Sharif University of Technology
Department of Computer Engineering

Low Power
Digital System Design

Power Components (Cont.)

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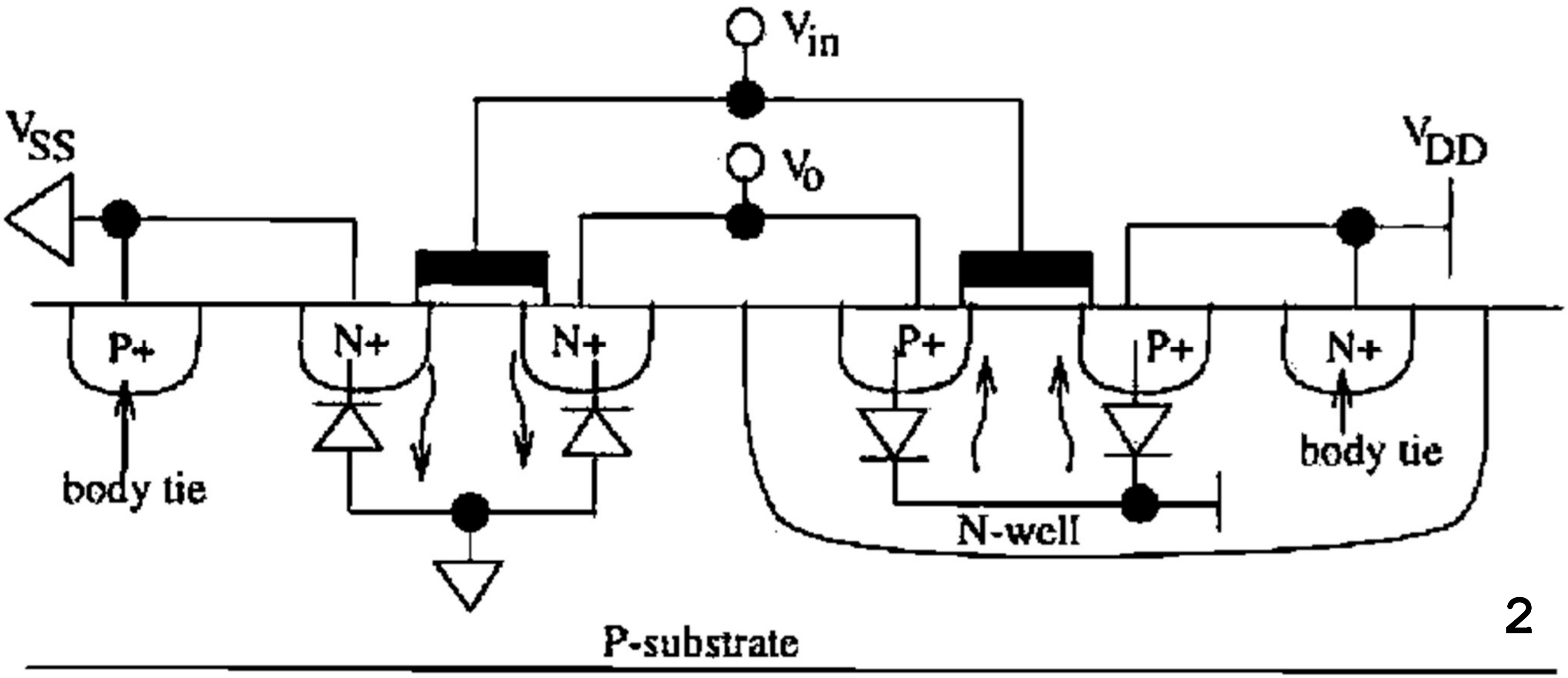
Reverse Leakage Power

- The reverse leakage occurs when the parasitic diodes are reversely biased.

$$I_D = A \cdot J_S (e^{\frac{qV_{bias}}{KT}} - 1)$$



Reverse Leakage Power

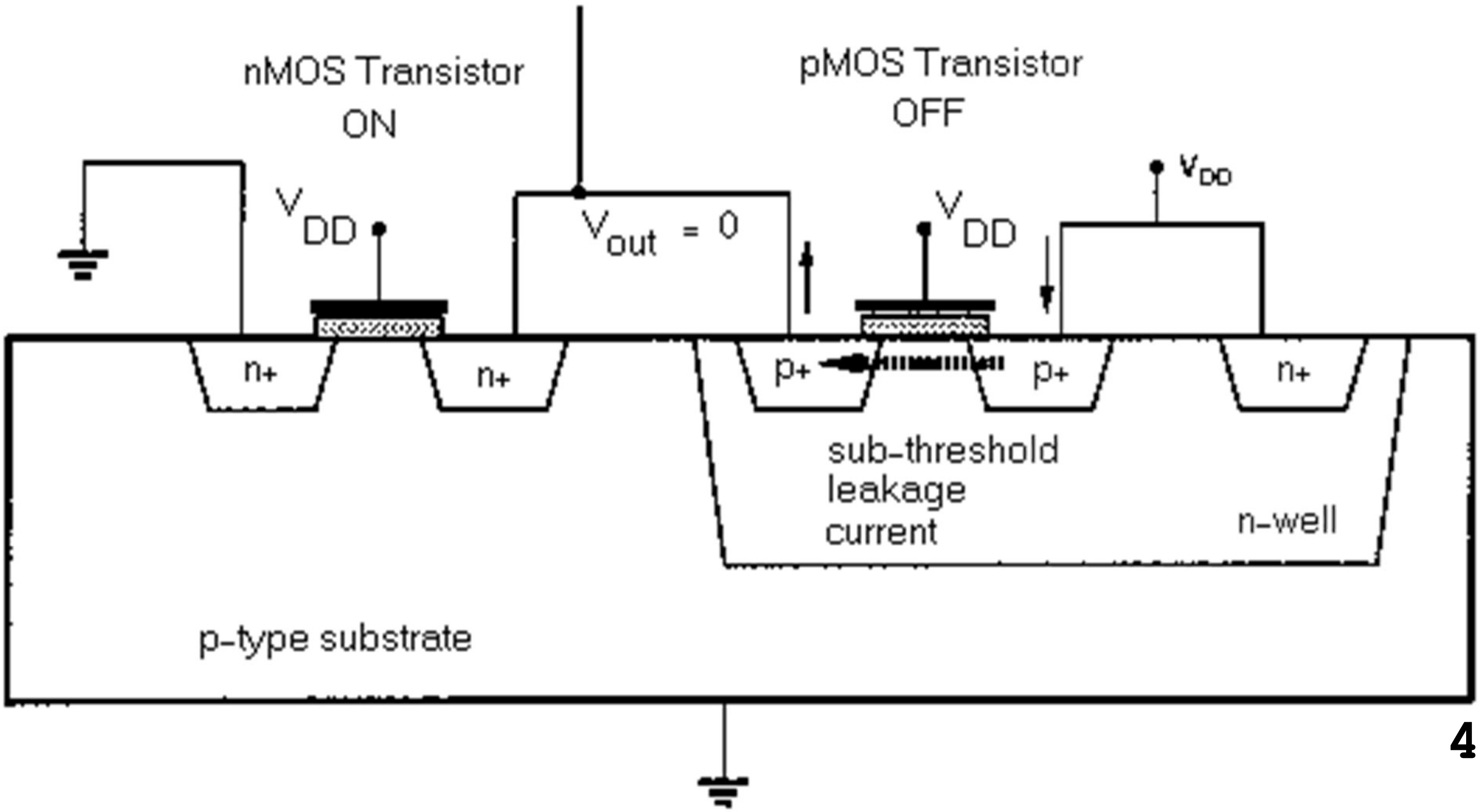
$$I_D = A \cdot J_S \left(e^{\frac{qV_{bias}}{KT}} - 1\right)$$

- A *Junction Area*
- J_S Reverse saturation current density
- q Electron's charge
- K Boltzmann constant
- T Temprature

J_S increases quite significantly with temperature.

Sub-threshold Leakage Power

- **A MOS transistor in the sub-threshold region behaves similar to a bipolar device.**



Sub-threshold Leakage Power

$$I(Sub-threshold) = \beta(1-\eta)V_T^2 \exp(\frac{V_{GS}-V_{th}}{\eta V_T})[1-\exp(-\frac{V_{DS}}{V_T})]$$

where $V_T = \frac{KT}{q}$

- Sub-threshold leakage power is the dominant static power component.
- Increasing almost 20 times for each new fabrication technology.

Summary

$$P_{SW} = \alpha C_L V_{DD}^2 f$$

$$P_{SC} = \alpha \cdot \frac{\beta}{12} (V_{DD} - 2V_t)^3 \cdot t_{rf} \cdot f$$

$$P_{SUB} = V_{DD} \cdot \beta (1-\eta) V_T^2 \exp(\frac{V_{GS} - V_{th}}{\eta V_T})[1 - \exp(-\frac{V_{DS}}{V_T})]$$

$$P_{\mathrm{Re}verse} = V_{DD} \cdot A \cdot J_S$$

- In LPD, we consider the following factors:

Activity	Supply Voltage
Load Capacitance	Frequency
Rise time/fall time	Process Technology
Transistor size	Threshold Voltage
Temperature	Scaling
Design Complexity	

Static Biasing Power

- Dissipated in non-CMOS families:
  - e.g., nMOS, Pseudo nMos, …
- There are some circuits where static biasing can be beneficial in reducing the total power:
  - applicable for higher-frequency circuits.
- There is usually a large area savings as well.