CSCI-GA.3033-008

Graphics Processing Units (GPUs): Architecture and Programming

Lecture 1: Gentle Introduction to GPUs

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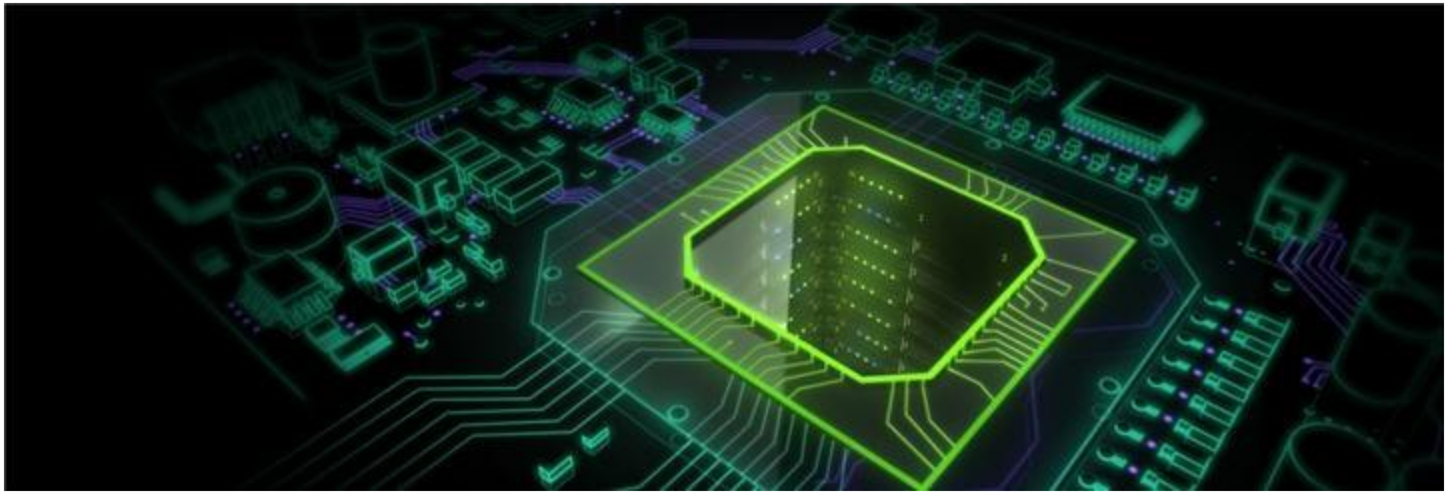


Who Am I?

- Mohamed Zahran (aka Z)
- Computer architecture/OS/Compilers Interaction
- http://www.mzahran.com
- Office hours: Tue 4:30-6:30 pm
  - Or by appointment
- Room: WWH 320
- Course web page:

http://cs.nyu.edu/courses/fall13/CSCI-GA.3033-008/index.html

Formal Goals of This Course

- Why GPUs
- GPU Architecture
- GPU-CPU Interaction
- GPU programming model
- Solving real-life problems using GPUs

Informal Goals of This Course

- To get more than an *A*
- To learn GPUs and enjoy it
- To use what you have learned in *MANY* different contexts
- To have a feeling about how hardware and software evolve and interact

The Course Web Page

- Lecture slides
- Info about mailing list, labs, … .
- Useful links (manuals, tools, book errata, …)

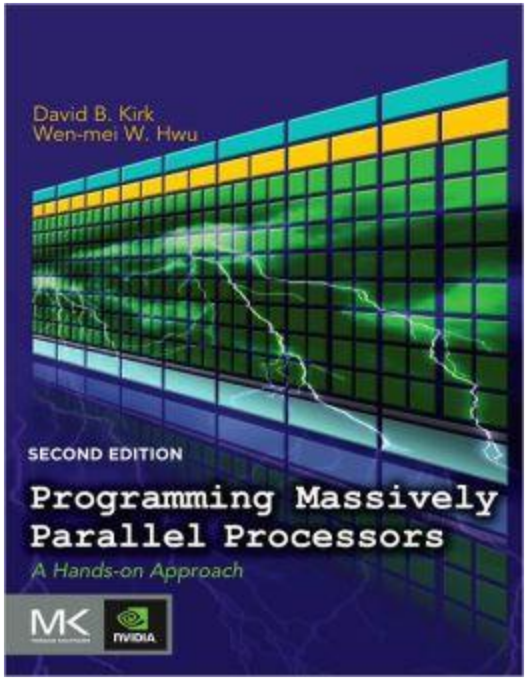
The Textbook

Programming Massively Parallel Processors:
A Hands-on Approach

By

David B. Kirk & Wen-mei W. Hwu

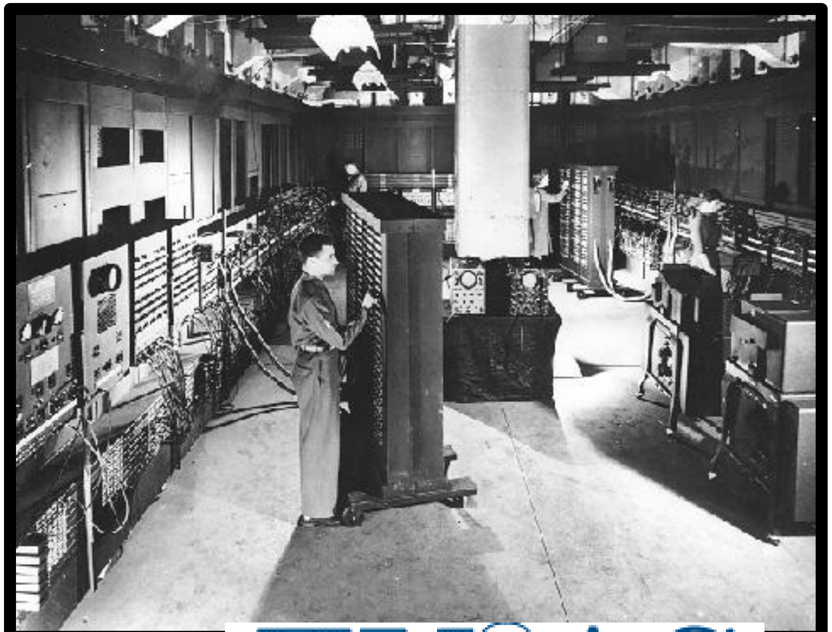
2nd Edition



Grading

- Homework assignments : 20%
- Project : 20%
- Programming assignments : 20%
- Final : 40%

Computer History

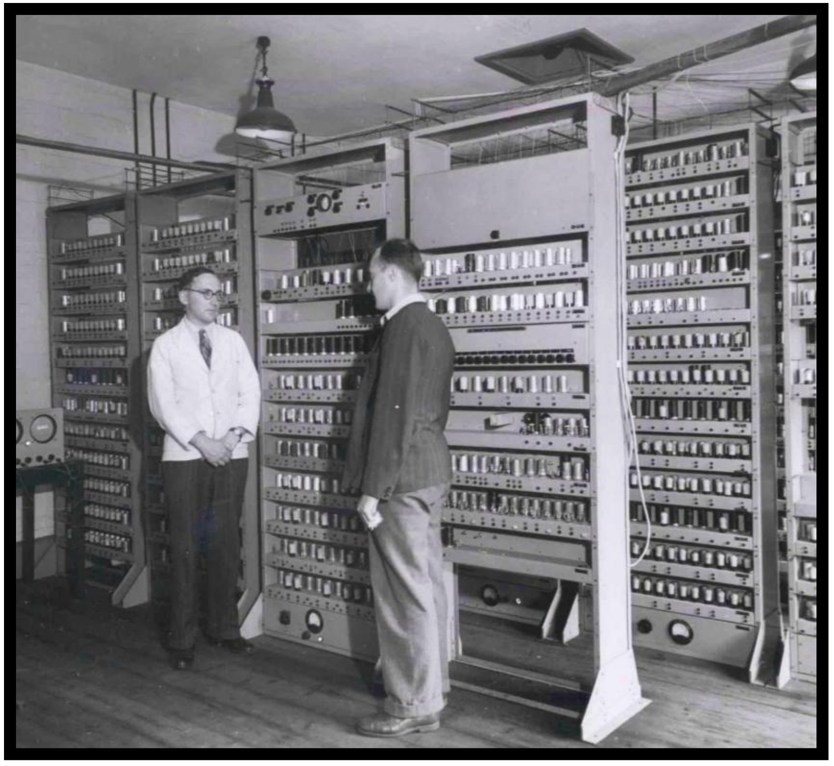


ENIAC

Eckert and Mauchly

- 1st working electronic computer (1946)
- 18,000 Vacuum tubes
- 1,800 instructions/sec
- 3,000 ft^3

Computer History



EDSAC 1 (1949)

http://www.cl.cam.ac.uk/UoCCL/misc/EDSAC99/

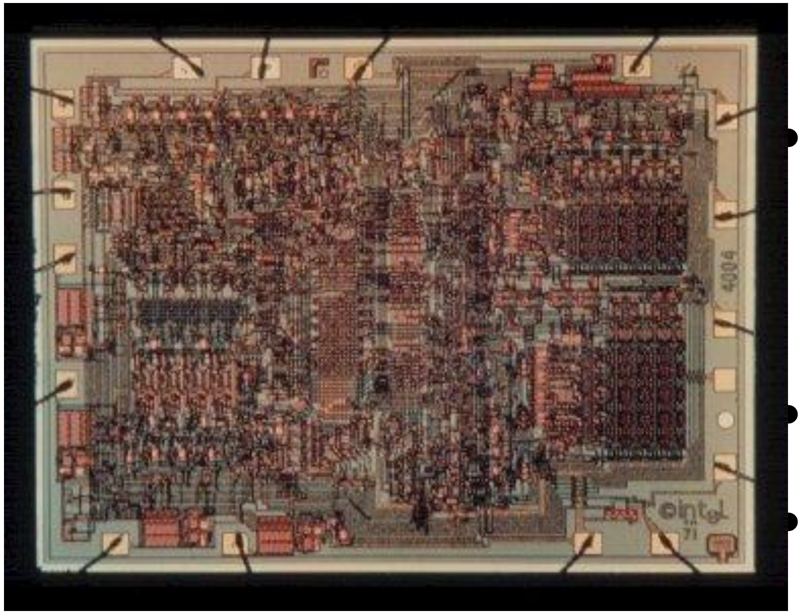
- Maurice Wilkes

1st stored program computer

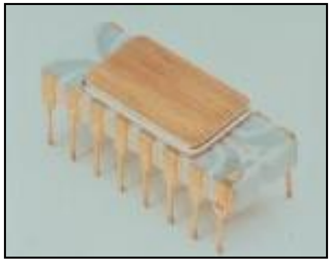
650 instructions/sec

1,400 ft^3

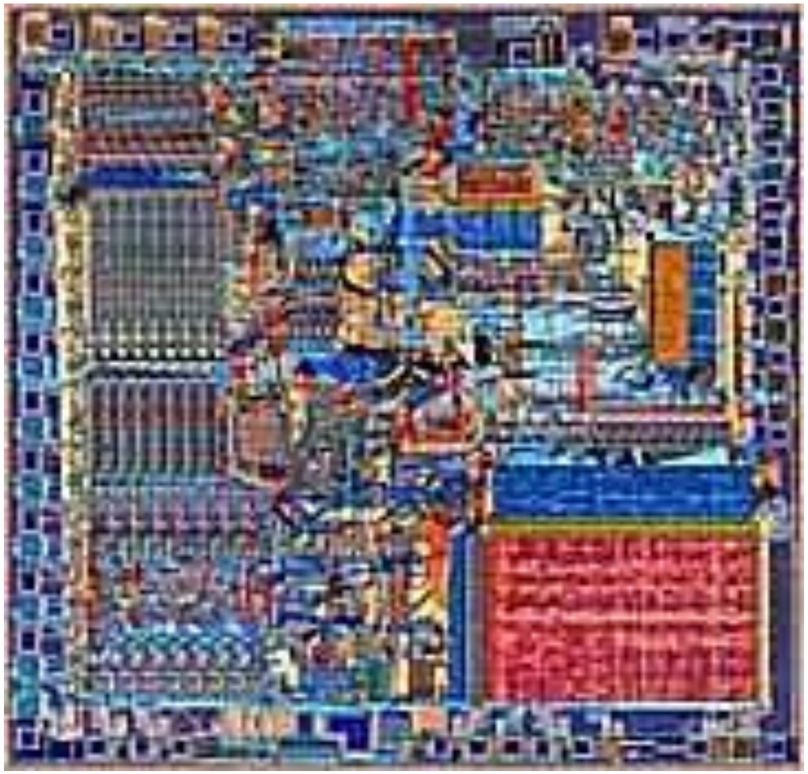
Intel 4004 Die Photo



- Introduced in 1970
  - First microprocessor
- 2,250 transistors
- 12 mm^2
- 108 KHz

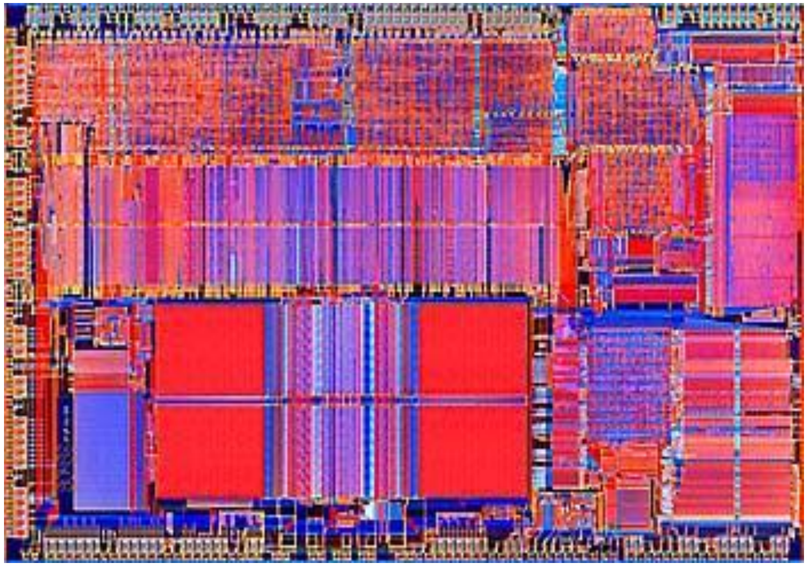


Intel 8086 Die Scan



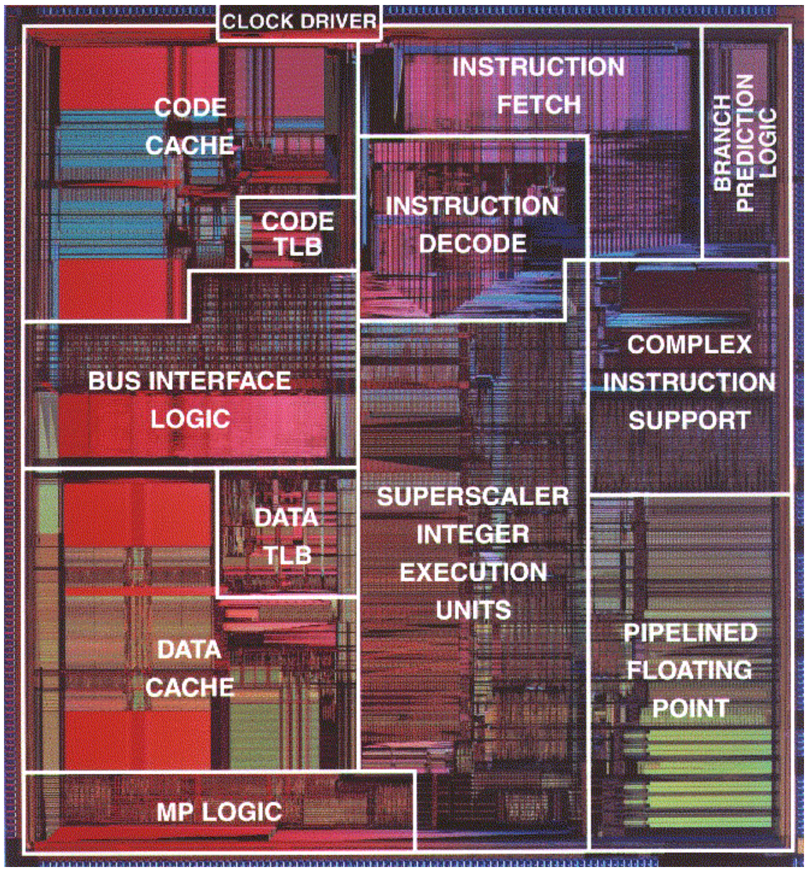
- 29,000 transistors
- 33 mm^2
- 5 MHz
- Introduced in 1979
  - Basic architecture of the IA32 PC

Intel 80486 Die Scan



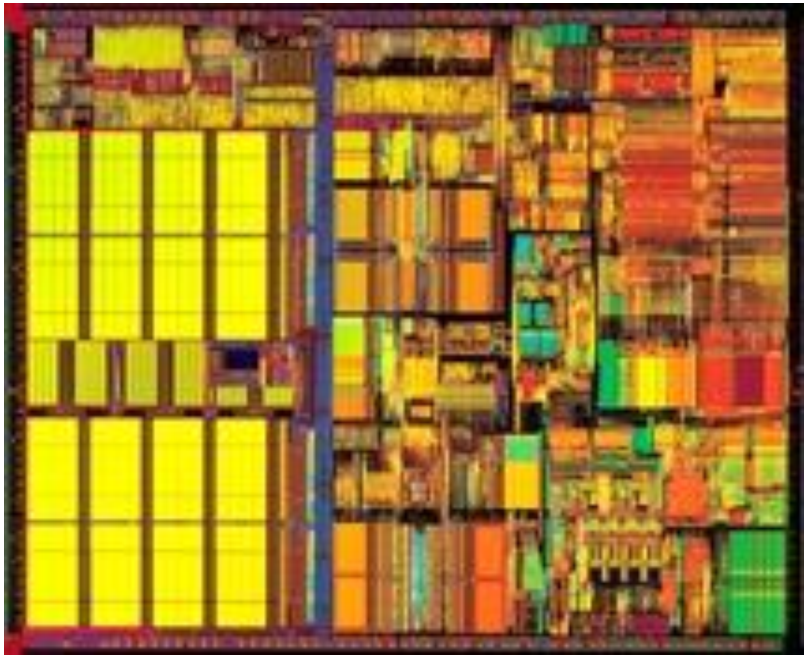
- 1,200,000 transistors
- 81 mm^2
- 25 MHz
- Introduced in 1989
  - 1^{st} pipelined implementation of IA32

Pentium Die Photo



- 3,100,000 transistors
- 296 mm^2
- 60 MHz
- Introduced in 1993
  - 1st superscalar implementation of IA32

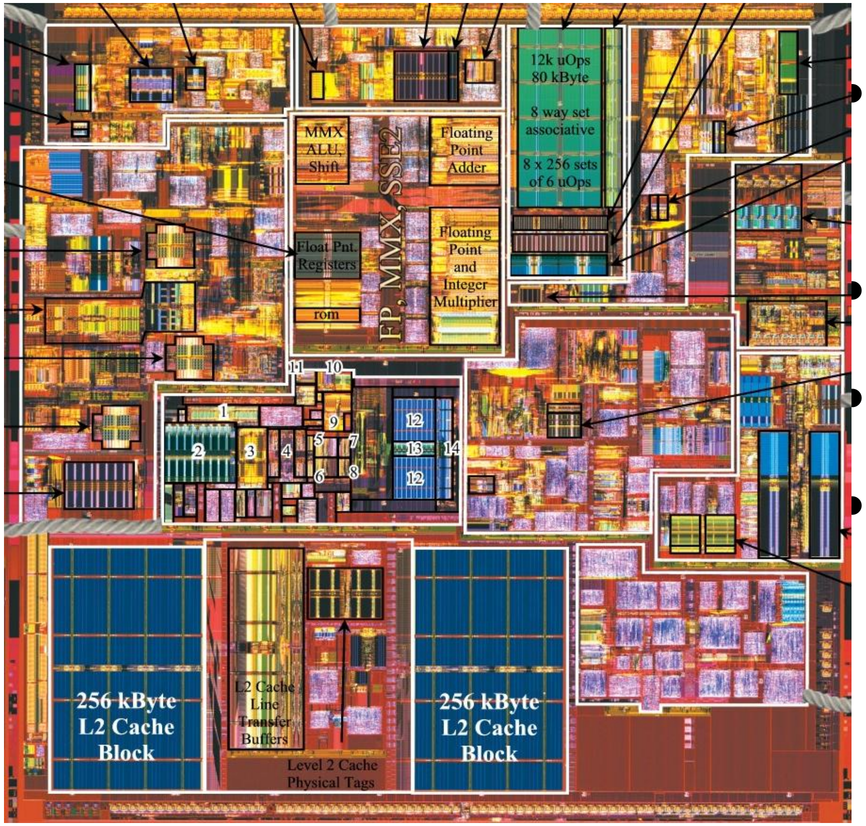
Pentium III



- 9,500,000 transistors
- 125 mm^2
- 450 MHz
- Introduced in 1999

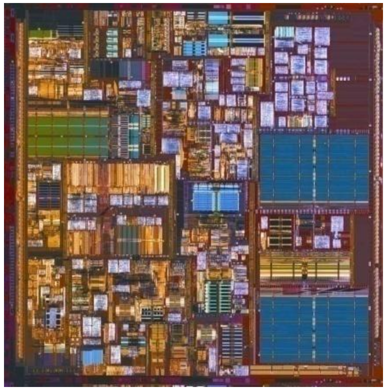
http://www.intel.com/intel/museum/25anniv/hof/hof_main.htm

Pentium 4

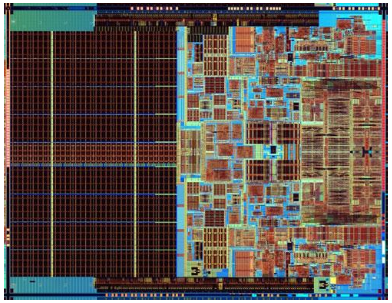


- 55,000,000 transistors
- 146 mm^2
- 3 GHz
- Introduced in 2000

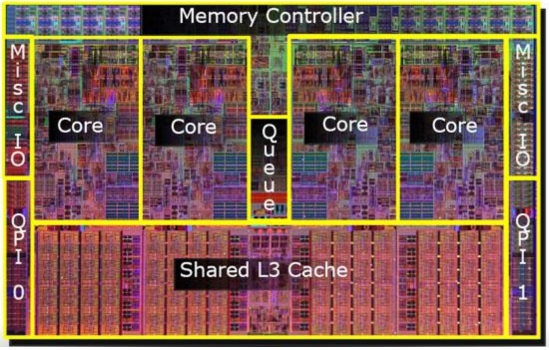
http://www.chip-architect.com



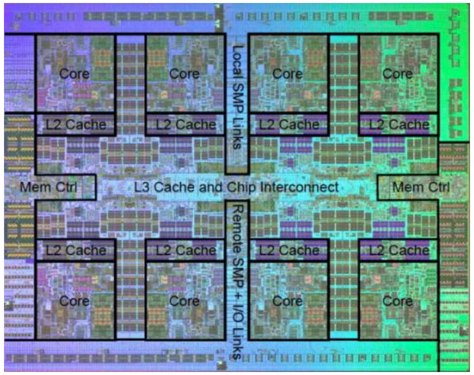
Pentium 4



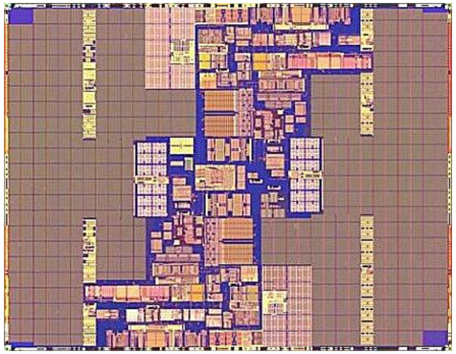
Core 2 Duo (Merom)



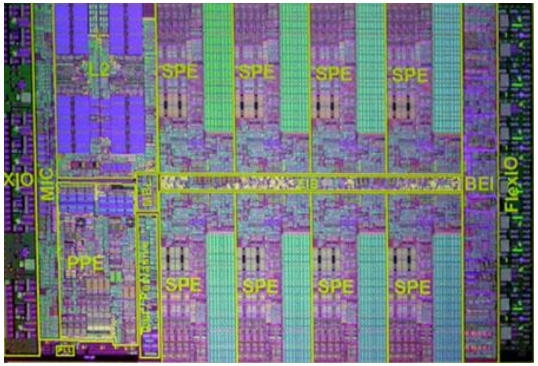
Intel Core i7 (Nehalem)



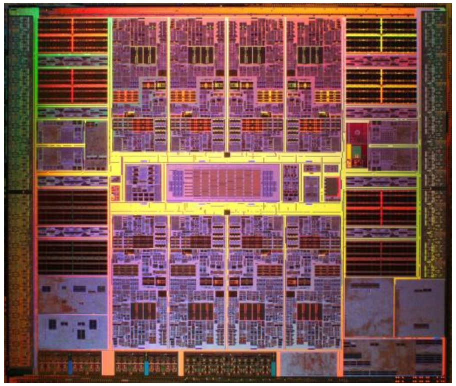
IBM Power 7



Montecito

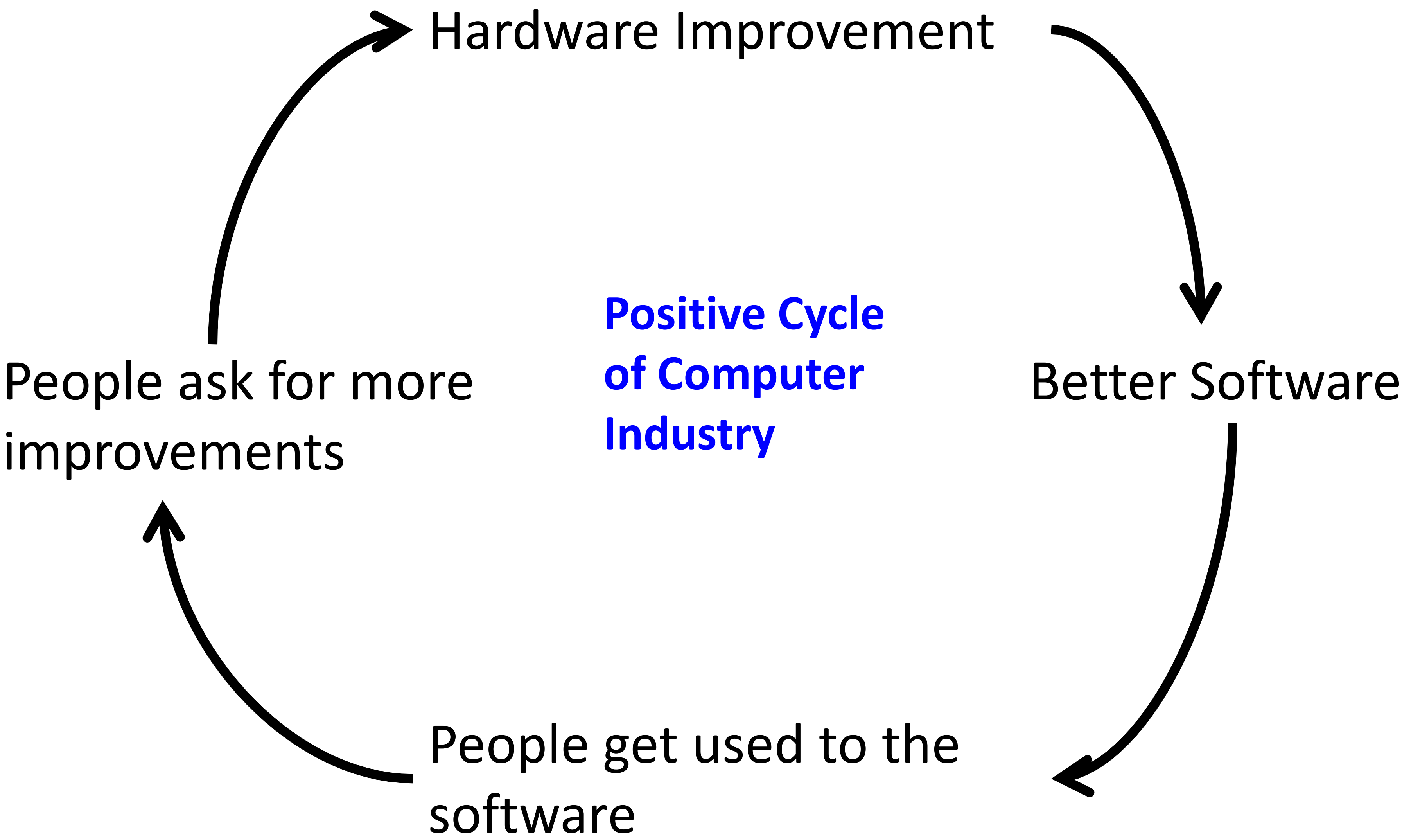


Cell Processor



Niagara
(SUN UltraSparc T2)

The Famous Moore's Law


Hardware Improvement
Better Software
People get used to the software
People ask for more improvements
Positive Cycle of Computer Industry

The Status-Quo

- We moved from single core to multicore
  - for technological reasons
- Free lunch is over for software folks
  - The software will not become faster with every new generation of processors
- Not enough experience in parallel programming
  - Parallel programs of old days were restricted to some elite applications -> very few programmers
  - Now we need parallel programs for many different applications

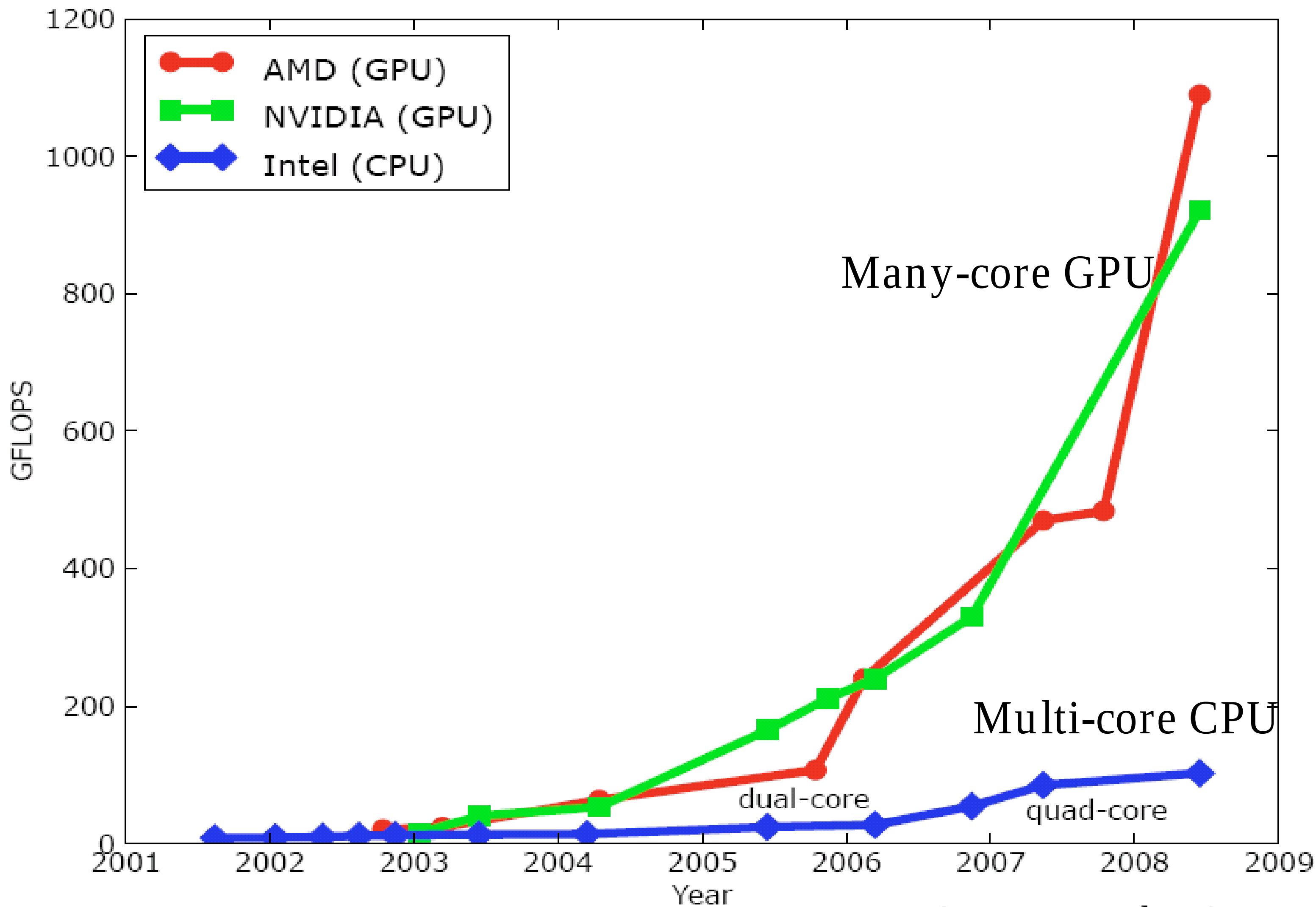
Two Main Goals

- Maintain execution speed of old sequential programs

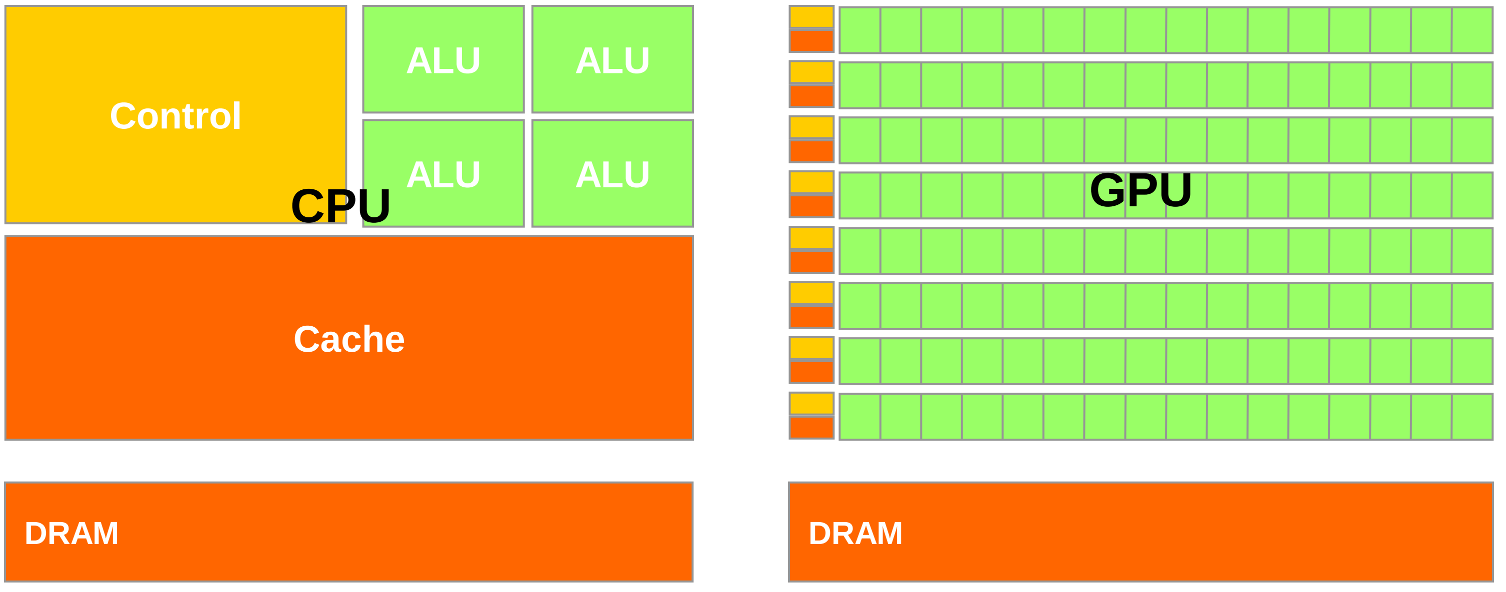
- Increase throughput of parallel programs

Two Main Goals

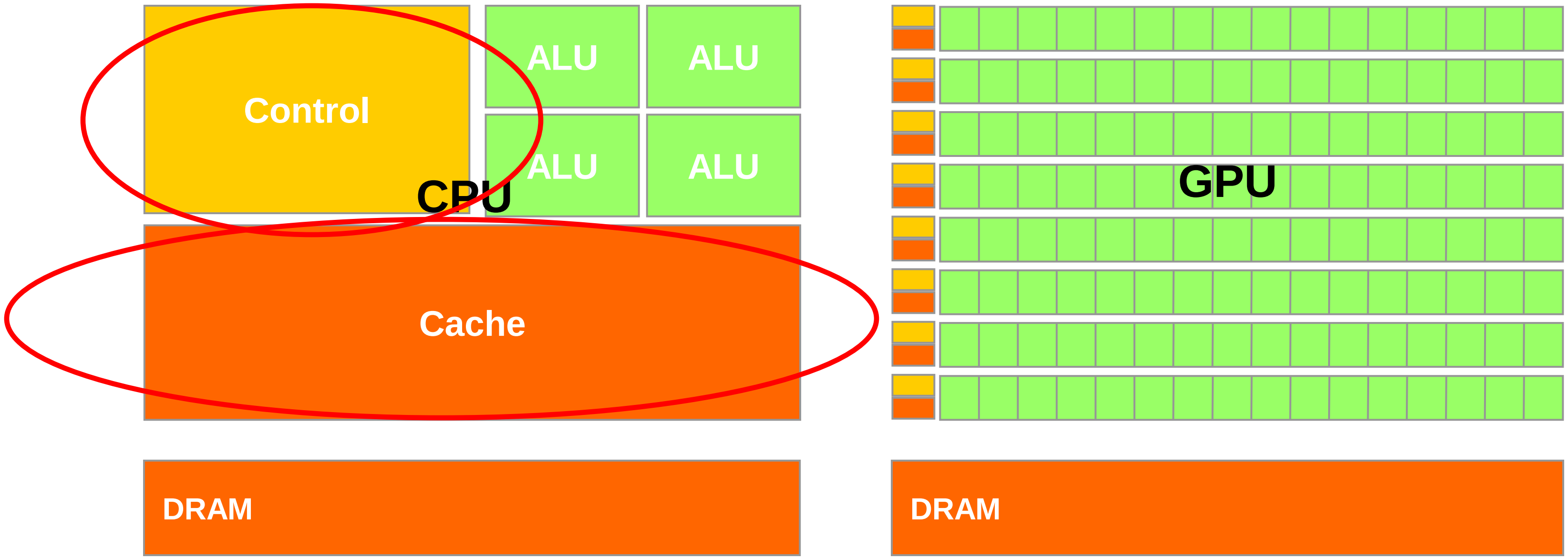
- Maintain execution speed of old sequential programs → **CPU**
- Increase throughput of parallel programs → **GPU**

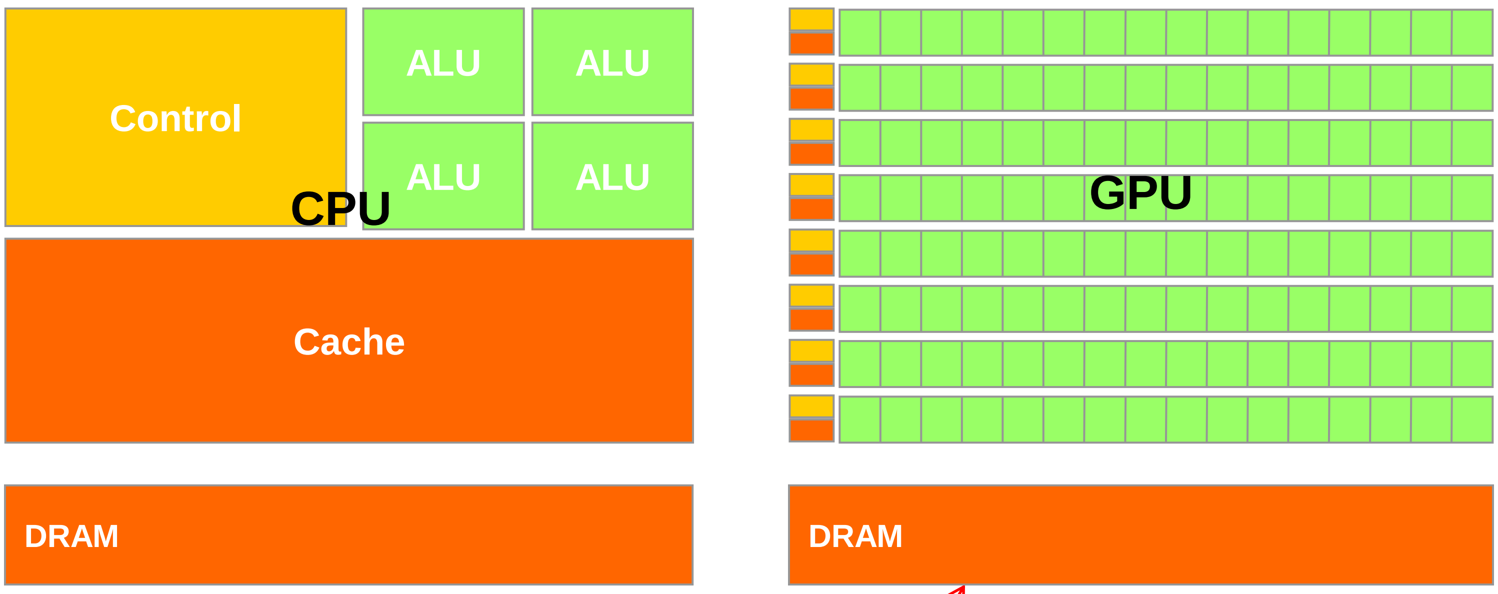


Courtesy: John Owens


Control
ALU
ALU
ALU
ALU
CPU
Cache
DRAM
GPU
DRAM

CPU is optimized for sequential code performance





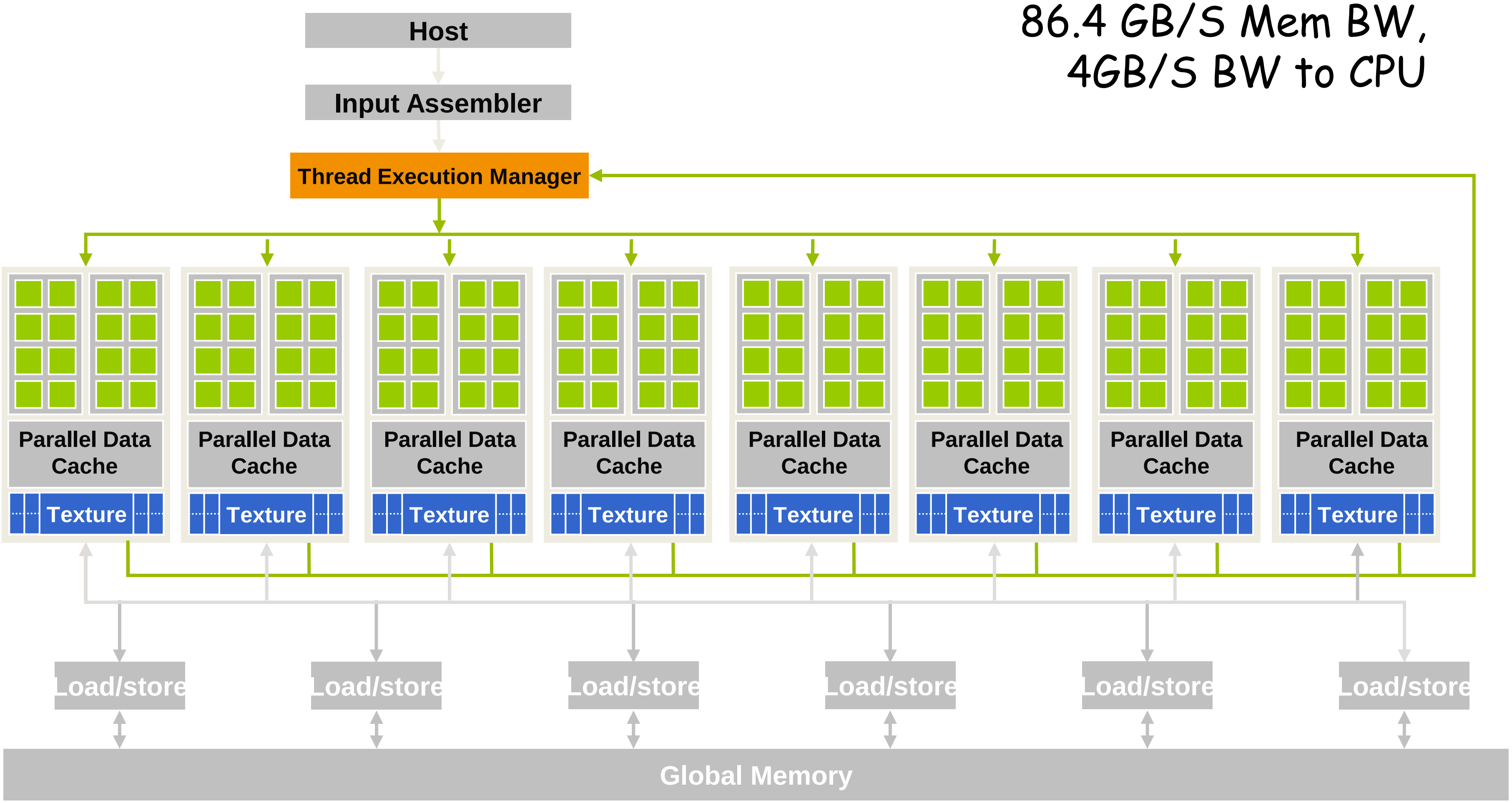
Almost 10x the bandwidth of multicore
(relaxed memory model)

How to Choose A Processor for Your Application?

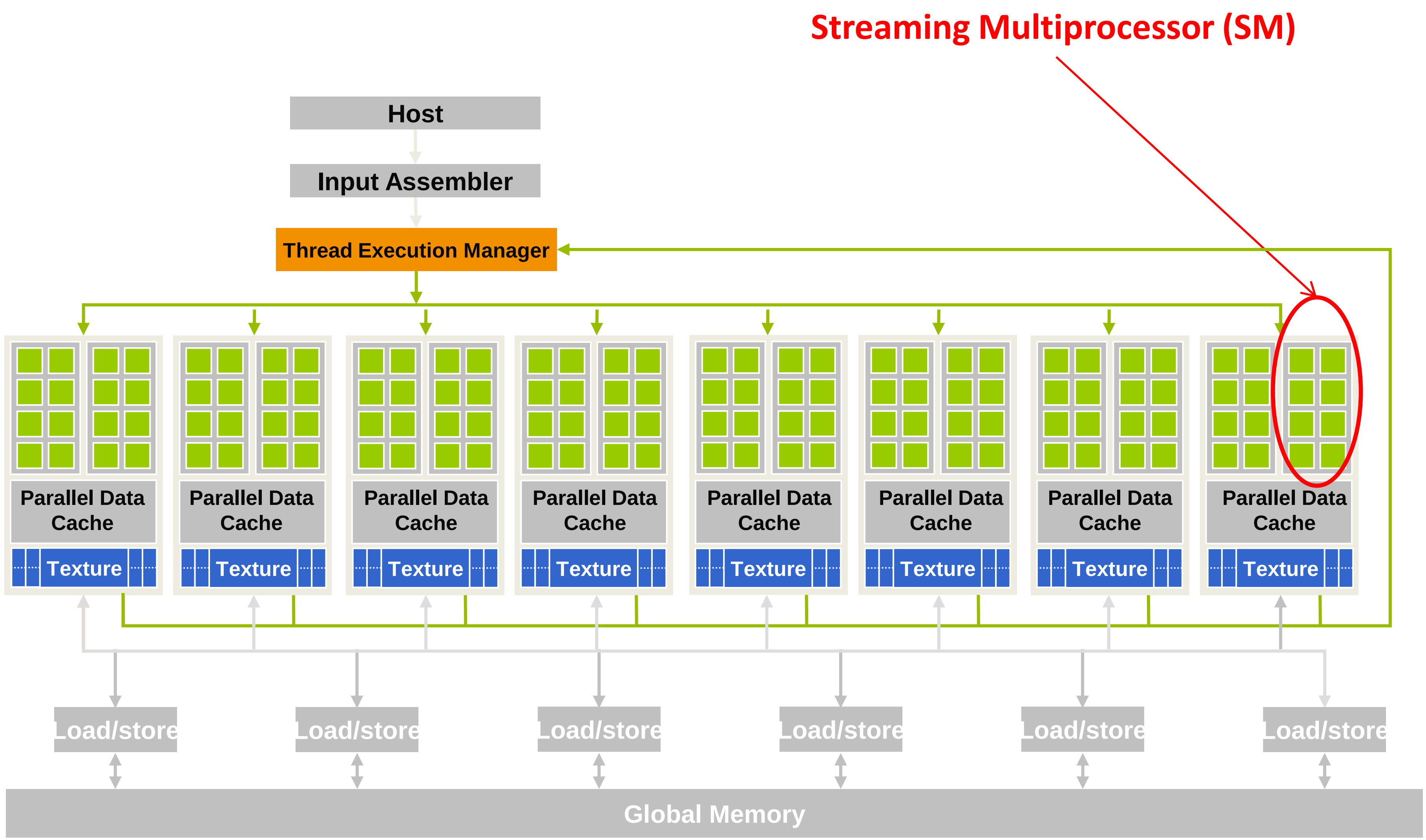
- Performance
- Very large installation base
- Practical form-factor and easy accessibility
- Support for IEEE floating point standard

A Glimpse at At A GPGPU: GeForce 8800 (2007)

16 highly threaded SM's, >128 FPU's,
367 GFLOPS, 768 MB DRAM,
86.4 GB/S Mem BW,
4GB/S BW to CPU



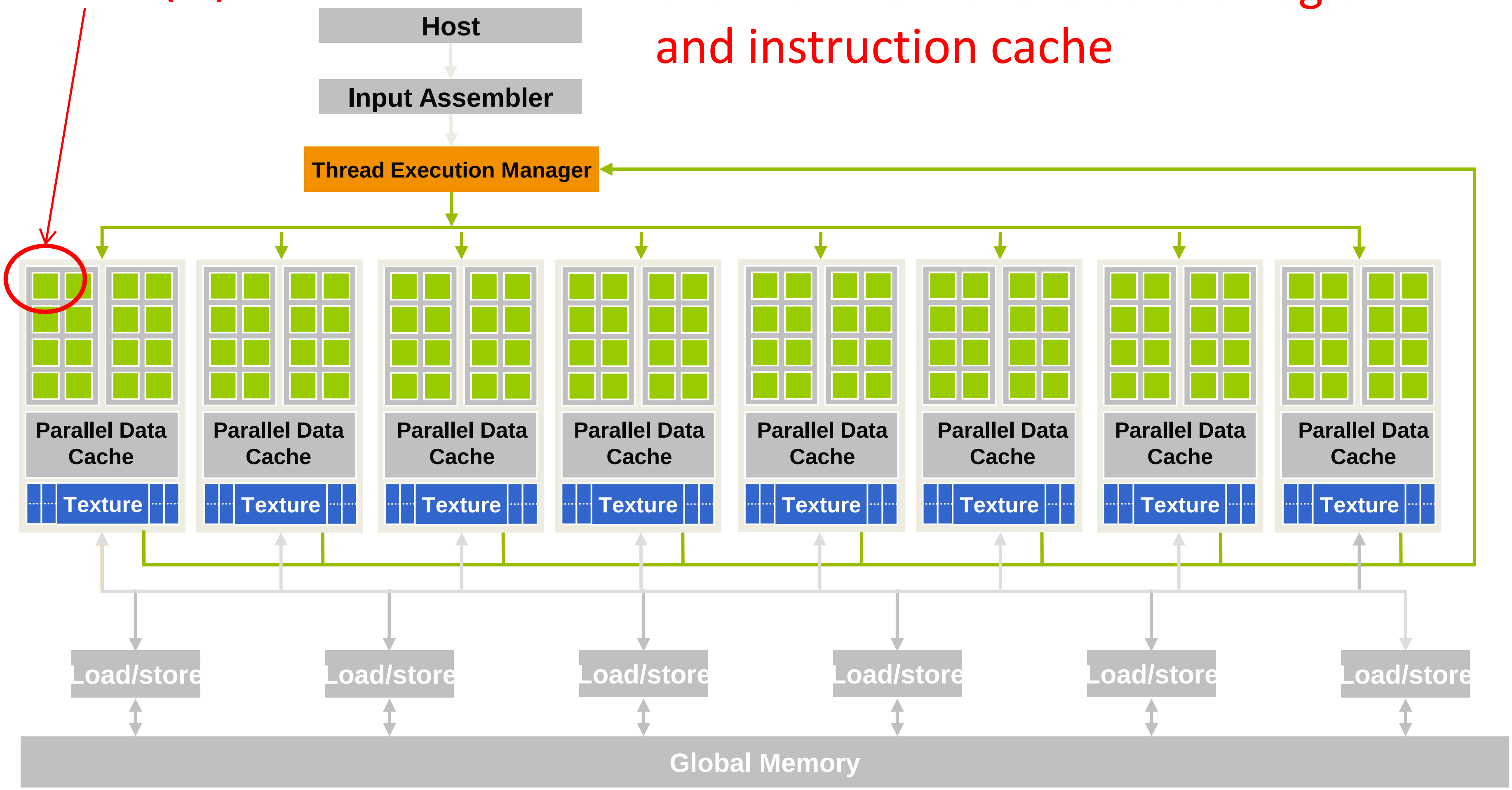
A Glimpse at A Modern GPU



A Glimpse at A Modern GPU

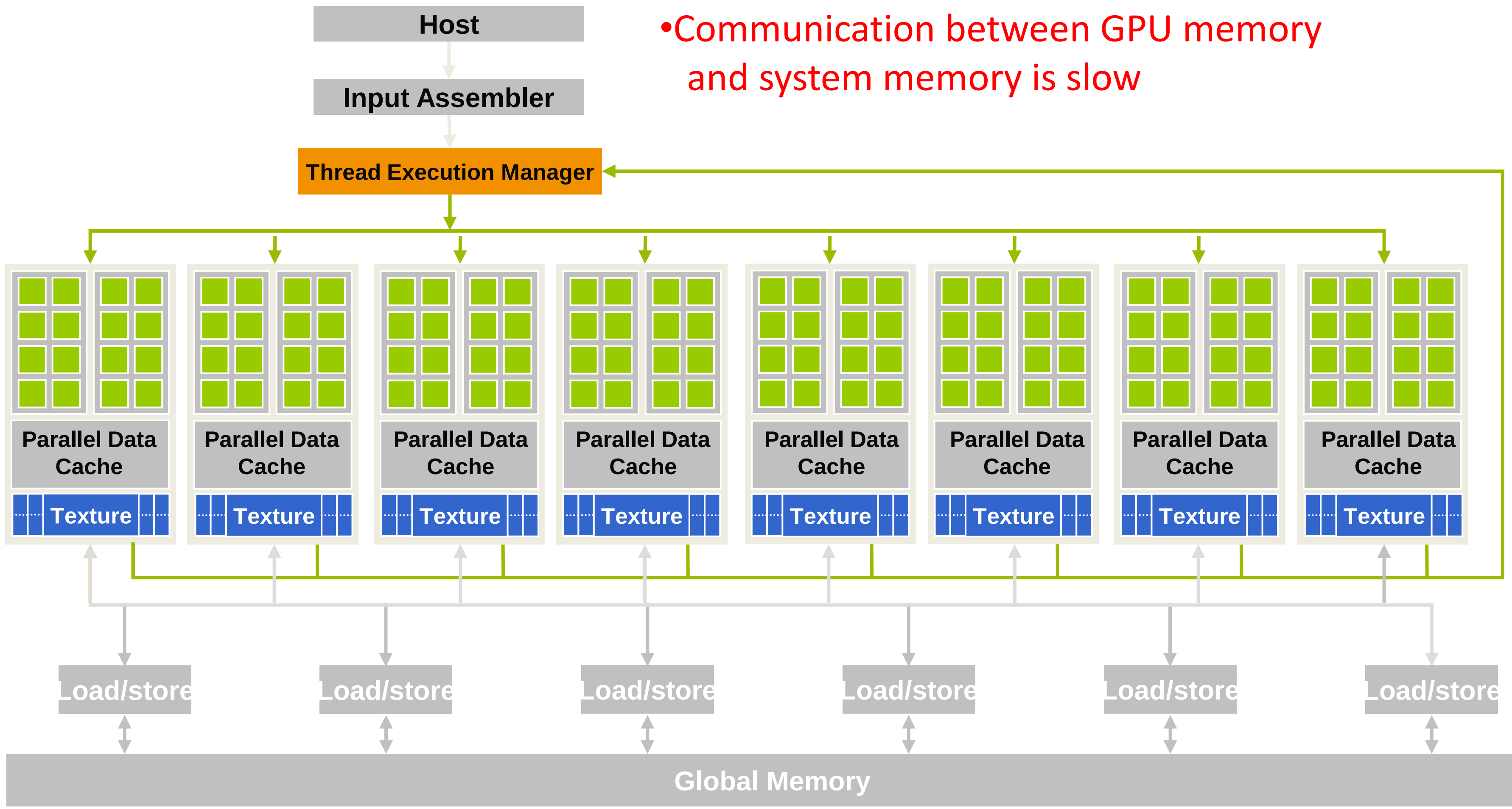
Streaming Processor (SP)

SPs within SM share control logic and instruction cache



A Glimpse at A Modern GPU

- Much higher bandwidth than typical system memory
- A bit slower than typical system memory
- Communication between GPU memory and system memory is slow



Amdahl's Law

Execution Time After Improvement =

Execution Time Unaffected +(Execution Time Affected / Amount of Improvement)

- Example:

"Suppose a program runs in 100 seconds on a machine, with multiply responsible for 80 seconds of this time. How much do we have to improve the speed of multiplication if we want the program to run 4 times faster?"

How about making it 5 times faster?

Improvement in your application speed depends on the portion that is parallelized

Things to Keep in Mind

- Try to increase the portion of your program that can be parallelized
- Figure out how to get around limited bandwidth of system memory
- When an application is suitable for parallel execution, a good implementation on GPU can achieve more than 100x speedup over sequential implementation.
- You can reach 10x fairly easy, beyond that … stay with us!

Enough for Today

- We are done with Chapter 1
- Some applications are better run on CPU while others on GPU
- If you don't care about performance, parallel programming is easy!
- Main limitations
  - The parallelizable portion of the code
  - The communication overhead between CPU and GPU
  - Memory bandwidth saturation