CDA5106 - Advanced Computer Architecture
Final Exam Review

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1 Module 1: High-Performance Microprocessor Architecture

1.1 Module 1.2: Power Wall and Dennard Scaling

1.1.1 Notes

- energy: ability of a physical system to do work on other physical systems (unit: joule)
- power: rate at which energy is transformed (unit: watt; 1 watt = 1 joule delivered per second)
  - power = $V \cdot I$ (V = voltage, I = current)
- for capacitors:
  - energy stored = $0.5 \cdot C \cdot V^2$ (C = capacitance, V = voltage)
  - if a capacitor is drained at a frequency of f per second: power = $\frac{energy}{second} = 2 \cdot 0.5CV^2 = CV^2$
- Power wall problem
  - $P_{dyn} = ACV^2 f$
  - A: fraction of gates actively switching
  - C: total capacitance of all gates
  - V: supply voltage
  - f: frequency of switching
- Power wall fundamentals
  - max frequency vs. threshold voltage:
  - $f_{max} = c \cdot \frac{(V - V_{thd})^{1.3}}{V}$
- **Dennard Scaling Example (old)**
  - if gate length (transistor size) scales by $S = 0.7$ (both length and width), then:
  - capacitance scales by $S = 0.7$
  - original area scales by $S^2 = 0.5$
  - number of transistors scales by $\frac{1}{S^2} \approx 2$
  - supply voltage (V) scales by $S = 0.7$
  - frequency (f) scales by $\frac{1}{S} = 1.4$
  - then, **dynamic power** $P_{dyn} = ACV^2 f$
  - and **new dynamic power** $P'_{dyn} = A'C'V'^2 f'$
  - $P'_{dyn} = (2A)(0.7C)(0.7V)^2(1.4f) \approx 1 \cdot ACV^2 f = P_{dyn}$
- **Post Dennard Scaling example (new)**
  - capacitance scales by $S = 0.7$
  - number of transistors scales by $\frac{1}{S^2} = 2$

- supply voltage (V) cannot scale without also scaling threshold voltage (V_{thd}), and doing that increases static power exponentially
- frequency (f) scales by $\frac{1}{S} = 1.4$
- result: dynamic power doubles every generation
- $P_{dyn} = ACV^2f$
- $P'_{dyn} = A'C'V'^2f' = (2A)(0.7C)(1 \cdot V)^2(1.4f) \approx 2 \cdot P_{dyn}$

1.1.2 Exercises