Lecture 8
Computer Systems

DM2112
Digital Entertainment Systems

Lecture 8

Computer Systems

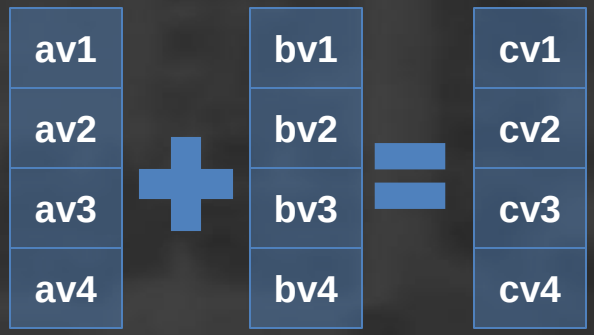
PROCESSOR PIPELINE

Recall : Vector & Scalar Processors

- Scalar
  - 1 instruction, 1 data at a time
  - SISD processor
    - Single instruction single data

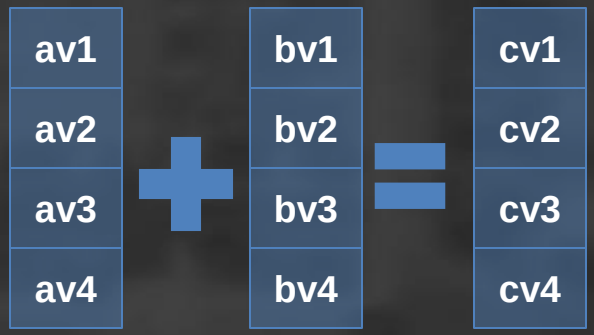
Recall : Vector & Scalar Processors

- Vector
  - 1 instruction, multiple data at a time
  - SIMD processor
    - Single instruction multiple data



Recall : Vector & Scalar Processors

- SIMD
  - Commonly do 4 calculations per set of vector
    - E.g. PS3 CELL Processor
  - In some instances 16 calculations per vector



Improving Computing Speed

- Vector processing is one way to improve computing speed

Example of Vector Processors:

- **Cell BE Processor (in PS3)**
- **Newer Intel/AMD x86 processors**
  - **AMD 3DNow!, Intel MMX, SSE, SSE2, SSSE3, SSE4, FMA3, FMA4, AVX, etc**

Example of Scalar Processors:

- **Earlier Intel chips (i.e. Intel 4004/8086/80286/80386)**
- **Earlier PowerPCs (i.e. PowerPC 603)**

- Pipelining is what we will be looking at today as another method to improve computing speed

What is Pipelining?

- Processing set of data processing elements in series
  - Output of one element is the input of the next one
  - Often executed in parallel or time-sliced fashion

What is Pipelining?

Pipelining : An Analogy – Factory Production

	Worker 1	Worker 2	Worker 3	Worker 4
1st Hour	Process Raw Materials	Nothing to Do	Nothing to Do	Nothing to Do
2nd Hour	Process Raw Materials	Assemble Parts	Nothing to Do	Nothing to Do
3rd Hour	Process Raw Materials	Assemble Parts	Put Toy in Shrink Wrap	Nothing to Do
4th Hour	Process Raw Materials	Assemble Parts	Put Toy in Shrink Wrap	Put in package
5th Hour	Process Raw Materials	Assemble Parts	Put Toy in Shrink Wrap	Put in package

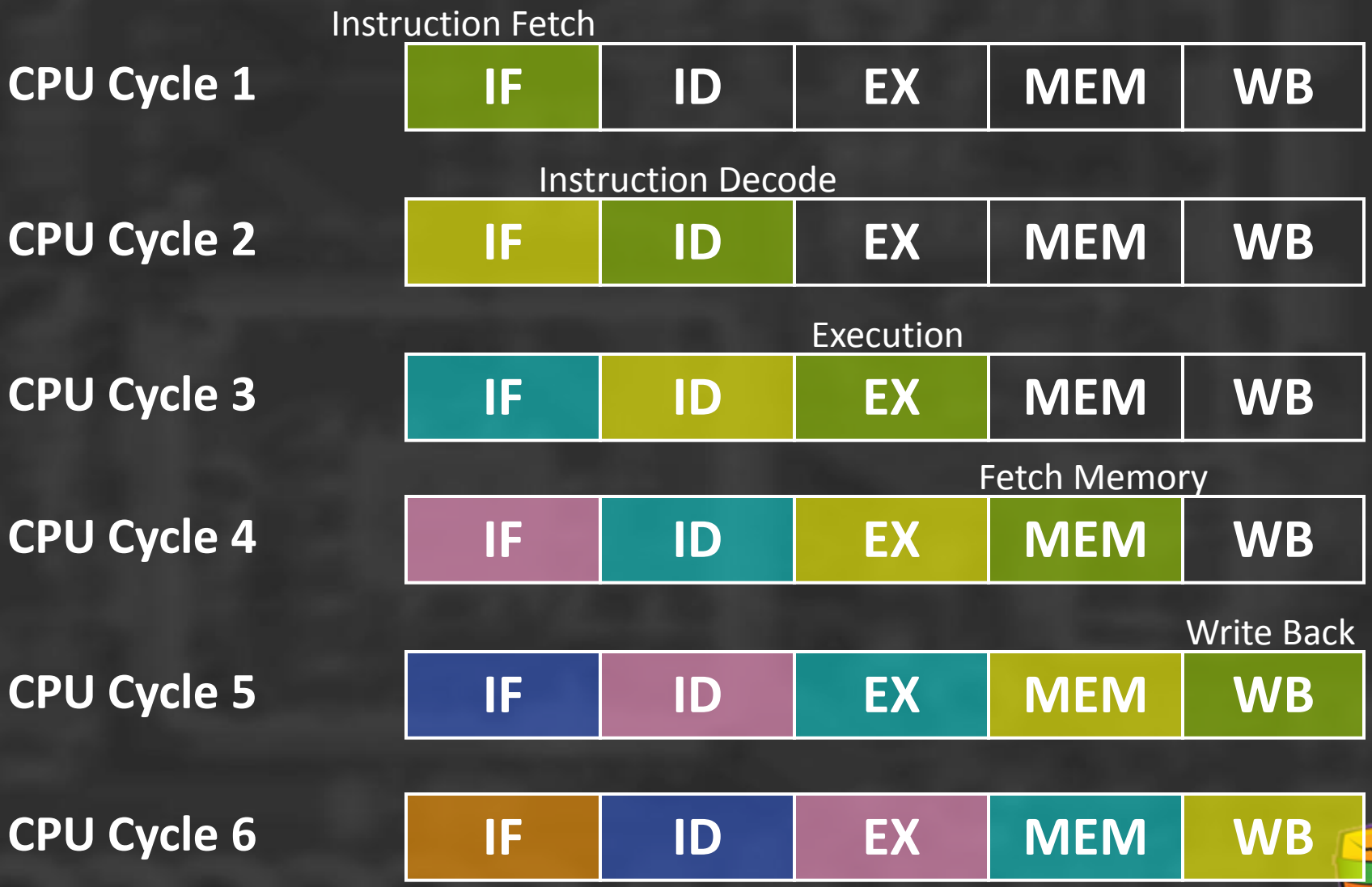
It takes a while for the whole pipeline to be filled.

Production will reach a point where every hour, a toy is ready.

Pipelining used in Computing

- Instruction Pipelines
  - Used in processor
  - Allow overlapping execution of multiple instructions within the same circuitry
- Graphics Pipelines
- Software Pipelines

Instruction Pipeline

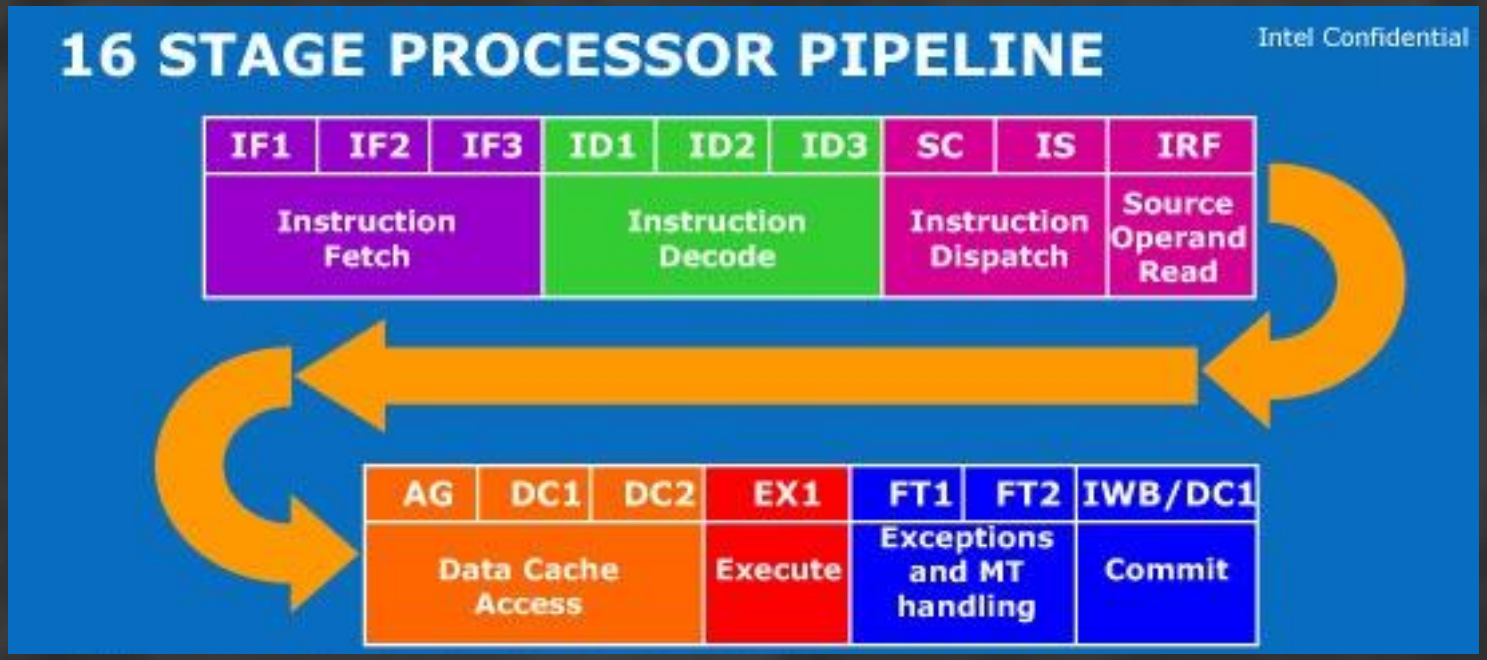


Instruction Pipeline

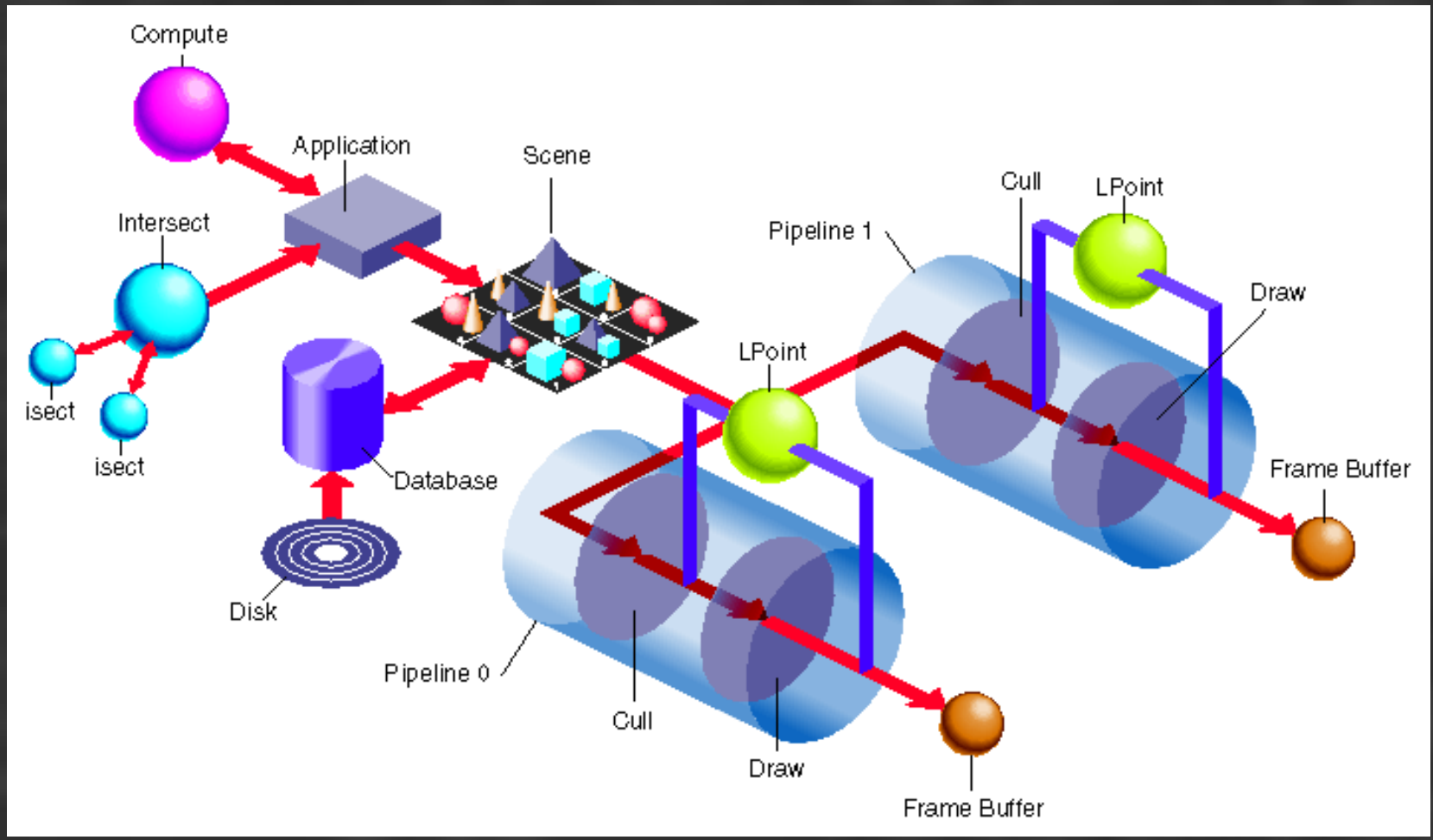
- IF - Instruction Fetch unit
  - typically referred to as "the load unit" in modern terminology
- ID - Instruction Decode unit
  - this unit gets instruction from IF, and extracts opcode and operand from that instruction. It also retrieves register values if requested by the operation.
- EX - Execution unit
  - runs the instructions, typically referred to as the ALU in modern terminology
- MEM - Memory access unit
  - the MEM unit fetches data from main memory, under the control of the instructions from ID and EX.
- WB – Write Back unit
  - typically referred to as "the store unit" in modern terminology.

Example: Intel Atom Pipeline

- Has 16 stages (versus 31 stages of a pentium D)



Graphics Pipeline



Short Pipeline VS Long Pipeline

- Shorter Pipeline
  - Lower chance for pipeline stall
  - Lower latency – takes a shorter time for pipeline to load up
  - Shorter pipelines = larger work per pipeline task
    - More difficult to optimise, harder to push for higher clock frequency

- Longer Pipeline
  - Smaller work unit per pipeline task – easier to optimise performance for each
  - Makes it easier to push for higher clock rate
  - Longer pipeline increase chance for stalls
    - i.e. Branch prediction makes an incorrect choice. Processor stops & flush existing commands. Wasted execution time

Lecture 8

Computer Systems

COMPUTER SYSTEMS

Computer System Classes

- Computer Systems are available in many configurations

- Depends on
  - CPU power
  - Storage capacity
  - I/O capacity
  - Number of users
  - Intended application software

Computer System Classes

- Microcomputer (PC/WorkStation)
- Midrange Computer
- Mainframe
- Supercomputer

Microcomputer (PC/WorkStation)

- Computer system designed to meet the information processing needs of a single user.
- Can be also called a PC or workstation.
- New type of microcomputer from the late 1990s
  - is the Network computer with minimal secondary storage capacity and
  - little or no installed software.
  - Slightly less expensive than ordinary microcomputers.
  - Network computer establishes a connection to a server when it is powered on. Server then transfers operating systems and application software via a computer network

Microcomputer

- Designed to meet information processing needs of a single user

The Commodore 64. Was one of the world's most popular microcomputers, best selling home computer of all time.

It had 64kB RAM (and 20 kB ROM). There was no external storage. Cassette tape player/recorder, floppy disk drive, and dot matrix printer all sold separately.

Mainframe

- Used mainly by large organizations for critical applications, typically bulk data processing
  - such as census, industry/consumer statistics, ERP (**Enterprise Resource Planning** systems), and financial transaction processing.
- Can also respond to thousands of simultaneous requests for shared resources.

Mainframe

- Designed to handle very high volume input and output (I/O).
- Since the mid-1960's, mainframe designs have included several subsidiary computers (called *channels* or *peripheral processors*) which manage the I/O devices,
  - leaving the CPU free to deal only with high-speed memory.
- Common in mainframe shops to deal with massive databases and files.
  - Giga-record or tera-record files are not unusual.
- Compared to a typical PC, mainframes commonly have hundreds to thousands of times as much data storage online, and can access it much faster.

Mainframe

- Have unique execution integrity characteristics for fault tolerant computing.
  - System z9 servers execute each instruction twice, compare results, and shift workloads "in flight" to functioning processors, including spares, without any impact to applications or users.
  - This feature, also found in HP's NonStop systems, is known as lock-stepping, because both processors take their "steps" (*i.e.* instructions) together.
  - Not all applications absolutely need the assured integrity that these systems provide, but many do, such as financial transaction processing.

Mainframe

- Handles information processing needs of a large number of users and applications

Midrange Computer

- In general, midrange refers to computers that are
  - more powerful and capable than personal computers but
  - less powerful and capable than mainframe computers.
- It's a designation used by IBM.
- Midrange computers provide information processing for multiple users and to execute many application programs simultaneously.
  - It requires sophisticated system software than is typically installed on microcomputers.
  - Midrange computer can support several dozen people using video display terminals.

Midrange Computer

- Provides Information processing for multiple users

IBM System/38

iSeries from IBM

Why Midrange & Mainframe?

- Very common especially in around 1980s to late 1990s.
- High-end processors were very expensive.
- Commonly deployed as shared commodity.
  - A lot of focus on thin client concepts in that era
  - What's a thin client? Research on it ☺

Interacting with a Mainframe

- There were 2 ways to interact with a mainframe.
  - Time sharing
  - Batch processing

- Time sharing – the mainframe gives each user a slice of its processing time in a round-robin fashion.

- Batch processing – the mainframe gives its full attention to a user, so that the user's program can be run without interruption.

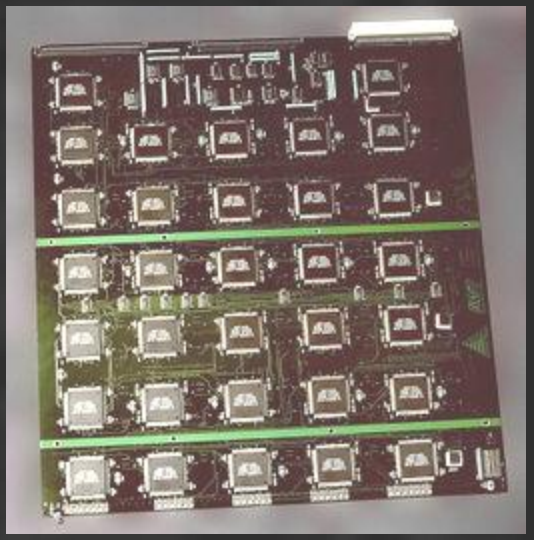
- http://www.computersciencelab.com/ComputerHistory/HistoryPt4.htm

Supercomputer

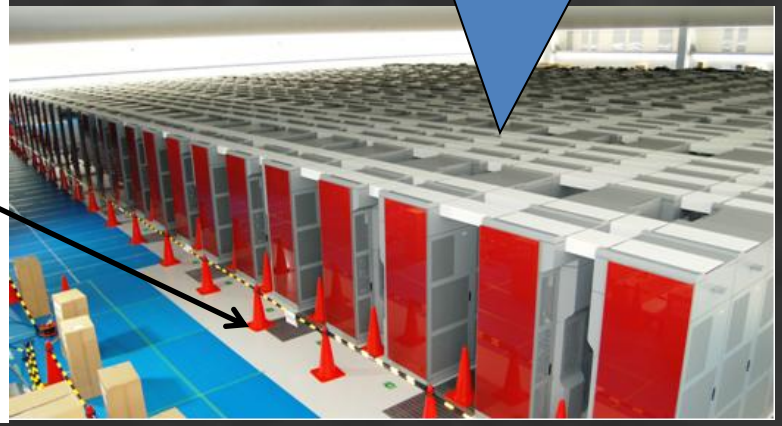
- Designed for 1 purpose
  - rapid mathematical computation.
- It leads the world in terms of processing capacity, particularly speed of calculation, at the time of its introduction.

Supercomputer

- Rapid Mathematical Computation
  - Either build for special-purpose or general-purpose use.



RIKEN & Fujitsu's K Computer. Currently world's fastest supercomputer. Calculates 8,162 petaflops.

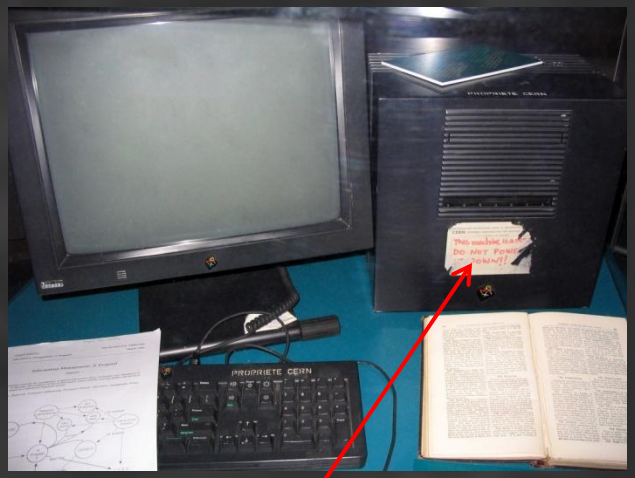


The K Computer has 672 equipment racks that contain a current total of 68,544 CPUs. It will be available to users around the world in 2012.

Deep Blue by IBM was a special-purpose supercomputer for playing chess.

Servers

- Also called host computers
- Manages one or more shared resources
  - Such as file systems, databases, websites
  - First web server built in 1989
- Allow users to access those resources over a local- or wide-area network
  - Modern-day servers can be very compact in size

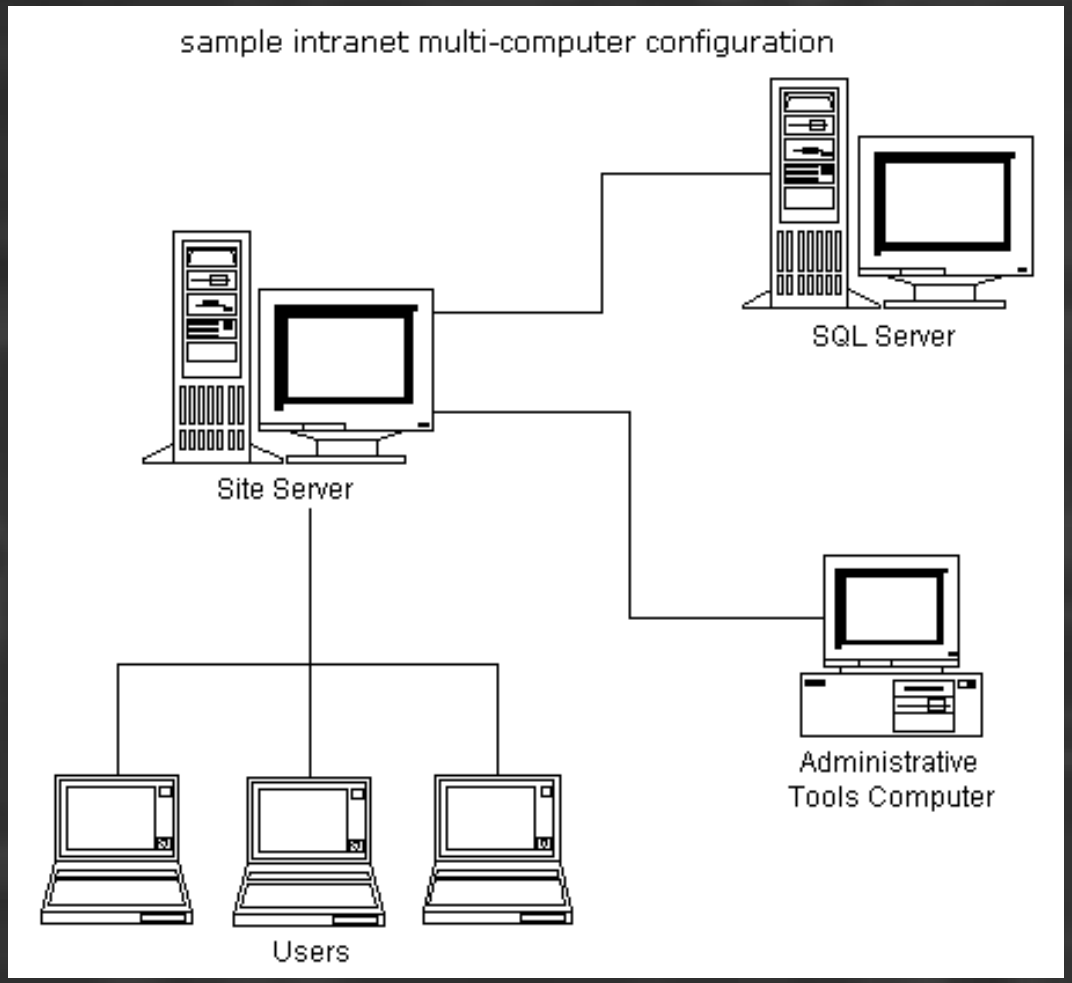


"This computer is a server. DO NOT POWER DOWN!!"

Servers

- Mainly serving the whole network that it is connected to in any form,
  - whether by queueing up the printing jobs of several users,
  - to even acting as a file server for applications that online terminals could access.
- Should not be confused with mainframes,
  - which are very large computers that centralize certain information-processing activities in large organizations and may or may not act as servers in addition to their other activities.
  - Many large organizations have both mainframes and servers, although servers usually are smaller and much more numerous and decentralized than mainframes.
- The term ‘server’ implies a specific mode of use,
  - it does not imply any minimum set of hardware capabilities.

Multicomputer Configurations



Multicomputer Configurations

- Cluster
  - Connected by high speed network that cooperates to provide services
    - Or execute a common application
  - Ensure reliability of service (ie. 1 main, 1 backup)

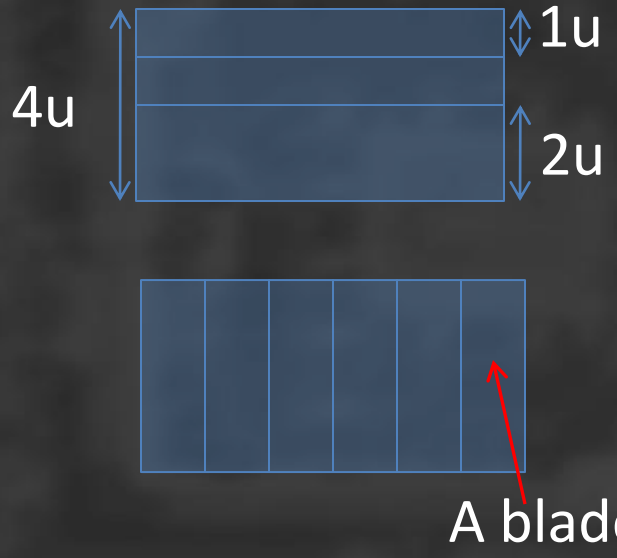
Cluster

- Group of similar or identical computers
  - works like a single large web server
- Group of coupled computers that work together closely
  - Can be viewed as though they are a single computer.
- The components of a cluster are commonly, but not always, connected to each other through fast local area networks.
  - Clusters are usually deployed to improve performance and/or availability over that provided by a single computer, while typically being much more cost-effective than single computers of comparable speed or availability.

Cluster

Blade

- Circuit board that contains most of a server computer



Blade

- is a specialized cluster.
- Has same advantages and disadvantages as a cluster.
  - Simpler to modify a blade configuration as compared to a cluster configuration.
- Blade also concentrate on more computing power in less space than a typical cluster.
- Blade servers are ideal for specific purposes such as
  - web hosting and cluster computing.
  - Individual blades are typically hot-swappable.
  - As more processing power, memory and I/O bandwidth are added to blade servers,
    - they are being used for larger and more diverse workloads.

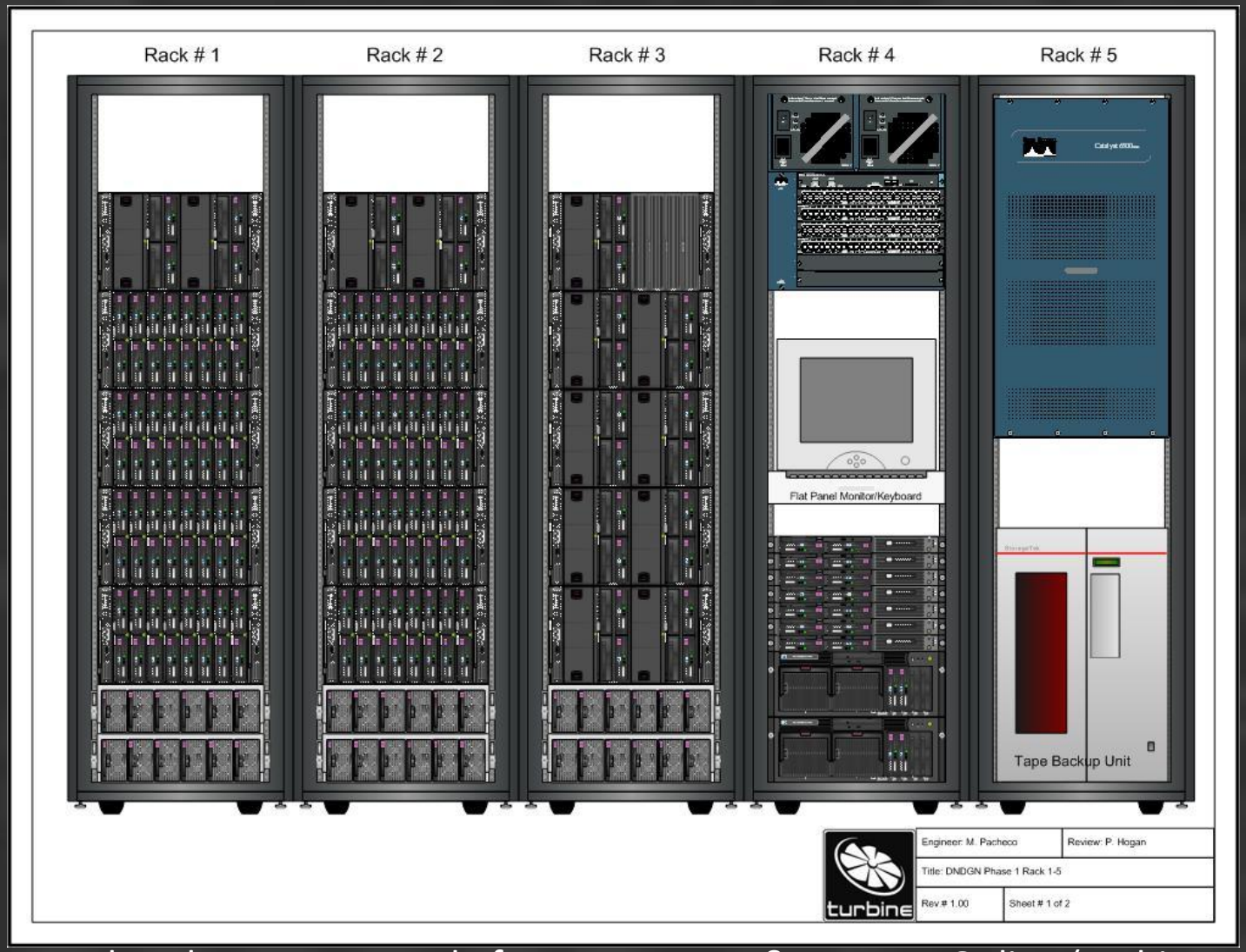
Grid

- Group of dissimilar computer systems
  - Connected by high speed network
- Cooperate to provide services or execute a common application.
- Grids can be implemented typically by installing the software on each machine that
  - accepts tasks from a central server and
  - performs them when not busy doing other work.

Grid VS Cluster

- Computers do not need to be located close together
  - can be separated in different buildings
- Work cooperatively at some times and independently at others

Example of Real-World Server Racks



Actual Rack Layout Example from Dungeons & Dragons Online (Turbine Ent.)

Lecture 8

Computer Systems

POWER

A little bit of Physics & Atomic Science

- Atoms are made up of nucleus (containing neutrons & protons) and electrons that orbit it.

Metallic elements (e.g. copper which is used in making electric wires) have a special property.

Some electrons are loosely held by atomic structure.

If electric current is applied, electrons can 'jump' from 1 atom to the next, which creates electric power

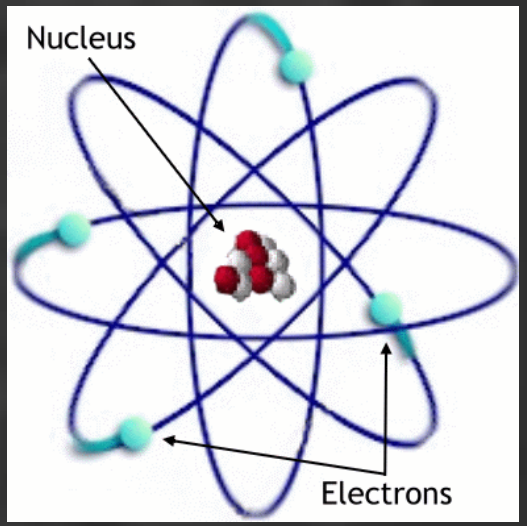
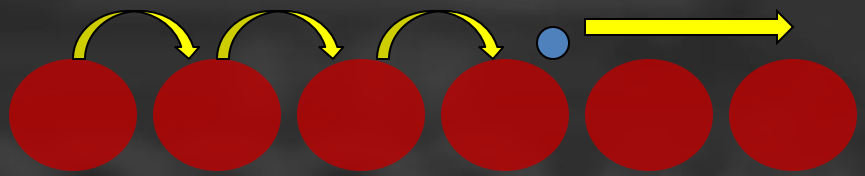


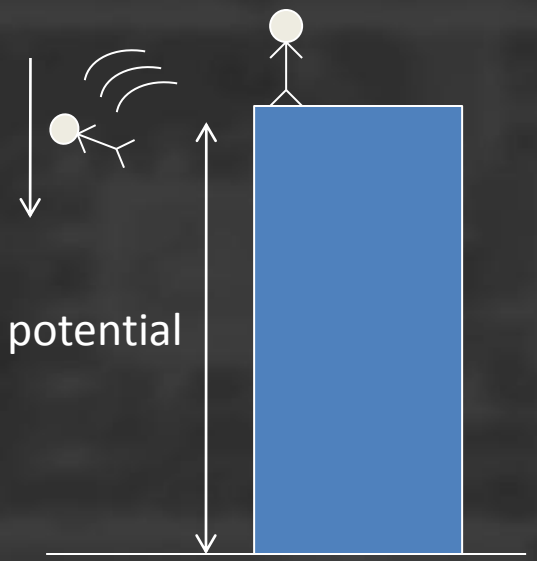
Image from US Dept of Energy

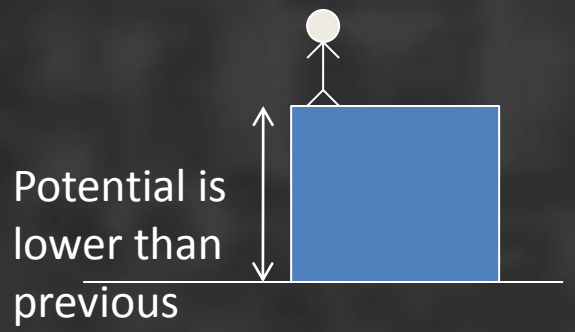


Power

- Current – “Speed” at which electrons flow
- Voltage – Electric Potential

Falling speed (i.e. gravity) can be seen as an analogy for concept of electric current





Power

- Measure of electric power that a device consumes is the Watt (W).
  - Watt is the electric work done (i.e. amount of processing done)
  - Watt is also the waste heat generated
- Manufacturers state the maximum amount of power in a computer that a cooling system must be able to dissipate as the Thermal Design Power (TDP), also called Thermal Design Point.
  - So the TDP value shows the maximum power that the component can produce.
- Some computer components that consume power:
  - CPU
    - E.g consumer ultra low voltage (CULV) processors – TDP is 10W
    - I7-3770K – TDP is 77W
  - GPU
    - e.g. GeForce 9800 GX2 – TDP is 197W
  - HDD spinning
  - Motherboard & its Devices

Power

- About power usage in general:

$$W = V^2 / R = I^2 x R = V x I$$

W – Power (Watt)

V – Voltage (Volts)

I – Current (Ampere)

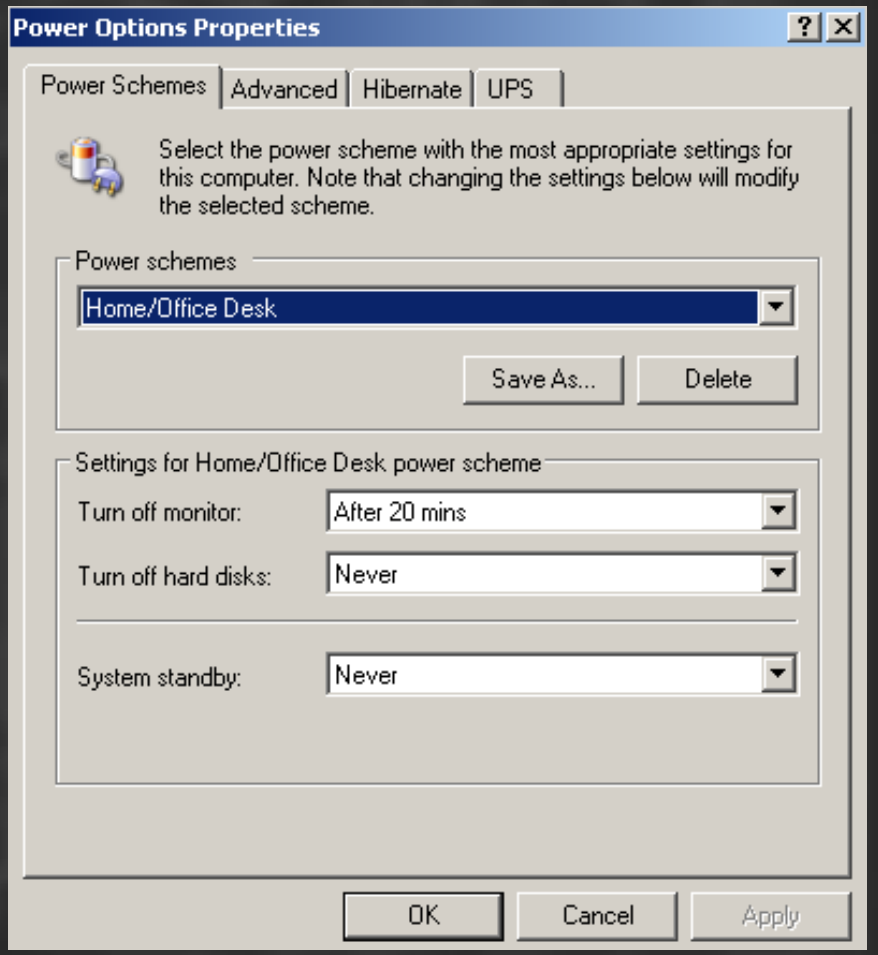
R – Impedance/Resistance (Ohms)

You can figure out how much power your laptop's power supply uses by taking a look at the output current and output voltage.

Multiply these 2 values together to get the power consumption of your laptop (in Watts).

Power Management - ACPI

- All modern computer systems have a way to monitor and reduce power consumption by e.g. turning off hardware when not in use.
- The Advanced Configuration and Power Interface (ACPI) standard allows the operating system to discover and configure devices, and manage and monitor the power consumption of these devices.
- In order for the hardware to be able to “tell” the operating system about itself and how much power it’s using, the device must be ACPI-compliant.



Power Management – Energy Star

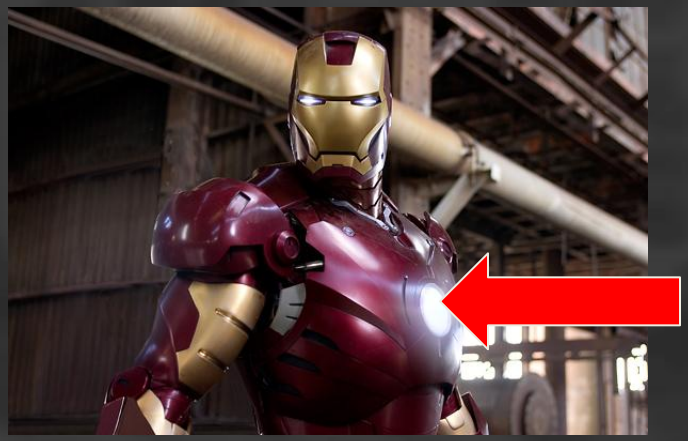
- Energy Star is an international standard for energy efficient consumer products.
- If a device meets the Energy Star requirements, it will have the Energy Star label on it.
  - The current Energy Star version is 5.0
- Some of the Energy Star specifications:
  - Air conditioners are at least 10% more efficient
  - Televisions use at least 30% less energy
  - Flourescent lights use up to 75% less energy, and last 10 times longer
  - Computer power supplies must be 80% efficient, i.e. only 20% of the electric energy produced is given off as heat. This is called the 80 PLUS certification.
    - 80 PLUS also has a Bronze, Silver, and Gold standard.
- There is a separate standard for computer servers.

Power & Laptops

- Power consumption / Heat output is a major consideration for Notebooks too
- i.e. Mobile version CPU & GPU
  - ↓ power consumption
  - ↓ heat output
  - ↓ processing power
- Generally, when semiconductor process improves
  - i.e. From 65nm process → 45nm process → …
  - ↓ operating voltage, ↓ power used, ↓ waste heat
  - ↑ energy efficiency

Laptop Power Considerations

- Fastest CPU & GPU not necessarily a good thing
  - They require more power to run
- Battery technology today is still limited
  - Today's batteries are still chemical-based



We're still a long way to discovering 'perpetual energy'

Power & Servers

- Power consumption per PC/Server is important
  - In a datacentre, there are commonly hundreds (or thousands) of servers.
  - Each server has CPU, GPU, Motherboard, RAM, HDD, etc.
  - Costs $$ to keep servers running (i.e. electric bills).
  - Servers generate waste heat (require cooling)
    - Requires more $$

Power & Servers

- A useful read on Analyzing server power consumption & costs:
- http://mvolo.com/blogs/serverside/archive/2009/02/01/Analyzing-server-power-consumption-and-costs.aspx

Next Lecture

COMPUTER DISPLAYS