Computer Science E-1

Lecture 2: Hardware

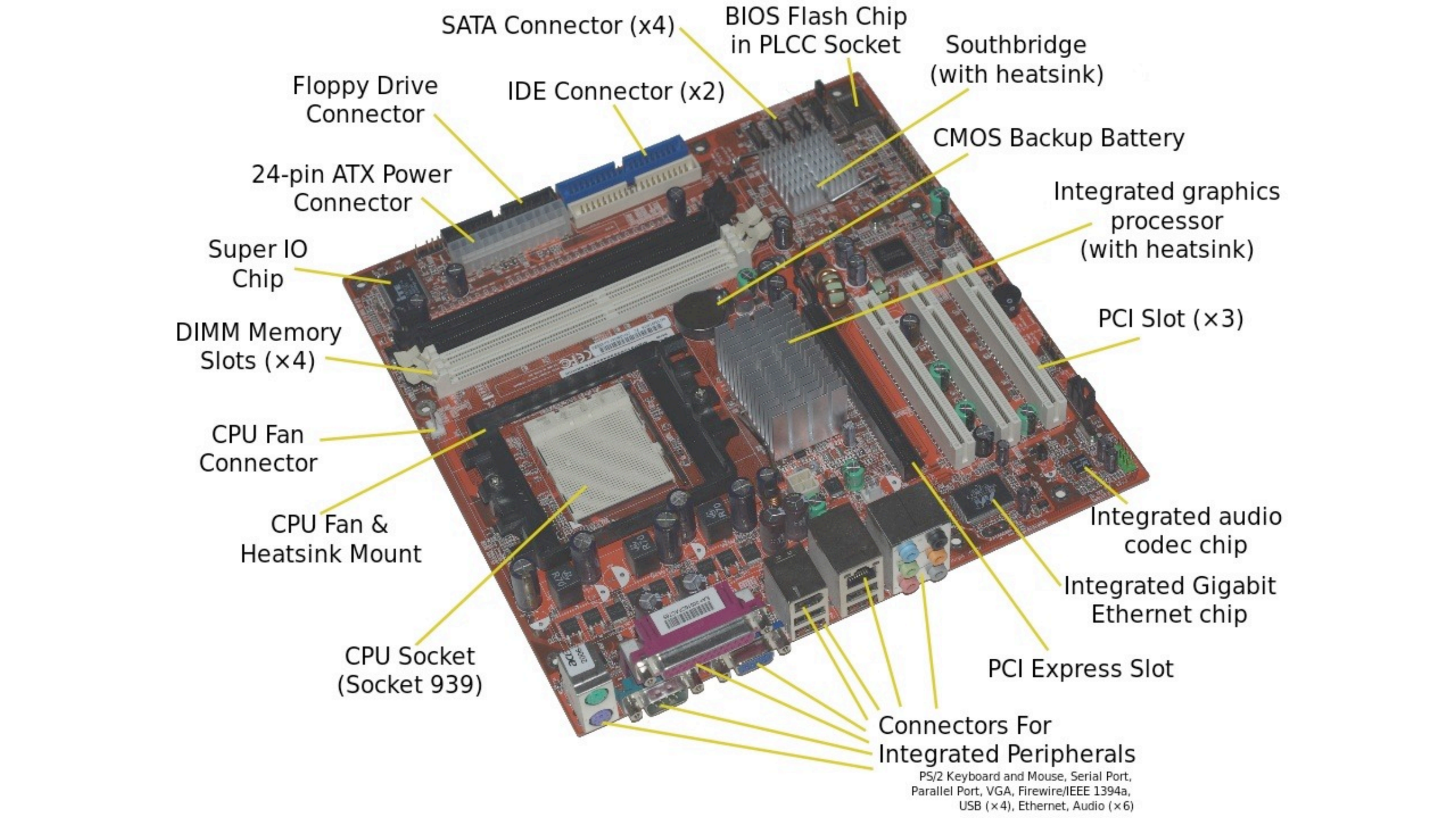
From last time...

Pre-requisites

~~Pre-requisites~~

Math

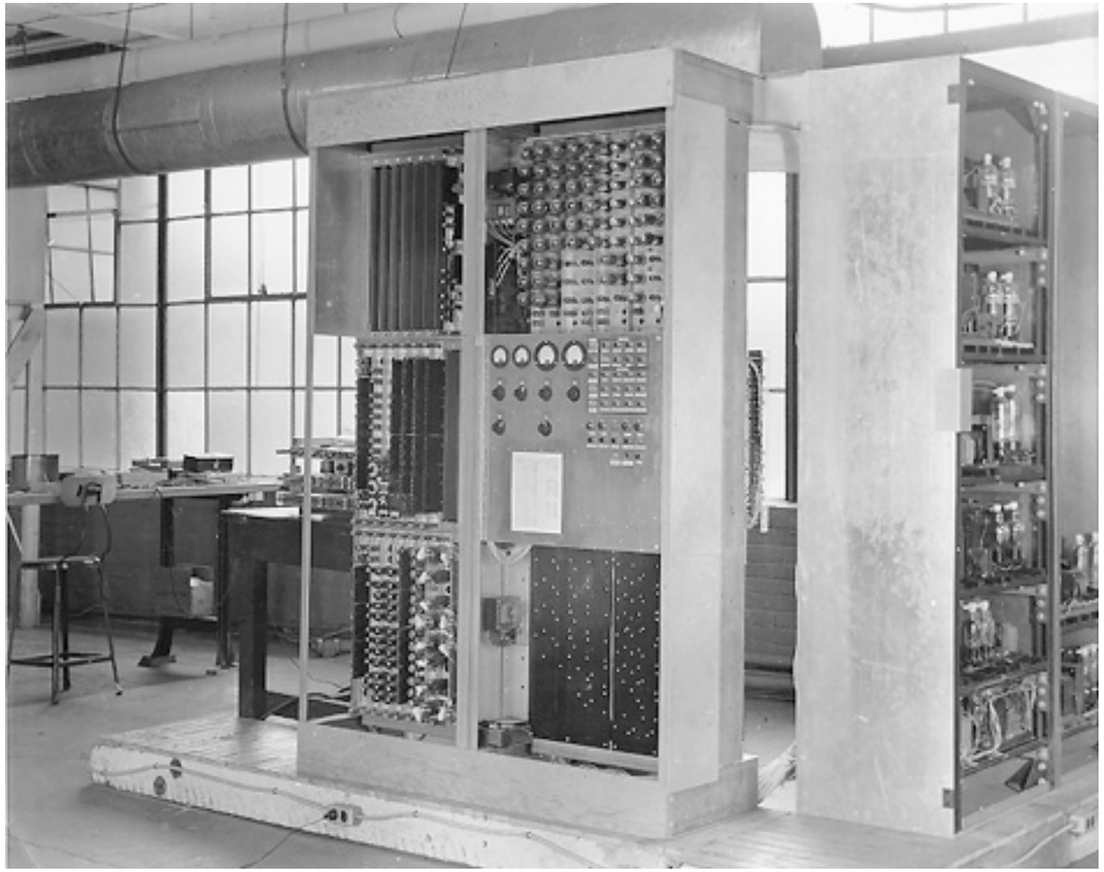
~~Math~~

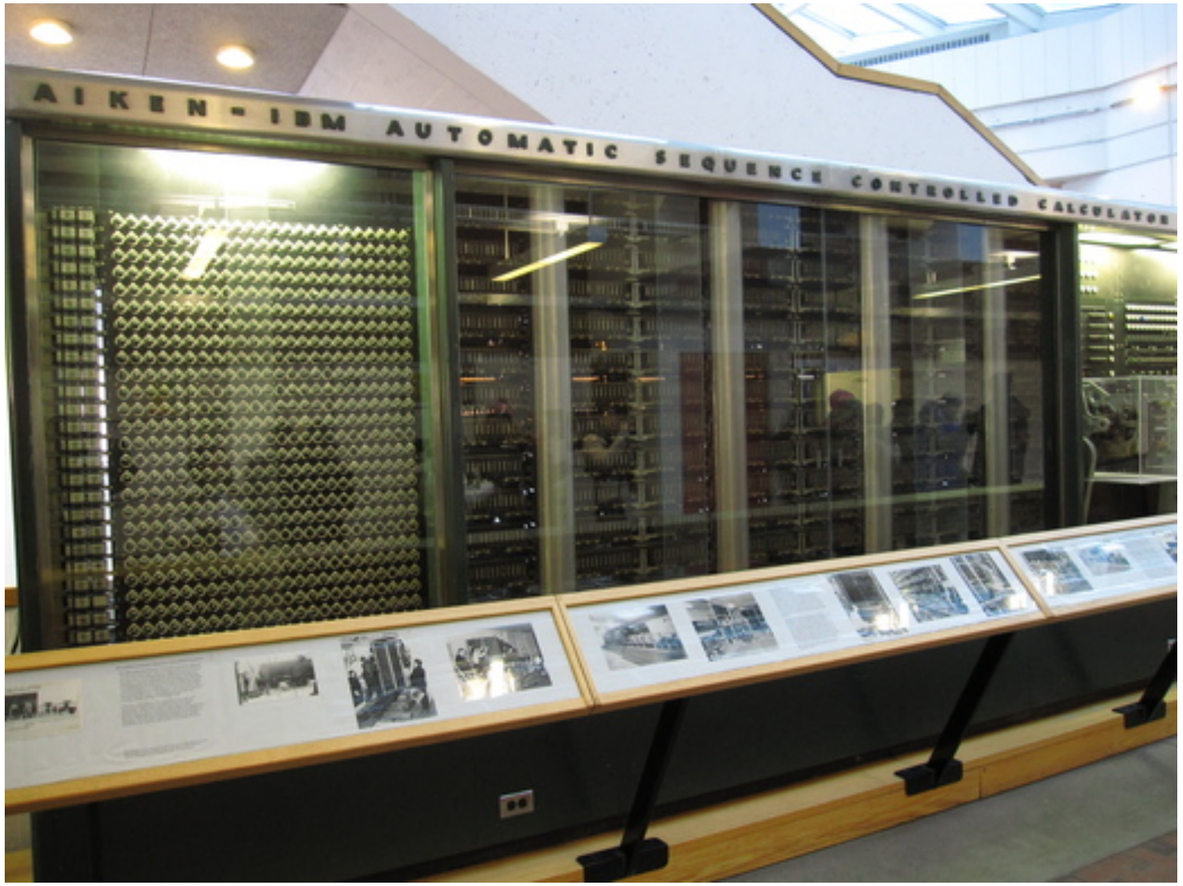

SATA Connector (x4)
BIOS Flash Chip in PLCC Socket
Southbridge (with heatsink)
Floppy Drive Connector
IDE Connector (x2)
CMOS Backup Battery
24-pin ATX Power Connector
Integrated graphics processor (with heatsink)
Super IO Chip
PCI Slot (×3)
DIMM Memory Slots (×4)
CPU Fan Connector
Integrated audio codec chip
CPU Fan & Heatsink Mount
Integrated Gigabit Ethernet chip
CPU Socket (Socket 939)
PCI Express Slot
Connectors For Integrated Peripherals
PS/2 Keyboard and Mouse, Serial Port, Parallel Port, VGA, Firewire/IEEE 1394a, USB (×4), Ethernet, Audio (×6)

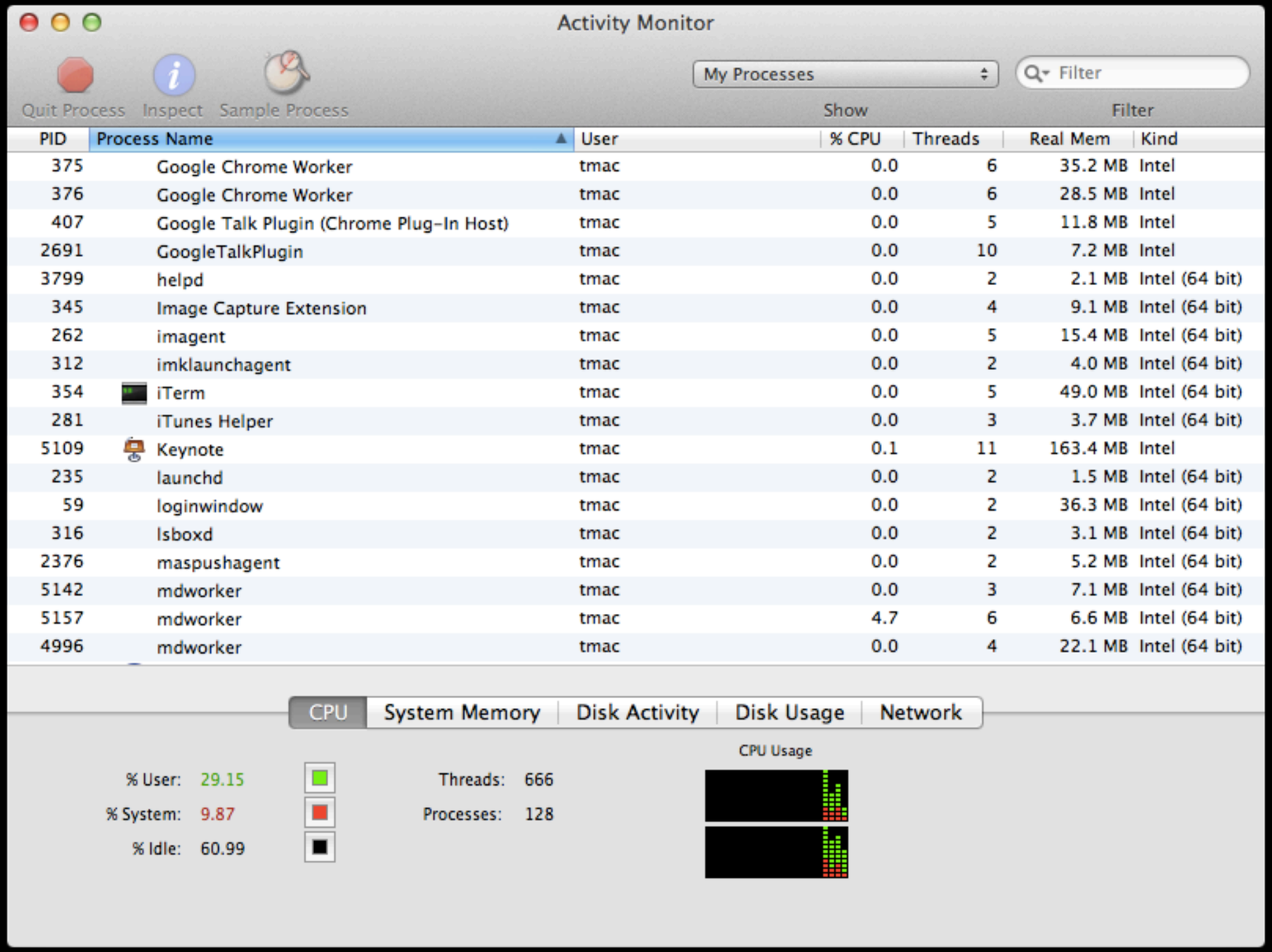

CPU
RAM
Hard Drive

CPU


AMD Phenom II
Socket AM3
Intel Core i7
LGA 1366
Intel Core i5
LGA 1156




AIKEN-IBM AUTOMATIC SEQUENCE CONTROLLED CALCULATOR


Activity Monitor
Quit Process
Inspect
Sample Process
My Processes
Filter
Show
Filter
PID
Process Name
User
% CPU
Threads
Real Mem
Kind
375 Google Chrome Worker tmac 0.0 6 35.2 MB Intel
376 Google Chrome Worker tmac 0.0 6 28.5 MB Intel
407 Google Talk Plugin (Chrome Plug-In Host) tmac 0.0 5 11.8 MB Intel
2691 GoogleTalkPlugin tmac 0.0 10 7.2 MB Intel
3799 helpd tmac 0.0 2 2.1 MB Intel (64 bit)
345 Image Capture Extension tmac 0.0 4 9.1 MB Intel (64 bit)
262 imagent tmac 0.0 5 15.4 MB Intel (64 bit)
312 imklaunchagent tmac 0.0 2 4.0 MB Intel (64 bit)
354 iTerm tmac 0.0 5 49.0 MB Intel (64 bit)
281 iTunes Helper tmac 0.0 3 3.7 MB Intel (64 bit)
5109 Keynote tmac 0.1 11 163.4 MB Intel
235 launchd tmac 0.0 2 1.5 MB Intel (64 bit)
59 loginwindow tmac 0.0 2 36.3 MB Intel (64 bit)
316 lsboxd tmac 0.0 2 3.1 MB Intel (64 bit)
2376 maspushagent tmac 0.0 2 5.2 MB Intel (64 bit)
5142 mdworker tmac 0.0 3 7.1 MB Intel (64 bit)
5157 mdworker tmac 4.7 6 6.6 MB Intel (64 bit)
4996 mdworker tmac 0.0 4 22.1 MB Intel (64 bit)
CPU
System Memory
Disk Activity
Disk Usage
Network
% User: 29.15
% System: 9.87
% Idle: 60.99
Threads: 666
Processes: 128
CPU Usage

Instruction Set

Instruction Set

- **data**: read/write data from RAM

Instruction Set

- **data**: read/write data from RAM
- **arithmetic**: add two numbers

Instruction Set

- **data**: read/write data from RAM
- **arithmetic**: add two numbers
- **control flow**: where do we go next?

Pipeline

Pipeline

- **fetch**: get the next instruction

Pipeline

- **fetch**: get the next instruction
- **decode**: determine which instruction was fetched

Pipeline

- **fetch**: get the next instruction
- **decode**: determine which instruction was fetched
- **execute**: run the instruction

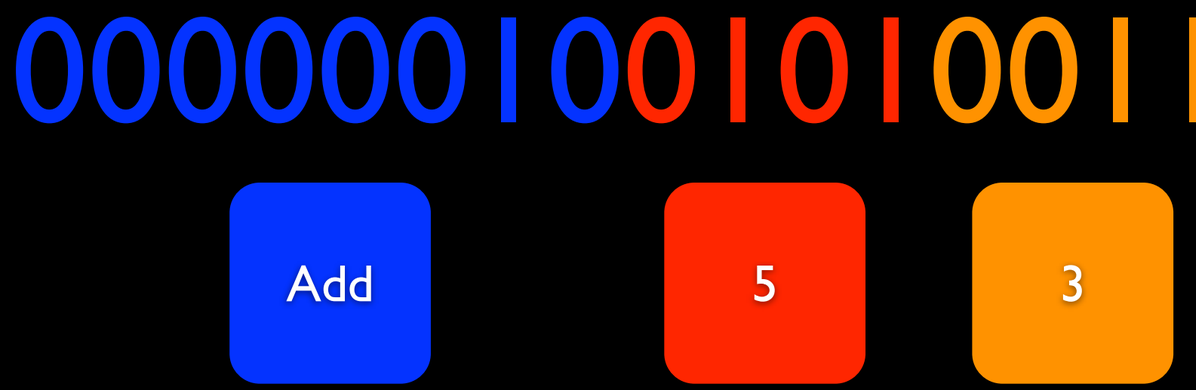
Pipeline

- **fetch**: get the next instruction
- **decode**: determine which instruction was fetched
- **execute**: run the instruction
- **writeback**: store the result (if necessary)

Fetch

000000100101001 1

Decode



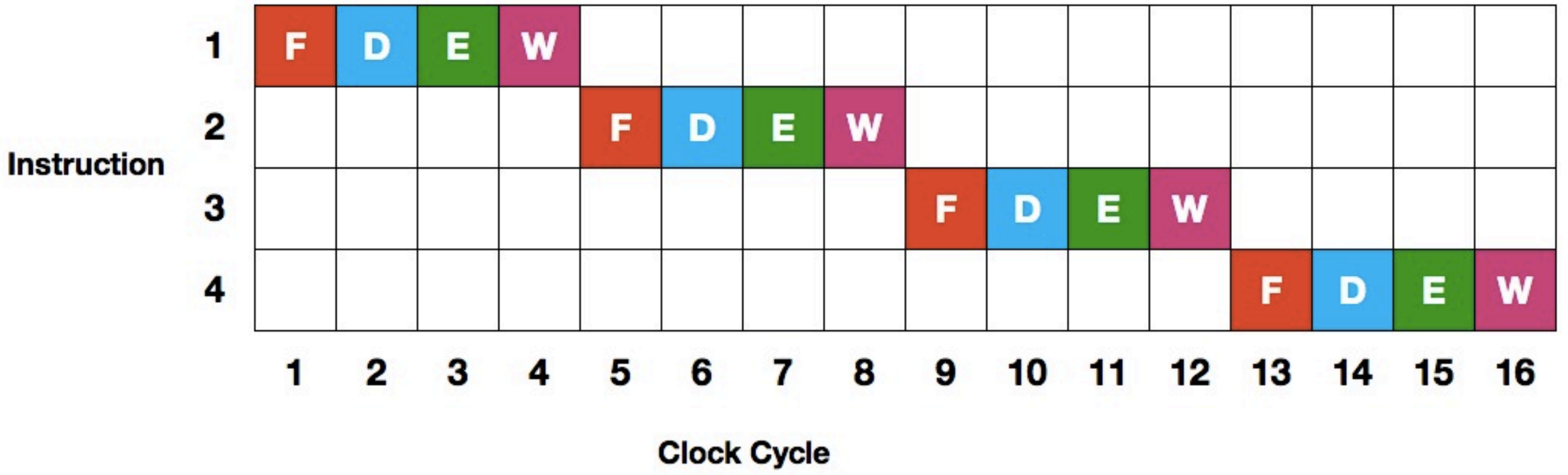
Decode

Add 5 + 3

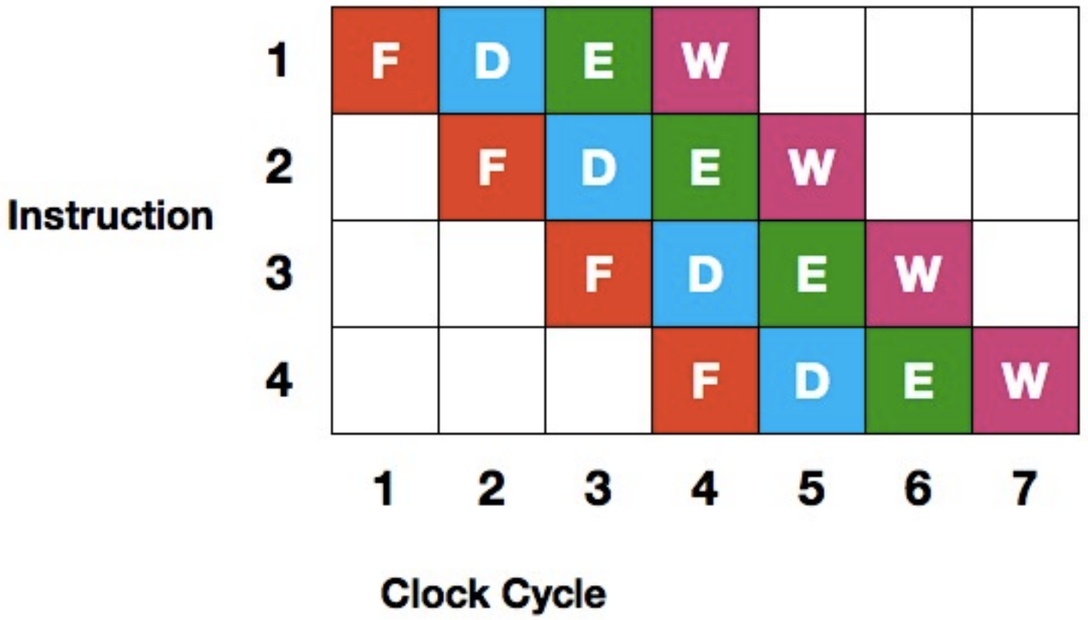
Execute

5 + 3 = 8

Writeback


Instruction
1
2
3
4
F
D
E
W
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Clock Cycle

Parallelism


Instruction
1
2
3
4
F
D
E
W
1
2
3
4
5
6
7
Clock Cycle

Superscalar

Multi-core

Counting Candy

1. Start with a total of 0
2. For each piece in the pile, add 1 to total
3. Remember that piece was counted

1. Find 4 friends
2. Divide candy among friends
3. Friends count at same time

Four times as fast!

~~Four times as fast!~~

1. Find 4 friends
2. Divide candy among friends
3. Friends count at same time
4. Add up friends' totals

More friends!

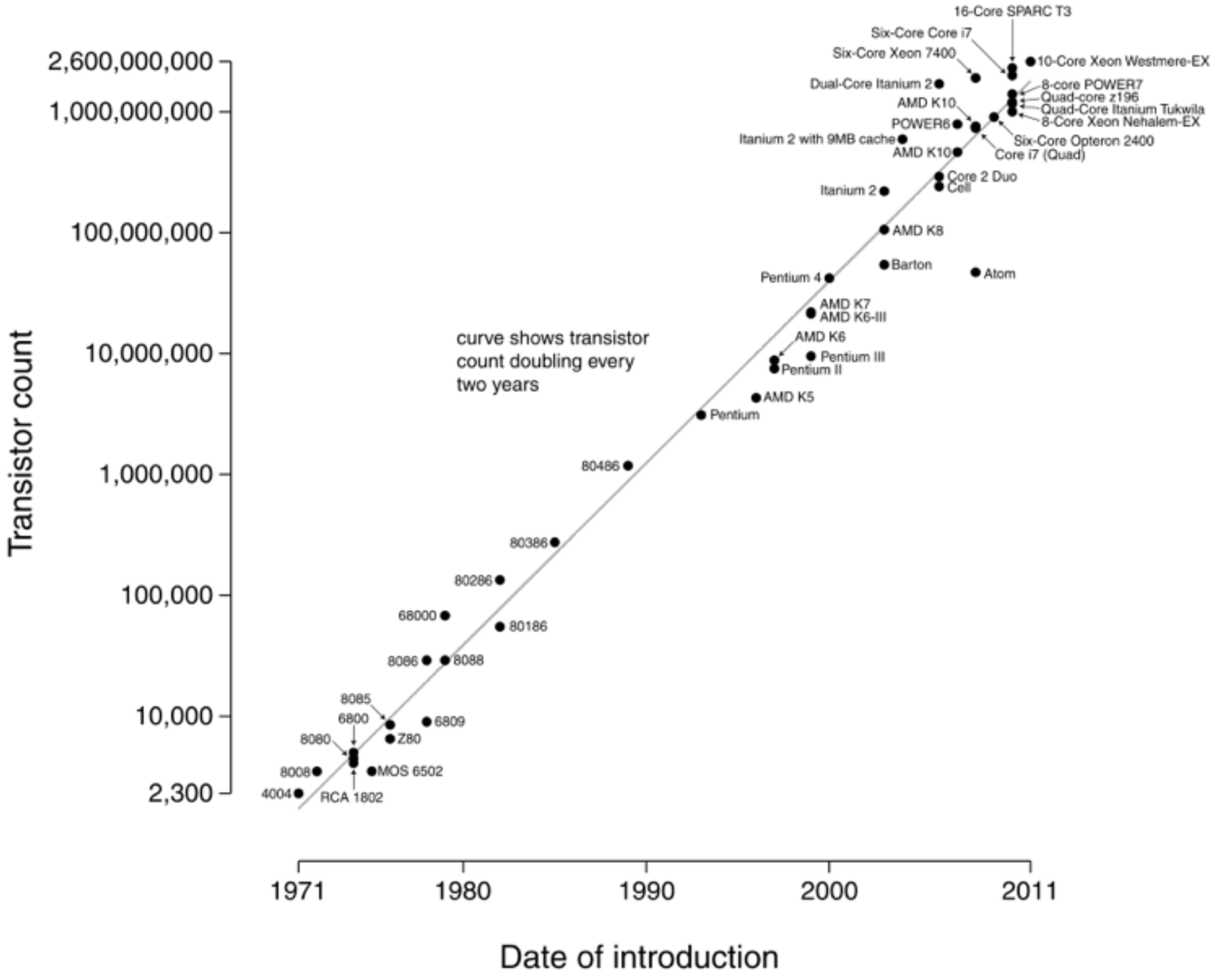
Not faster :(

1. Pair up, add totals together
2. One friend goes home, other remembers total
3. Repeat until counted

Much faster!

CPU Performance

Microprocessor Transistor Counts 1971-2011 & Moore's Law



“Megahertz Myth”

http://www.youtube.com/watch?v=PKF9GOE2q38


CPU
RAM
Hard Drive

Memory

Byte	B	8 bits
Kilobyte	KB	1000 bytes
Megabyte	MB	1000000 bytes (1000 KB)
Gigabyte	GB	1000000000 bytes (1000 MB)
Terabyte	TB	1000000000000 bytes (1000 GB)

Byte	B	
Kilobyte	KB	
Megabyte	MB	
Gigabyte	GB	
Terabyte	TB	

Byte	B	Character of text
Kilobyte	KB	
Megabyte	MB	
Gigabyte	GB	
Terabyte	TB	

Byte	B	Character of text
Kilobyte	KB	Word document
Megabyte	MB	
Gigabyte	GB	
Terabyte	TB	

Byte	B	Character of text
Kilobyte	KB	Word document
Megabyte	MB	MP3 song
Gigabyte	GB	
Terabyte	TB	

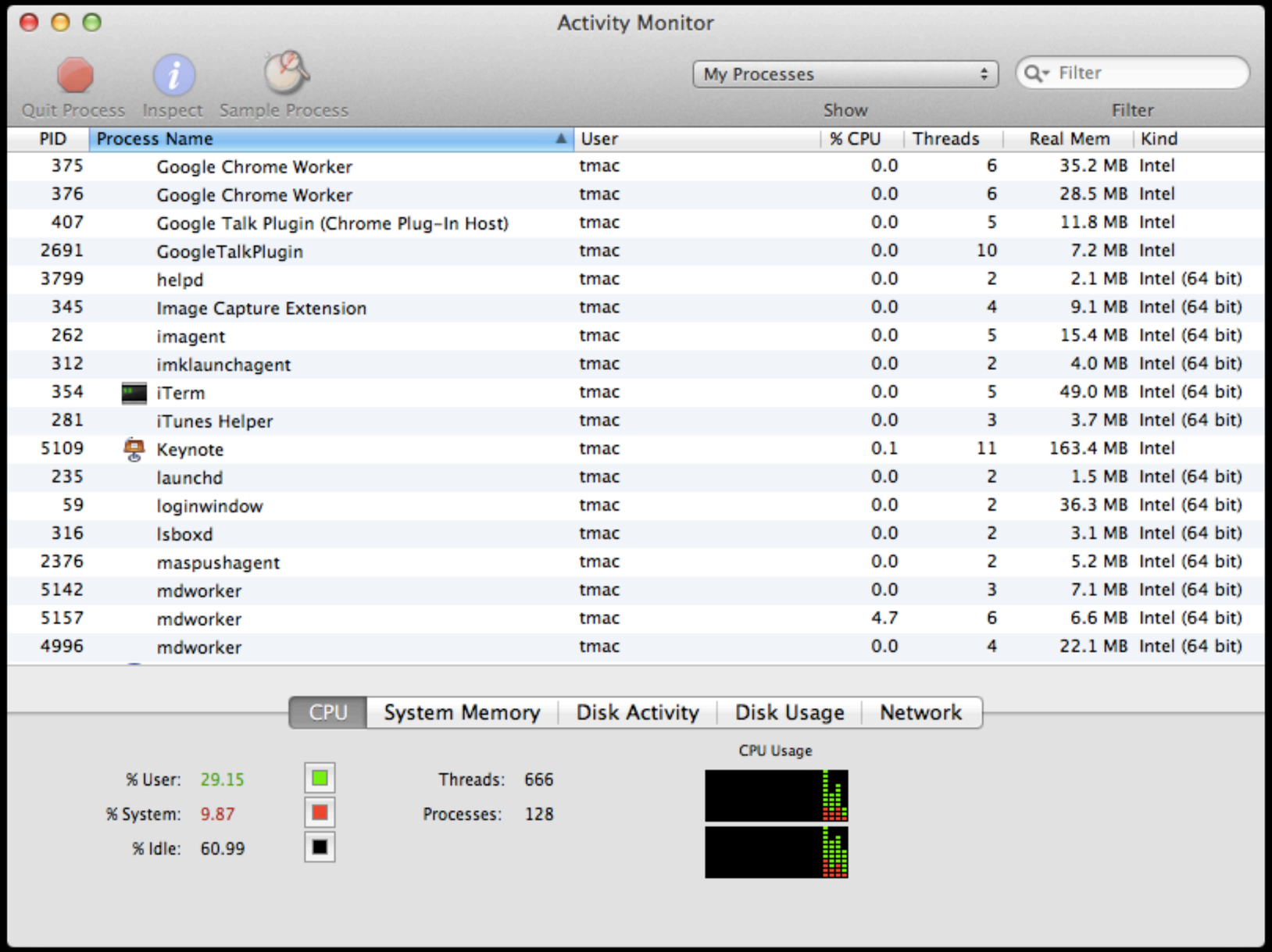
Byte	B	Character of text
Kilobyte	KB	Word document
Megabyte	MB	MP3 song
Gigabyte	GB	Movie
Terabyte	TB	

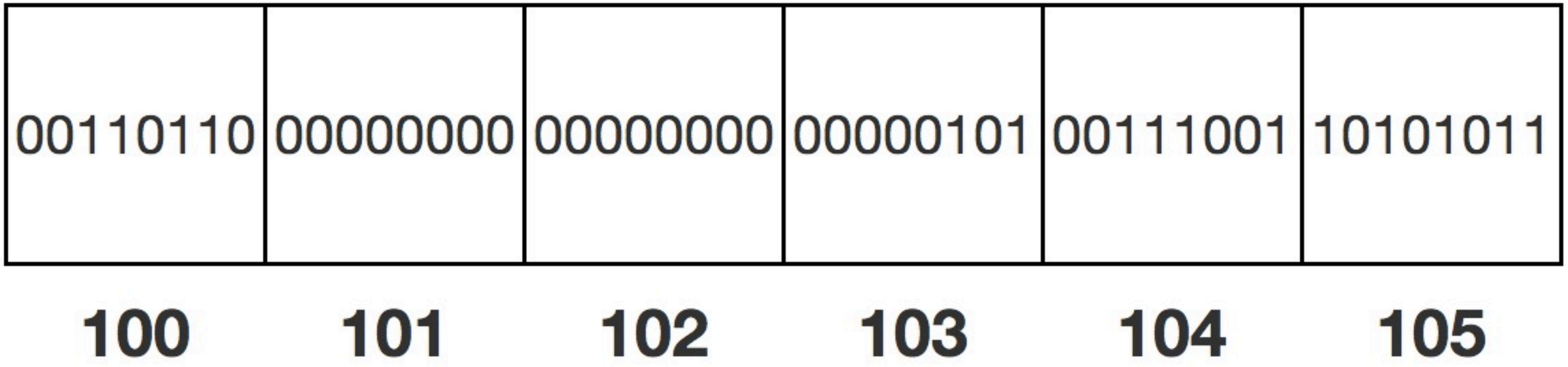
Byte	B	Character of text
Kilobyte	KB	Word document
Megabyte	MB	MP3 song
Gigabyte	GB	Movie
Terabyte	TB	250,000 songs

Registers

RAM


elixir
M2U51264DS8HC3G-5T
512MB DDR-400MHz-CL3
PC3200U-30331
Warranty Void If Removed
0542.MN06A1107A.5YM0410N08.XX.CN


Activity Monitor
Quit Process
Inspect
Sample Process
My Processes
Filter
Show
Filter
PID
Process Name
User
% CPU
Threads
Real Mem
Kind
375 Google Chrome Worker tmac 0.0 6 35.2 MB Intel
376 Google Chrome Worker tmac 0.0 6 28.5 MB Intel
407 Google Talk Plugin (Chrome Plug-In Host) tmac 0.0 5 11.8 MB Intel
2691 GoogleTalkPlugin tmac 0.0 10 7.2 MB Intel
3799 helpd tmac 0.0 2 2.1 MB Intel (64 bit)
345 Image Capture Extension tmac 0.0 4 9.1 MB Intel (64 bit)
262 imagent tmac 0.0 5 15.4 MB Intel (64 bit)
312 imklaunchagent tmac 0.0 2 4.0 MB Intel (64 bit)
354 iTerm tmac 0.0 5 49.0 MB Intel (64 bit)
281 iTunes Helper tmac 0.0 3 3.7 MB Intel (64 bit)
5109 Keynote tmac 0.1 11 163.4 MB Intel
235 launchd tmac 0.0 2 1.5 MB Intel (64 bit)
59 loginwindow tmac 0.0 2 36.3 MB Intel (64 bit)
316 lsboxd tmac 0.0 2 3.1 MB Intel (64 bit)
2376 maspushagent tmac 0.0 2 5.2 MB Intel (64 bit)
5142 mdworker tmac 0.0 3 7.1 MB Intel (64 bit)
5157 mdworker tmac 4.7 6 6.6 MB Intel (64 bit)
4996 mdworker tmac 0.0 4 22.1 MB Intel (64 bit)
CPU
System Memory
Disk Activity
Disk Usage
Network
% User: 29.15
% System: 9.87
% Idle: 60.99
Threads: 666
Processes: 128
CPU Usage


00110110
00000000
00000000
00000101
00111001
10101011
100
101
102
103
104
105


00000000 00000000 00000 101 00 111 001
101
102
103
104

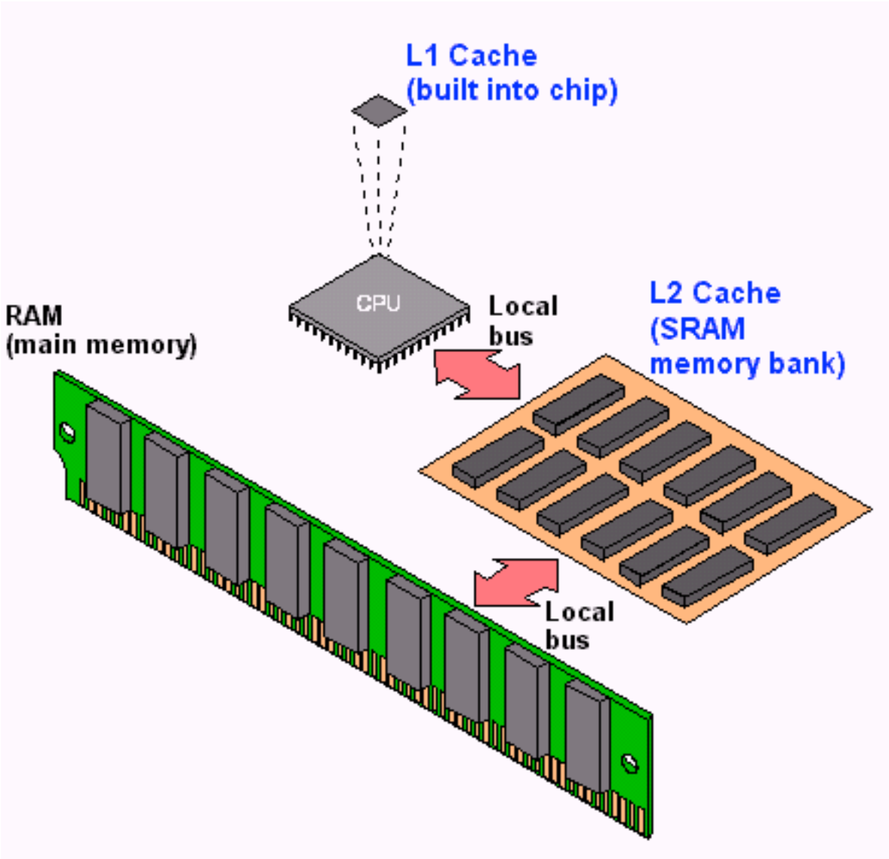
Big-Endian

00111001000001010000000000000000

104 103 102 101

Little-Endian

Cache

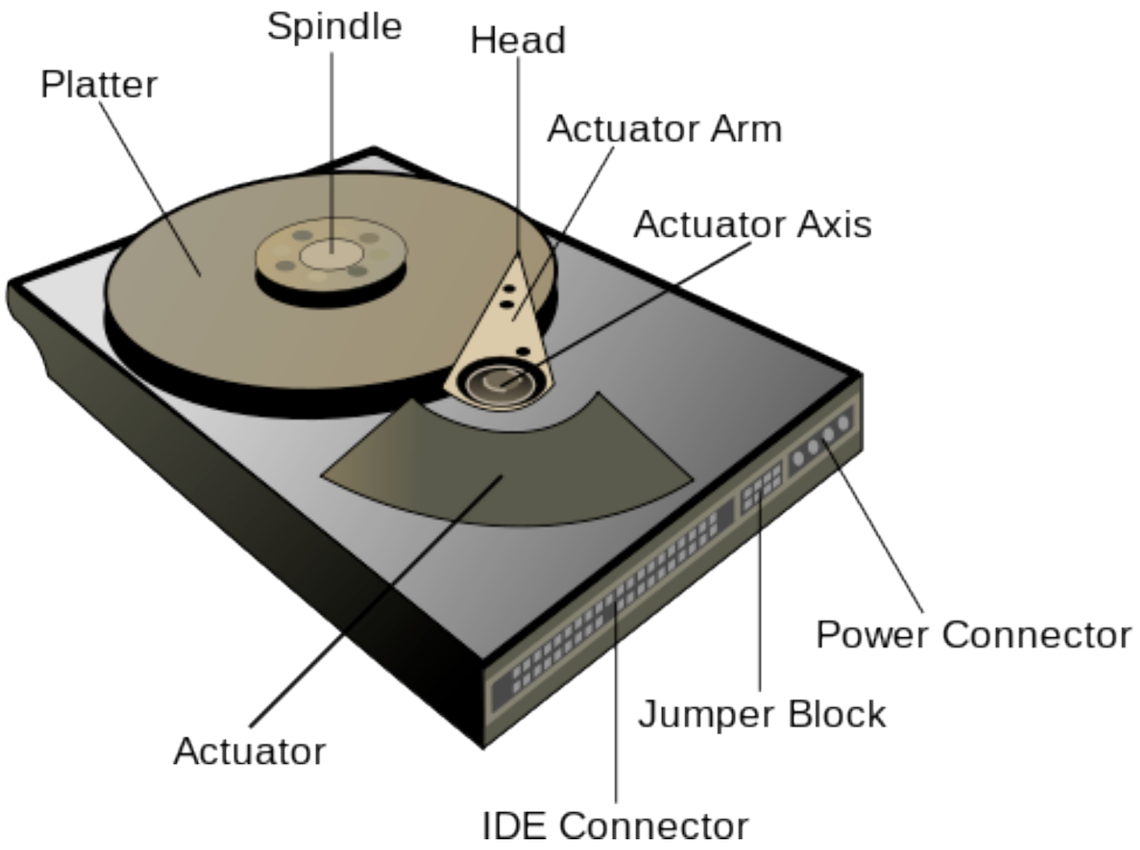

L1 Cache
(built into chip)
CPU
Local
bus
L2 Cache
(SRAM
memory bank)
RAM
(main memory)
Local
bus


CPU
RAM
Hard Drive

Hard Disk Drive


WARRANTY
VOID
IF REMOVED


PAA


Spindle
Head
Platter
Actuator Arm
Actuator Axis
Power Connector
Jumper Block
Actuator
IDE Connector

http://www.youtube.com/watch?v=kdmLvl1n82U

Filesystems

HDD Performance

- **seek time**: position platters and read-write head
- **data rate**: transfer data to motherboard

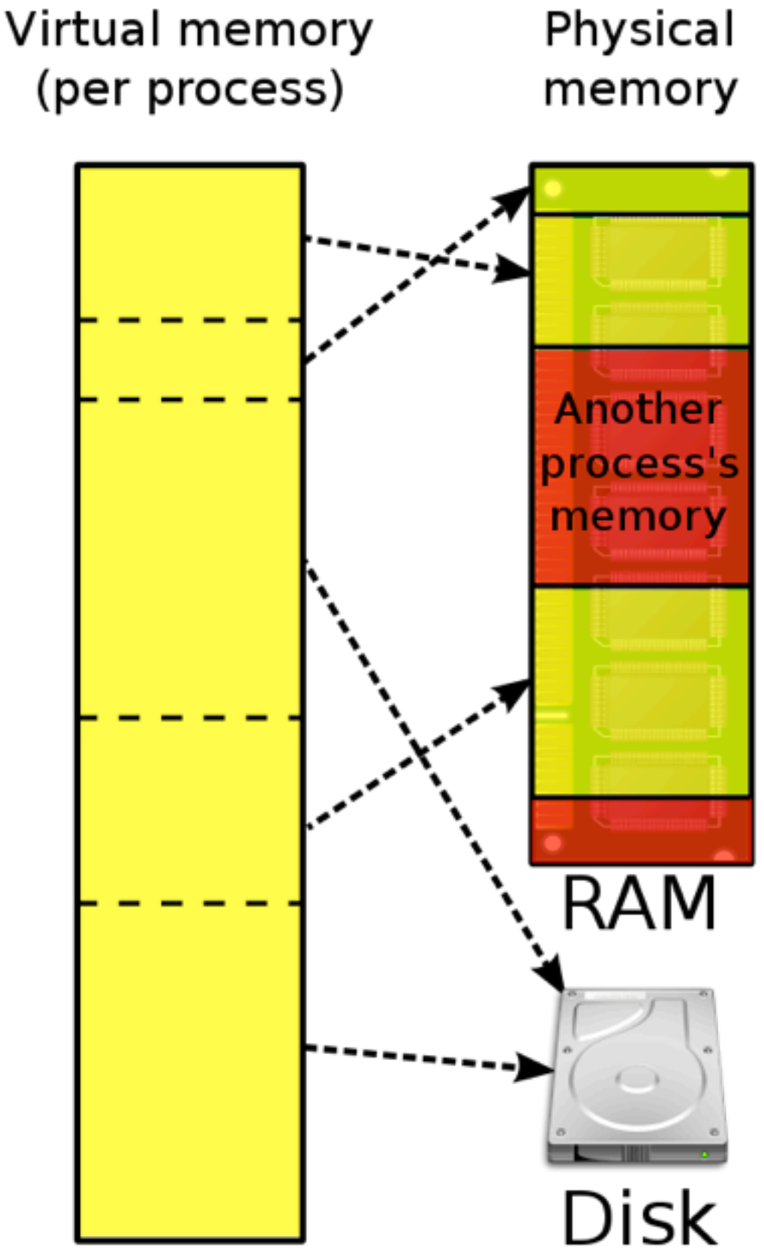
Solid State Drive

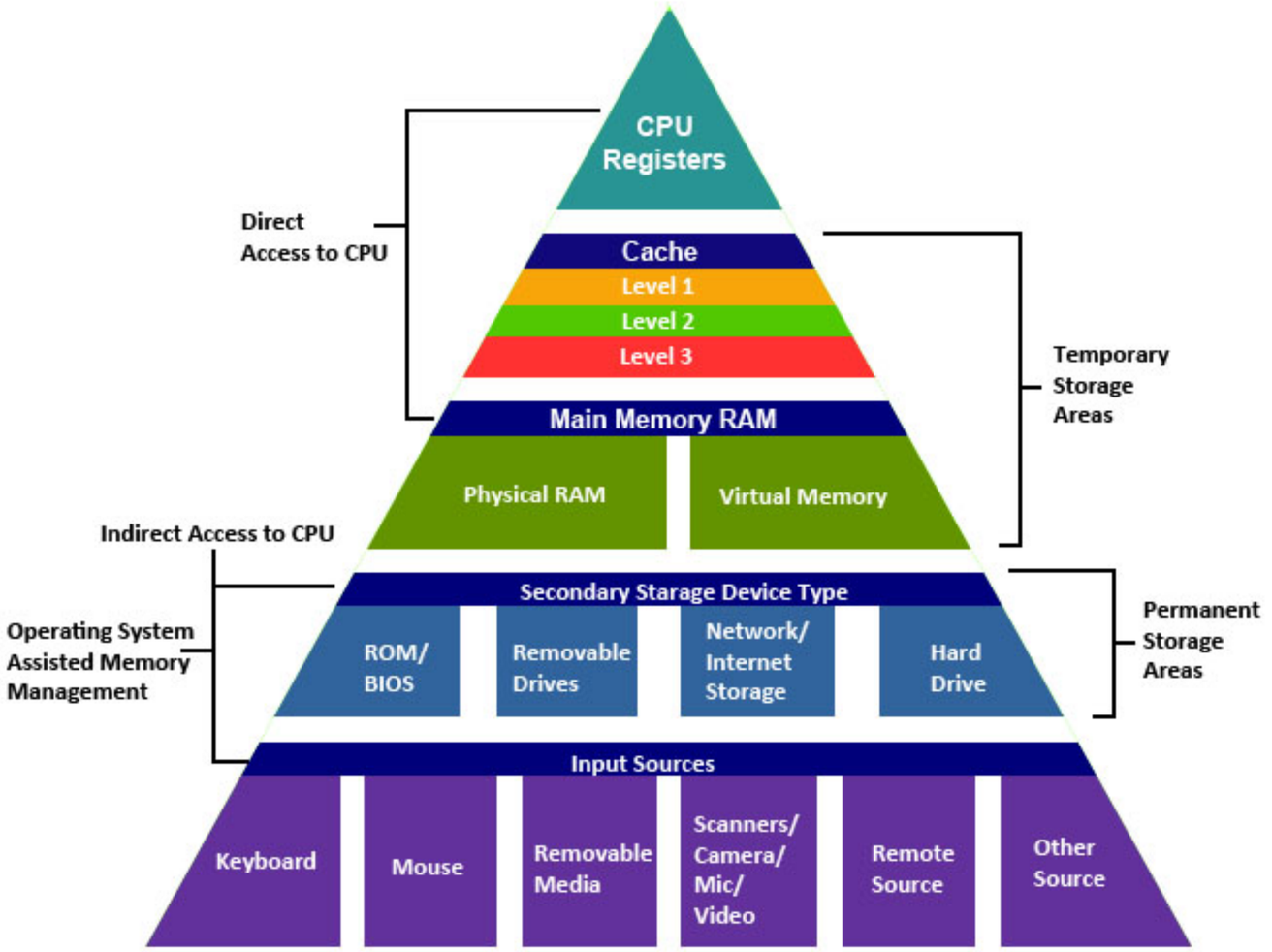

TOSHIBA
SD
Solid State Drive
128 GB

http://www.youtube.com/watch?v=j84eEjP-RL4

Flash Memory

Virtual Memory


Virtual memory
(per process)
Physical
memory
Another
process's
memory
RAM
Disk


CPU Registers
Direct Access to CPU
Cache
Level 1
Level 2
Level 3
Main Memory RAM
Physical RAM
Virtual Memory
Temporary Storage Areas
Indirect Access to CPU
Secondary Starage Device Type
Operating System Assisted Memory Management
ROM/ BIOS
Removable Drives
Network/ Internet Storage
Hard Drive
Permanent Storage Areas
Input Sources
Keyboard
Mouse
Removable Media
Scanners/ Camera/ Mic/ Video
Remote Source
Other Source

Capacity

L1 cache	64 kilobytes
L2 cache	8 megabytes
1 MB from RAM	4 gigabytes
1 MB from SSD	256 gigabytes
1 MB from HDD	1 terabyte

Performance

L1 cache	0.5 nanoseconds	
L2 cache	7 nanoseconds	
1 MB from RAM	0.25 milliseconds	
1 MB from SSD	1 millisecond	
1 MB from HDD	20 milliseconds	

L1 cache	0.5 nanoseconds	blink of an eye
L2 cache	7 nanoseconds	
1 MB from RAM	0.25 milliseconds	
1 MB from SSD	1 millisecond	
1 MB from HDD	20 milliseconds	

L1 cache	0.5 nanoseconds	blink of an eye
L2 cache	7 nanoseconds	4 seconds
1 MB from RAM	0.25 milliseconds	
1 MB from SSD	1 millisecond	
1 MB from HDD	20 milliseconds	

L1 cache	0.5 nanoseconds	blink of an eye
L2 cache	7 nanoseconds	4 seconds
1 MB from RAM	0.25 milliseconds	2 days
1 MB from SSD	1 millisecond	
1 MB from HDD	20 milliseconds	

L1 cache	0.5 nanoseconds	blink of an eye
L2 cache	7 nanoseconds	4 seconds
1 MB from RAM	0.25 milliseconds	2 days
1 MB from SSD	1 millisecond	1 week
1 MB from HDD	20 milliseconds	

L1 cache	0.5 nanoseconds	blink of an eye
L2 cache	7 nanoseconds	4 seconds
1 MB from RAM	0.25 milliseconds	2 days
1 MB from SSD	1 millisecond	1 week
1 MB from HDD	20 milliseconds	4.5 months

Shopping!

Factors to Consider

- display
- weight
- resolution
- CPU cores
- CPU cache size
- RAM size
- storage capacity
- HDD / SSD
- peripherals
- keyboard

Summary

CPU

- instruction set
- pipeline
- parallelism
- superscalar
- multi-core
- clock speed
- Moore's Law
- Megahertz Myth

Memory

- byte, kilobyte, megabyte
- registers
- RAM
- addressing
- big-endian, little-endian
- caching
- L1 cache, L2 cache, L3 cache
- hard disk drive
- platters, tracks, sectors
- read-write heads
- file allocation table
- seek time, data rate
- solid state drive
- flash memory

Computer Science E-1

Lecture 2: Hardware