Sharif University of Technology
Department of Computer Engineering

Embedded System Design

Interplay of Low Energy and Fault Tolerance Techniques (22)

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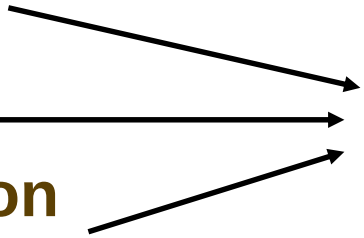
Embedded System Requirements

- Real-time computing
- High reliability
- Low energy consumption



Conflicting objectives

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System Level Low Energy Design

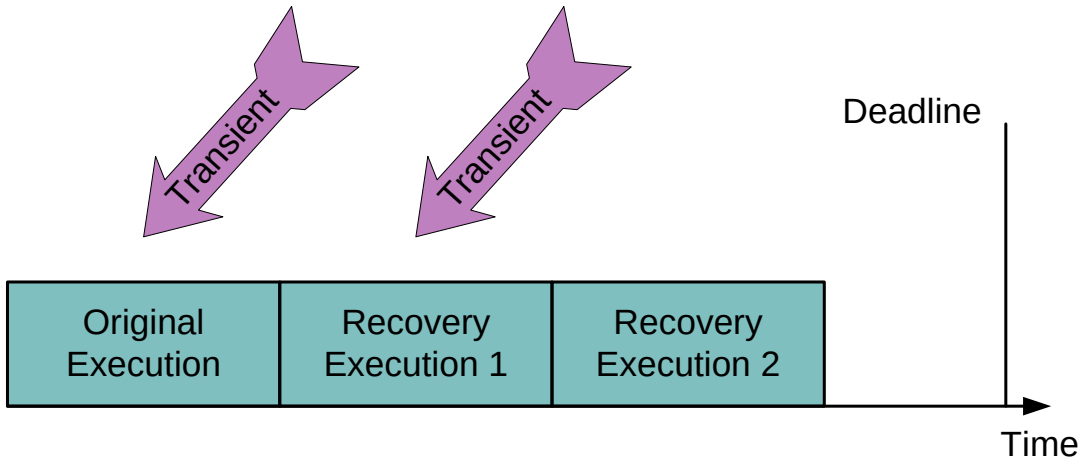
- DVS (Dynamic Voltage Scaling):
  - lowering V_{dd} and F
- ABB (Adaptive Body Biasing):
  - lowering *Vbs*
- DPM (Dynamic Power Management):
  - turning off the unused components

Energy Consumption

$$E_{cyc} = \underbrace{C_{eff} V_{dd}^{2}}_{Dynamic\ \ Energy} + \underbrace{\frac{L_g}{f(V_{dd})}\left(V_{dd} K_3 e^{K_4 V_{dd}} e^{K_5 V_{bs}} + |V_{bs}| I_j\right)}_{Static\ \ Energy}$$

Reliability Problems in DVS-Enabled Systems

- **Increased fault rate and error rate**
  - **Reduced Noise Margin**
  - **Reduced Critical Charge**
    - **More susceptible to SEUs**
- **Increased execution time** $\rho = 1 - e^{-\lambda \cdot T_{exe}}$
- **Reduced slack time in real time systems**



Energy Problem in FT Systems

- **Fault Handling** requires **redundancy.**

- **Redundancy is simply the** addition **of**
  - **Time**
  - **Hardware**
  - **Software**
  - **Information**

  beyond **what is needed for normal system operation.**

Example 1: Low Precision Redundant Units