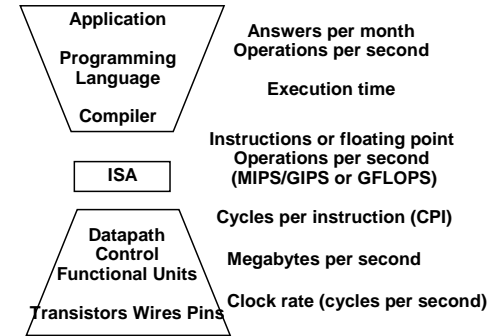


Last Class ...

- Loop fusion
- Loop unrolling
- Gcc compiler optimizations
- List scheduling algorithm

Metrics of Performance



Performance Metrics

- Throughput
- Execution time
- Instruction count
- Instruction rate (MIPS/GIPS)
- Cycles per instruction (CPI)
- Clock cycle time
- Clock rate – inverse of clock cycle time

Relating Performance Metrics

- CPU Time = Instructions X Average CPI X Cycle time

	Instr. Count	Avg. CPI	Clock rate
Program	x		
Compiler	x	X	
ISA	x	X	
Organization		X	X
Technology			X

How To Evaluate Performance

- Benchmarking
 - Evaluate different systems or changes to a single system
 - Represent a large class of important programs so as to provide a target to improve performance
 - Choice of benchmarks important

Programs to Evaluate Processor Performance

- Microbenchmarks – stress test different aspects of the system
- Synthetic benchmarks – attempt to match average instruction mixes of real workloads, e.g., Whetston, Dhrystone
- Kernels – time critical excerpts of programs, e.g., Livermore loops
- Real programs – e.g., gcc, spice
 - See www.spec.org (Standard Performance Evaluation Corporation)
 - Emphasizes speedup, throughput, reproducibility of results
 - Constantly updated (SPEC89, SPEC92, SPEC95, SPEC2000, SPEC2006, ...)

Averaging/Summarizing Performance

- Arithmetic (or weighted arithmetic) mean of time-based metric tracks execution time
- Harmonic mean (or weighted harmonic mean) of rates (e.g., instructions per second) tracks execution time
- Normalized execution time is handy for scaling performance (e.g., time on reference machine/time on measured machine)
 - But, use geometric mean to average normalized execution time

Amdahl's Law

- Speedup limited by the part of the program that has not been optimized/enhanced
- Suppose enhancement E accelerates a fraction F of the task by a factor S and the remainder of the task is unaffected
 - Execution time(with E) = $((1-F)+F/S) \times \text{ExTime}(\text{without E})$
 - Speedup(with E) = $\text{ExTime}(\text{without E}) / \text{ExTime}(\text{with E})$