V_{GT}^2$$

$$(\textbf{\textit{saturation region}}\ \text{-}\ V_{GT} > 3V_T, V_{DS} \geq V_{GT})$$

$$= 0$$

$$(\textbf{\textit{cutoff region}}\ \text{-}\ V_{GT} \leq 3V_T,\ \textbf{\textit{any}}\ \boldsymbol{V_{DS}})$$



I_D-V_{DS} Characteristics