Storage Device Hierarchy

* Regs
* L1 cache
* L2 cache
* L3 cache
* Main Memory
* Local Secondary Storage
* Remote Secondary Storage

Computer system

* A diagram of assembly program

  Description automatically generated

Relative Performance equation

* Performance = 1/Execution\_Time
* “X is *n* time faster then Y”
  + A equation with black text

    Description automatically generated
* Example
  + Time taken to run a program
    - 10s on A, 15s on B
    - Execution\_TimeB / Execution\_TimeA
      * =15s/10s = 1.5
    - A is 1.5 times faster than B

CPU Time

* CPU Time = CPU Clock Cycles \* Clock Cycle Time = CPU Clock Cycles / Clock Rate
* Performance Improved by
  + Reducing number of clock cycles
  + Increasing clock rate
  + Hardware designer must often trade off clock rate against cycle count
* Example
  + Computer A: 2GHz clock, 10s CPU Time
  + Designing Computer B
    - Aim for 6s CPU time
    - Can do faster clock but causes 1.2x clock cycles
  + How fast mush Computer B clock be?
    - Clock Rate B = Clock Cycles B/ CPU Time B
      * = (1.2\* Clock Cycles A)/ 6s
    - Clock Cycles A = CPU Time A\* Clock Rate A
      * = 10s\*2GHz = 20\*10^9
    - Clock Rate B = (1.2\*20\*10^9)/6s
      * (24\*10^9)/6s
        + 4GHz

Instruction Count and CPI

* Clock Cycles = Instruction Count \* Cycles per Instruction
* CPU Time = Instruction Count \* CPI \* Clock Cycles Time
  + = Instruction Count \* CPI / Clock Rate
* Instruction Count for a program
  + Determined by program, ISA and compiler
* Average Cycles per instruction
  + Determined by CPU hardware
  + If different instruction have different CPI
    - Average CPU affected by instruction mix

CPI Example

* Computer A: Cycle Time = 250ps, CPI = 2.0
* Computer B: Cycle Time = 500ps, CPI = 1.2
* Same ISA
* Which is Faster and by how much?
  + CPU Time A = Instruction Count \* CPI A \* Cycle Time A
    - = I \* 2.0 \* 250ps = I\*500ps
    - A is faster
  + CPU Time B = Instruction Count \* CPI B \* Cycle Time B
    - = I \* 1.2 \* 500ps = I\*600ps
  + CPU Time B / CPU Time A
    - (I\*600ps)/(I\*500ps) = 1.2
      * A is faster by 1.2

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**ADDRESSES MUST BE A MULTIPLE OF 4: A[8] = 32($s0)**