VLSI Design EE 523
Spring 2025

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Lecture 7

Topics for lecture 8

- MOS Capacitance model
- Difference between Area capacitance and Perimeter capacitance
- Concept of Lambda λ based design rules
- Area calculation using λ rules and its relation to technology
- Example of MOS Drain Capacitance Calculation
- Variation of typical MOS transistor characteristics due to:
  - Velocity Saturation, Mobility Degradation, Temperature Effects, Tunneling Effect, Geometry Effect, Channel Length Modulation, Body Effect Voltage
- Simple CMOS Inverter – transfer characteristics Vin and Vout
- Noise Margin from these transfer characteristics

Shockley Model for CMOS Transistor

where

$$\beta = \mu C_{ox} \frac{W}{L};\ V_{GT} = V_{gs} - V_t \tag{2.6}$$

EQ (2.10) summarizes the current in the three regions:

$$I_{ds} = \begin{cases} 0 & V_{gs} < V_t & \text{Cutoff} \\ \beta\left(V_{GT} - V_{ds}/2\right)V_{ds} & V_{ds} < V_{dsat} & \text{Linear} \\ \frac{\beta}{2}V_{GT}^2 & V_{ds} > V_{dsat} & \text{Saturation} \end{cases} \tag{2.10}$$

Example 2.1

Consider an nMOS transistor in a 65 nm process with a minimum drawn channel length of 50 nm ($\lambda = 25$ nm). Let $W/L = 4/2\ \lambda$ (i.e., 0.1/0.05 μm). In this process, the gate oxide thickness is 10.5 Å. Estimate the high-field mobility of electrons to be 80 $\text{cm}^2/\text{V}\cdot\text{s}$ at 70 °C. The threshold voltage is 0.3 V. Plot I_{ds} vs. V_{ds} for $V_{gs} = 0$, 0.2, 0.4, 0.6, 0.8, and 1.0 V using the long-channel model.

SOLUTION: We first calculate β.

$$\beta = \mu C_{ox} \frac{W}{L} = \left(80 \frac{\text{cm}^2}{\text{V}\cdot\text{s}}\right)\left(\frac{3.9 \times 8.85 \times 10^{-14}\ \frac{\text{F}}{\text{cm}}}{10.5 \times 10^{-8}\ \text{cm}}\right)\left(\frac{W}{L}\right) = 262 \frac{W}{L} \frac{\text{A}}{\text{V}^2} \tag{2.11}$$

CMOS Output Characteristics

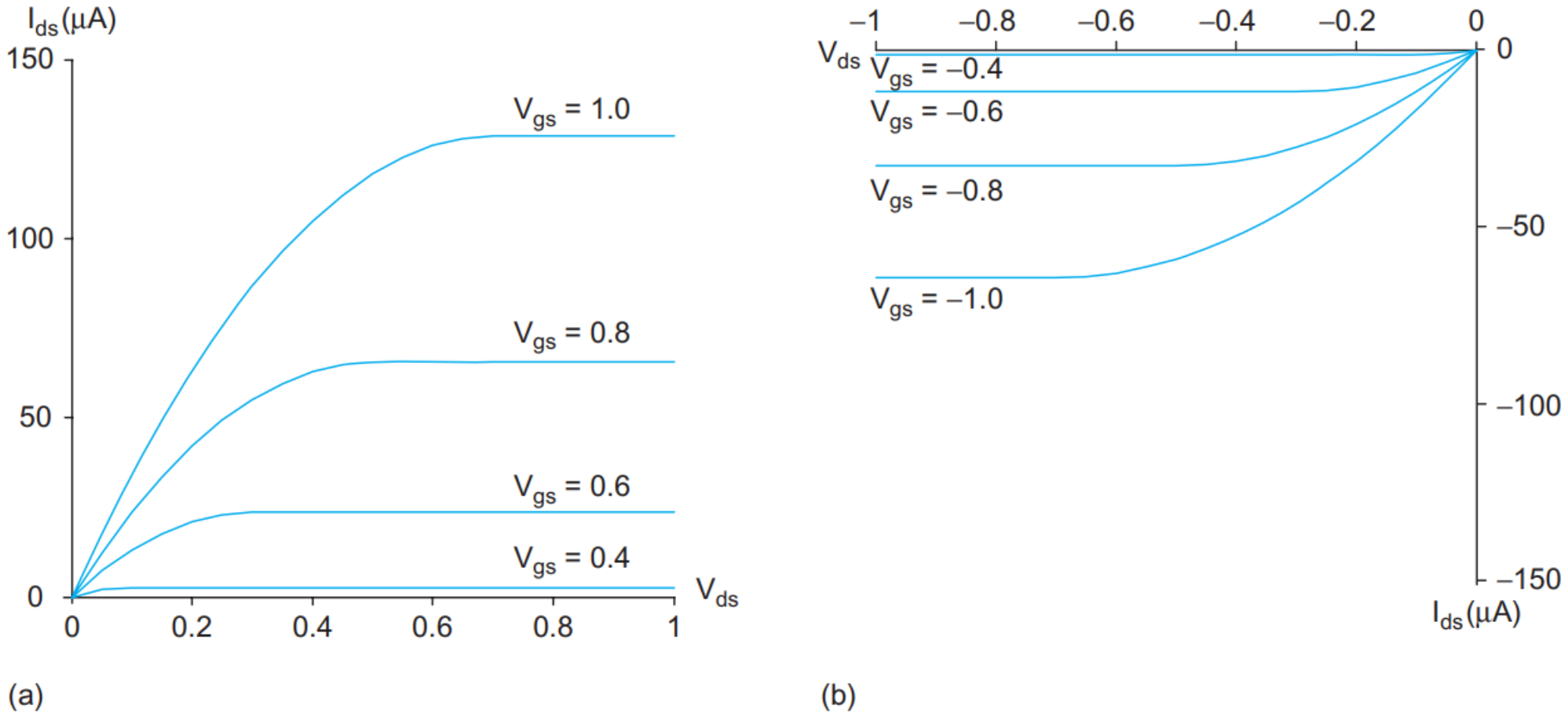

FIGURE 2.7 I-V characteristics of ideal 4/2 λ (a) nMOS and (b) pMOS transistors

Reading and Book

- Textbook can be downloaded online “CMOS VLSI Design by Weste and Harris, 4th Edition”
- Readings from starting portion of Chapter 2