Lecture9:
MOSFET, triode/saturation

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Triode mode

- Equation
  - A differential equation for $V(x)$

$$I_D = W C_{ox}[V_G - V(x) - V_{TH}]\mu_n \frac{dV}{dx}$$

- Solution
  - Potential

$$V(x) = V_G - V_{TH} - \sqrt{(V_G - V_{TH})^2 - \frac{2I_D}{\mu_n C_{ox} W} x}$$

  - Current

$$I_D = \mu_n C_{ox} \frac{W}{L}\left[(V_G - V_{TH})V_{DS} - \frac{1}{2} V_{DS}^2\right]$$

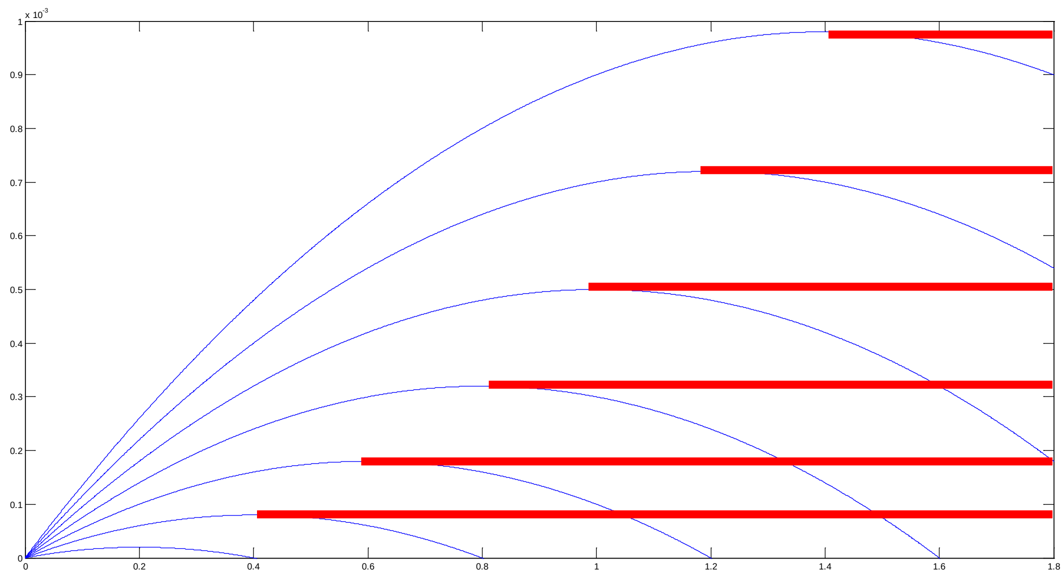
Saturation mode

- Current usually increases as the voltage increases…
- Recall (6.3).

$$Q_{elec} = WC_{ox}[V_G - V(x) - V_{TH}] \tag{6.3}$$

  - What happens when $V(x) = V_G - V_{TH}$?

Current

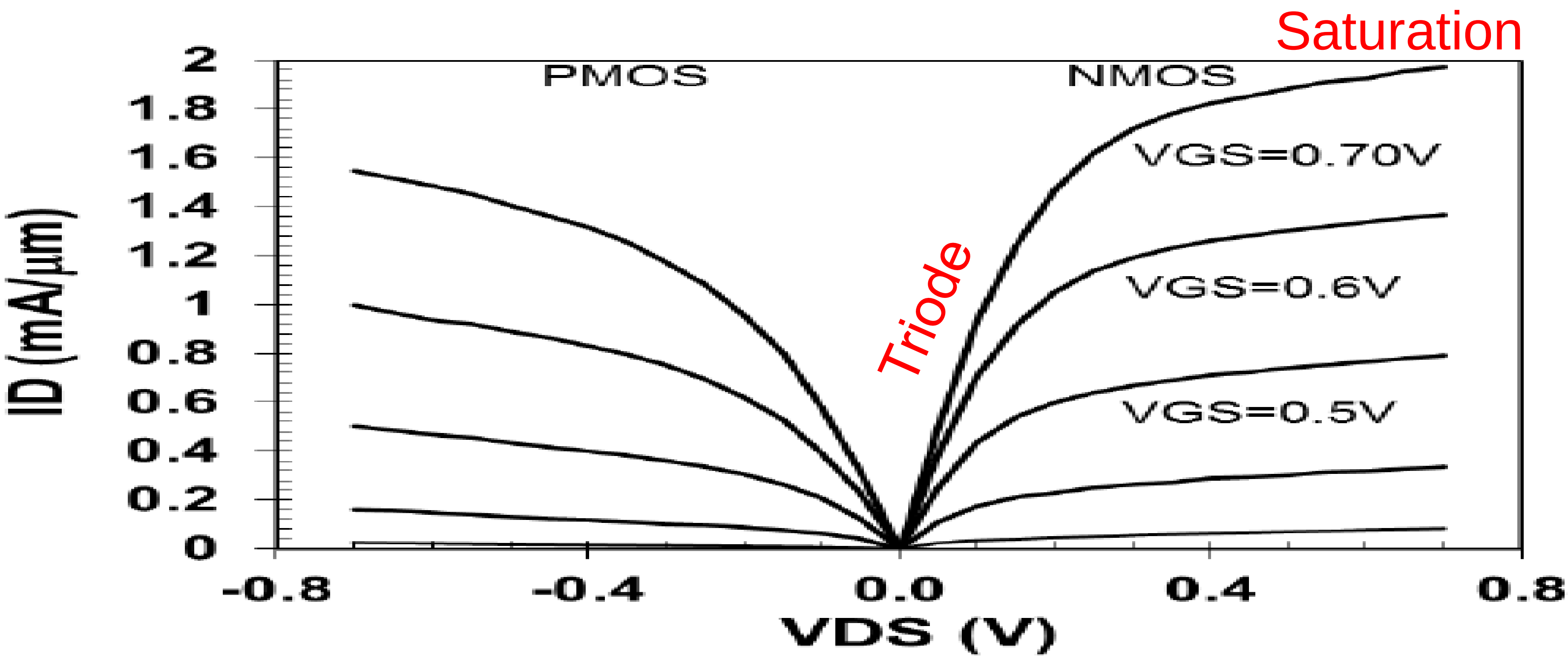


Voltage

🡐 Instead, the current is saturated. (Red lines)

IEDM 2017

- C. Auth et al. (Intel)
  - (Intentionally streched for visibility)
  - Slight increase of I_D in the satruation region



Homework#5 (1)

- Due: 09:00, April 9
- Write a program, which reads a netlist file.
  - Construct a square matrix, whose size is $N \times N$. The matrix is related with the vector in Homework#4.
  - Each row of the matrix represents an equation.

  - In this program, the matrix describes a system:
  - For every element terminal, the terminal current vanishes.
  - For every element terminal, the terminal voltage is equal to the circuit node voltage.
  - For the GND node, the node voltage is zero.
  - For all other circuut nodes, the KCL is applied.

Homework#5 (2)

- (Continued)
  - For example, consider the example in Homework#4. A voltage source and a resistor are found.
  - The matrix is explicitly shown below.

$$
\begin{array}{r}
\text{Currents} \\
\\
\text{Voltages} \\
\\
\text{Currents} \\
\\
\text{Voltages} \\
\\
\text{GND} \\
\text{KCL}
\end{array}
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\times
\begin{bmatrix}
I_1^V \\ I_2^V \\ V_1^V \\ V_2^V \\ I_1^R \\ I_2^R \\ V_1^R \\ V_2^R \\ V_0 \\ V_{in}
\end{bmatrix}
=
\begin{bmatrix}
0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0
\end{bmatrix}
$$

Homework#5 (3)

- Solve the following problems of the mid-term exam in 2017.
  - P25
  - P26
  - P27
  - P28
  - P29
  - P30
  - P31
  - P32
  - P33