PERFORMANCE AND ENERGY

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Overview

- Homework 1 due on Jan 17th (midnight)
- TA office hours were posted
  - One/two more TAs may be added
- This lecture
  - Amdal's Law
  - Energy and power
  - Instruction set architecture (ISA)

Recall: Principles of Comp. Design

- Designing better computer systems requires better utilization of resources
  - Parallelism
    - Multiple units for executing partial or complete tasks
  - Principle of locality (temporal and spatial)
    - Reuse data and functional units
  - Common Case
    - Use additional resources to improve the common case
    - 10% of the program accounts for 90% of execution time (90-10 rule)

Amdahl's Law

- The law of diminishing returns

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$$\boxed{\text{Speedup}_{\text{overall}} = \frac{\text{Execution time}_{\text{old}}}{\text{Execution time}_{\text{new}}} = \frac{1}{(1 - \text{Fraction}_{\text{enhanced}}) + \dfrac{\text{Fraction}_{\text{enhanced}}}{\text{Speedup}_{\text{enhanced}}}}}$$

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$f=0.4 \quad s=10$

Speedup = 1 / (0.6 + 0.4/10) = 1/0.64 = 1.5625

CPI example

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- Same ISA
- Which is faster, and by how much?

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$$\text{CPU Time}_A = \text{Instruction Count} \times \text{CPI}_A \times \text{Cycle Time}_A$$

$$= I \times 2.0 \times 250\text{ps} = I \times 500\text{ps}$$

A is faster…

$$\text{CPU Time}_B = \text{Instruction Count} \times \text{CPI}_B \times \text{Cycle Time}_B$$

$$= I \times 1.2 \times 500\text{ps} = I \times 600\text{ps}$$

$$\frac{\text{CPU Time}_B}{\text{CPU Time}_A} = \frac{I \times 600\text{ps}}{I \times 500\text{ps}} = 1.2$$

…by this much

Measuring Performance

- What program to use for measuring performance?
- Benchmarks Suites
  - A set of representative programs that are likely relevant to the user
  - Examples:
    - SPEC CPU 2006: CPU-oriented programs (for desktops)
    - SPECweb: throughput-oriented (for servers)
    - EEMBC: embedded processors/workloads

SPEC CPU Benchmark

- Programs used to measure performance
  - Supposedly typical of actual workload
- Standard Performance Evaluation Corp (SPEC)
  - Develops benchmarks for CPU, I/O, Web, …
- SPEC CPU2006
  - Elapsed time to execute a selection of programs
    - Negligible I/O, so focuses on CPU performance
  - Normalize relative to reference machine
  - Summarize as geometric mean of performance ratios
    - CINT2006 (integer) and CFP2006 (floating-point)

$$\sqrt[n]{\prod_{i=1}^{n} Execution\ time\ ratio_i}$$

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- Power = Voltage x Current (P = VI)
  - Instantaneous rate of energy transfer (Watt)
- Energy = Power x Time (E = PT)
  - The cost of performing a task (Joule)

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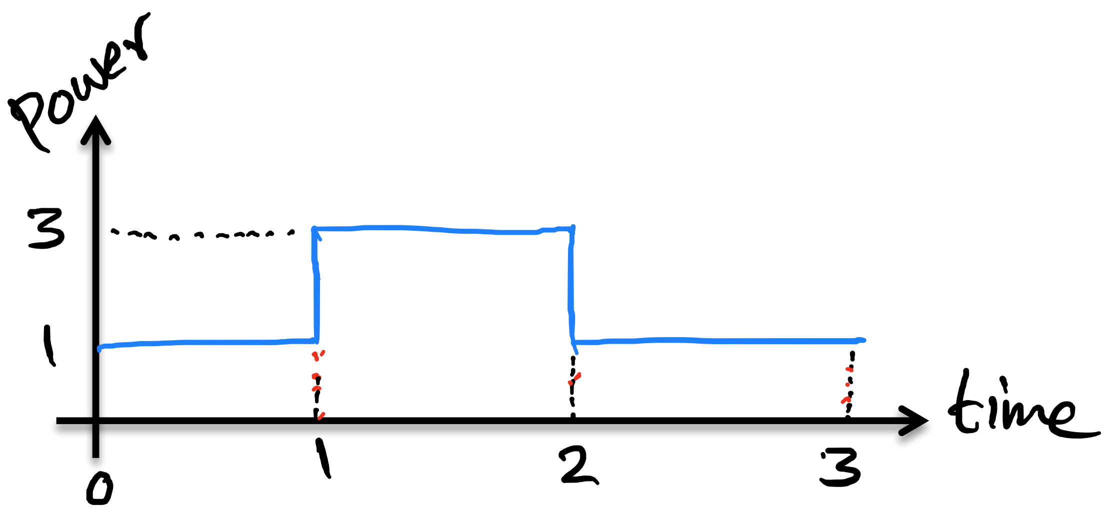

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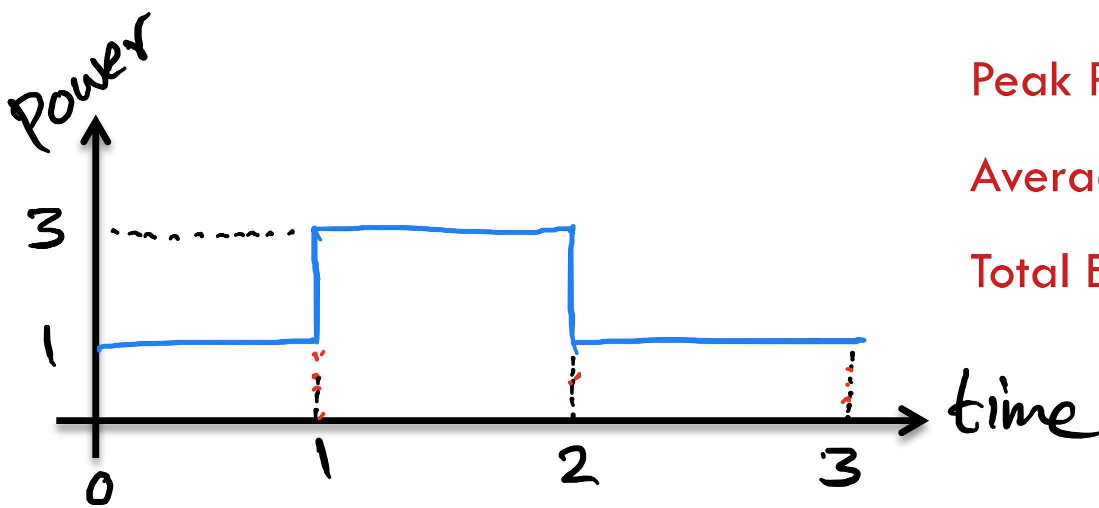

Peak Power = 3W

Average Power = 1.66W

Total Energy = 5J

CPU Power and Energy

- All consumed energy is converted to heat
  - CPU power is the rate of heat generation
  - Excessive peak power may result in burning the chip
- Static and dynamic energy components
  - $\text{Energy} = (\text{Power}_{\text{Static}} + \text{Power}_{\text{Dynamic}}) \times \text{Time}$
  - $\text{Power}_{\text{Static}} = \text{Voltage} \times \text{Current}_{\text{Static}}$
  - $\text{Power}_{\text{Dynamic}} \propto \text{Capacitance} \times \text{Voltage}^2 \times (\text{Activity} \times \text{Frequency})$