Building Blocks

CPUs, Memory and Accelerators

Dr Mark Bull, EPCC
markb@epcc.ed.ac.uk

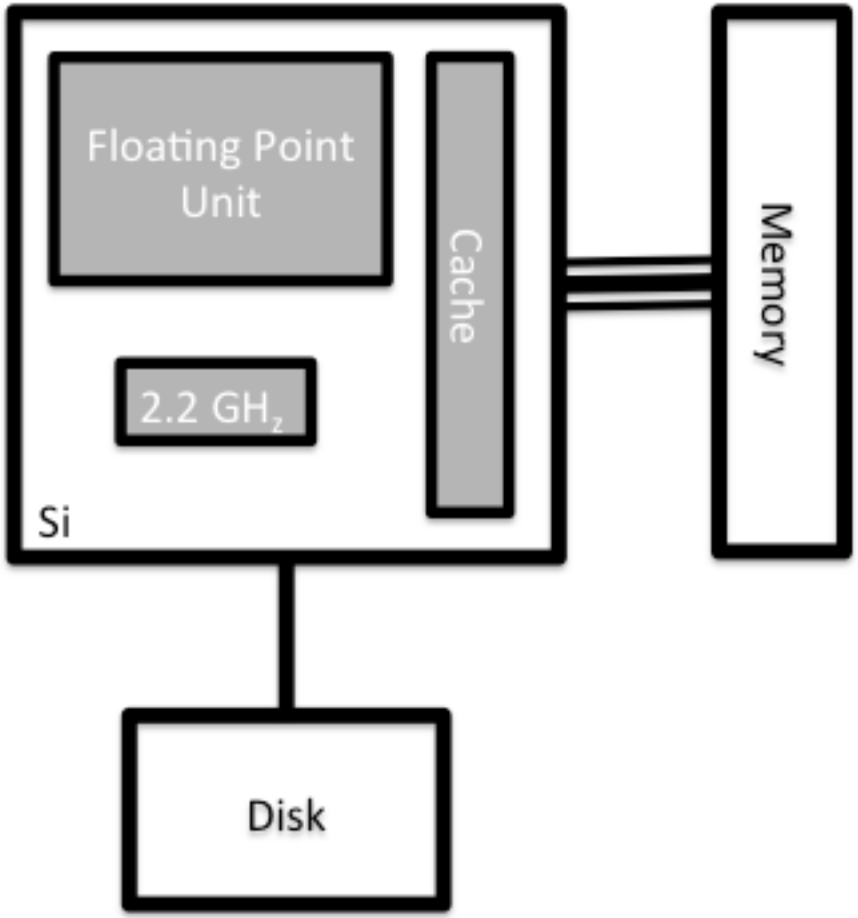
Outline

- Computer layout
  - CPU and Memory
  - What does performance depend on?
  - Limits to performance
- Silicon-level parallelism
  - Single Instruction Multiple Data (SIMD/Vector)
  - Multicore
  - Symmetric Multi-threading (SMT)
- Accelerators (GPGPU and Xeon Phi)
  - What are they good for?

Computer Layout

How do all the bits interact and which ones matter?

Anatomy of a computer



Performance

- The performance (time to solution) on a single computer can depend on:
  - Clock speed – how fast the processor is
  - Floating point unit – how many operands can be operated on and what operations can be performed?
  - Memory latency – how fast can we access the data?
  - Memory bandwidth – how much data can we access in one go?
  - Input/Output (IO) to storage – how quickly can we access persistent data (files)?

Performance (cont.)

- Application performance often described as:
  - Compute bound
  - Memory bound
  - IO bound
  - (Communication bound – more on this later…)

Limits to performance

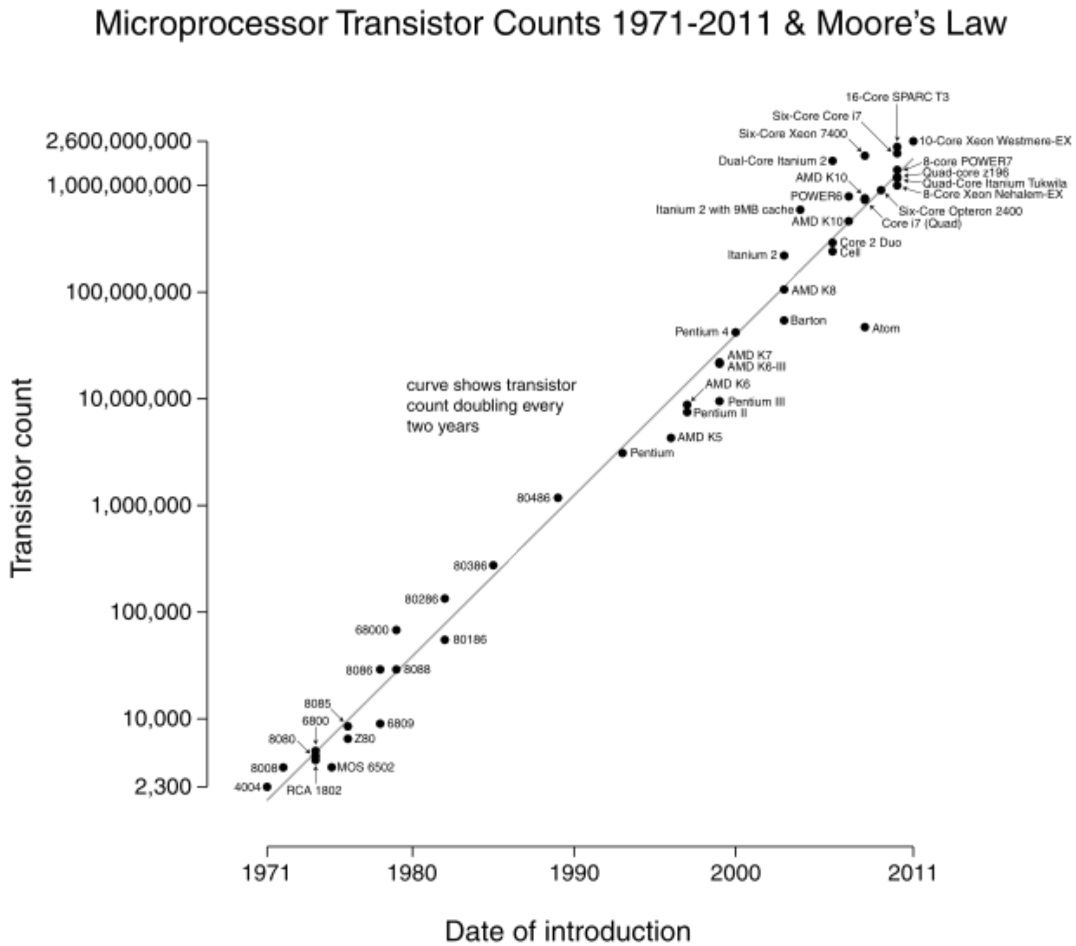
- Scientific simulation and modelling drive the need for greater computing power.
- Single systems can not be made that had enough resource for the simulations needed.
  - Making faster single chip is difficult due to both physical limitations and cost.
  - Adding more memory to single chip is expensive and leads to complexity.
- Solution: parallel computing – divide up the work among numerous linked systems.
  - HPC has become synonymous with *parallel computing*

Silicon-level parallelism

What does Moore's Law mean anyway?

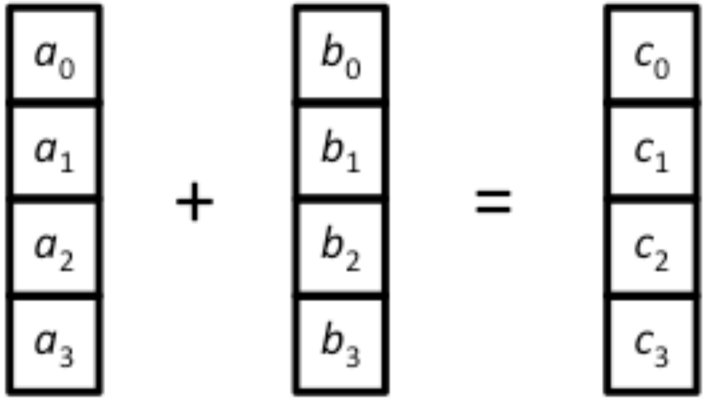
Moore’s Law

- Number of transistors doubles every 18 months
- What to do with all the extra silicon real estate?
  - Wider FPU, multicore and cache

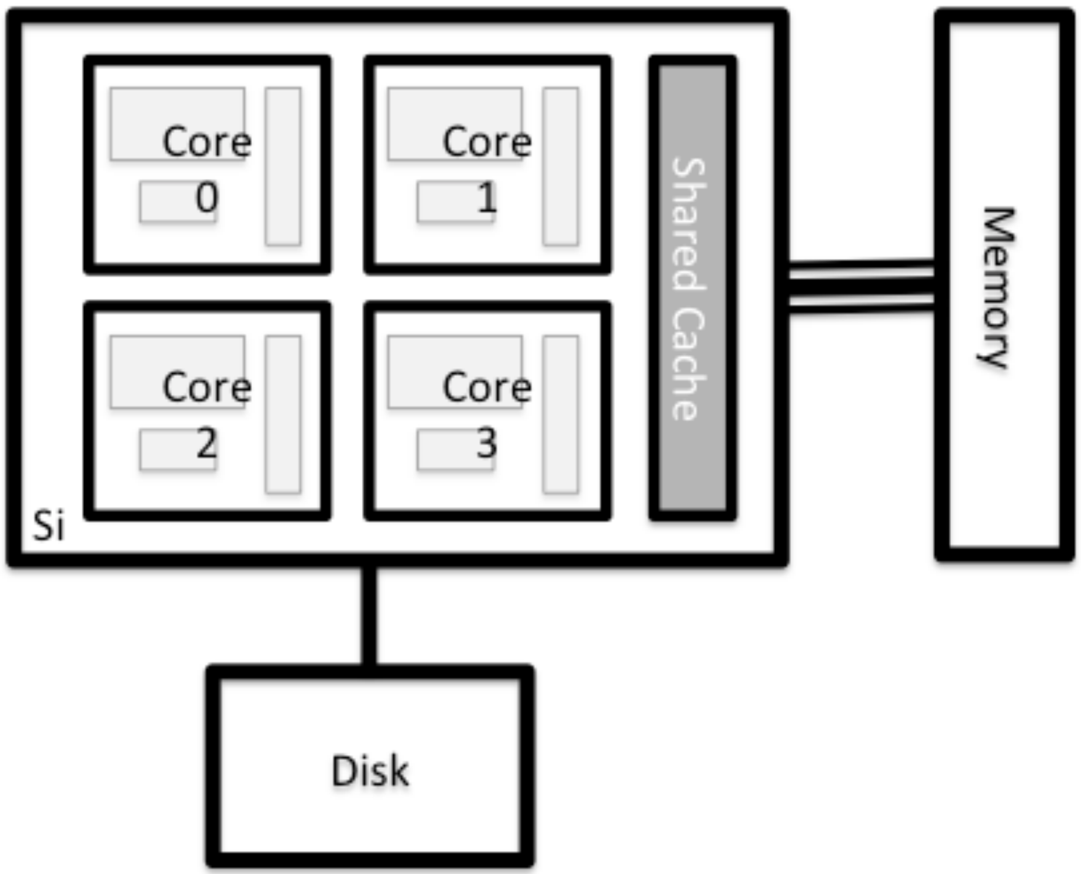


Single Instruction Multiple Data (SIMD)

- For example, vector addition:



Multicore



Symmetric Multi-threading (SMT)

- Some hardware supports running more processes than there are physical cores
- Known as *Symmetric Multi-threading (SMT)*
- Threading in this case can be a misnomer as it can refer to processes as well as threads
    - These are hardware threads, not software threads.
    - Intel Xeon supports 2-way SMT
    - IBM BlueGene/Q 4-way SMT

Chip types and manufacturers

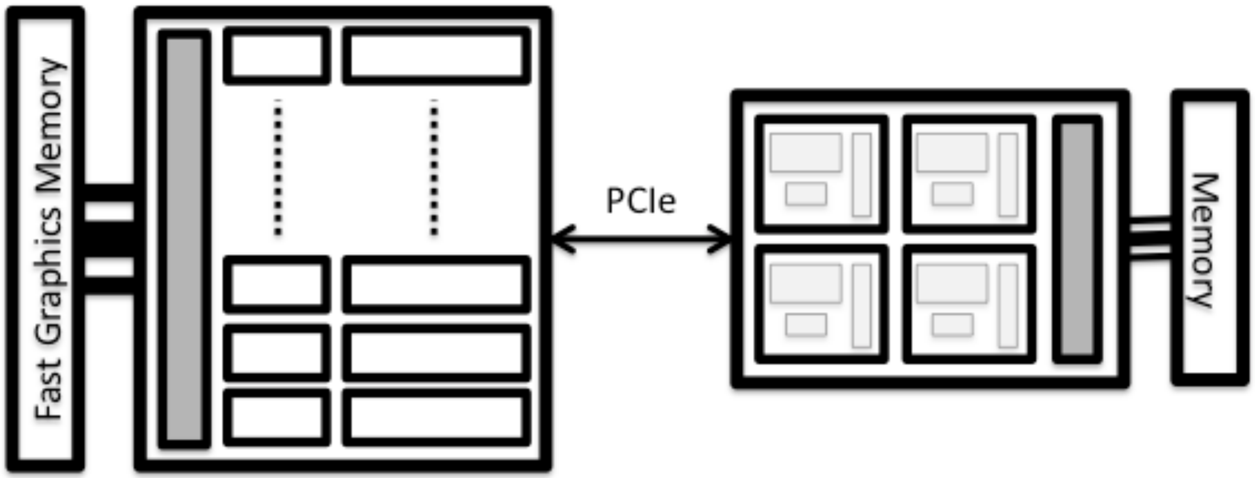
- x86 – Intel and AMD
  - "PC" commodity processors, SIMD (SSE, AVX) FPU, multicore, SMT (Intel), Intel currently dominate the HPC space.
- Power – IBM
  - Used in high-end HPC, high clock speed (direct water cooled), SIMD FPU, multicore, SMT, not as important anymore.
- PowerPC – IBM BlueGene
  - Low clock speed, SIMD FPU, multicore, high level of SMT.
- SPARC – Fujitsu
- ARM – Lots of manufacturers
  - Not yet relevant to HPC (weak FP Unit)

Accelerators

Go-faster stripes

Anatomy

- An *Accelerator* is a additional resource that can be used to off-load heavy floating-point calculation
  - It is an additional processing engine that is attached to the standard processor
  - It has its own floating point units and memory



Summary - What is automatic?

- Which features are managed by hardware/software and which does the user/programmer control?
  - Cache and memory – automatically managed
  - SIMD/Vector parallelism – automatically produced by compiler
  - SMT – automatically managed
  - Multicore parallelism – manually specified by the user
  - Use of accelerators – manually specified by the user