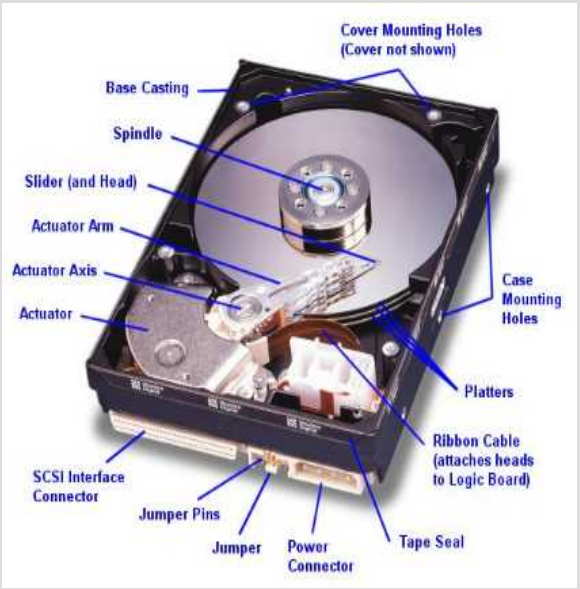
Hardware: The CPU & Storage



- Chapter 4 in book...

Homework Due Today...

- What is Bell Labs?
  - Three inventions...
  - People there...
- Museum computer specs...
- Modern computer specs...
- IPod touch specs...
- HTML progress
  - If still need help, feel free to email about an appointment...important that you get it working eventually even if it's a little “late”; can still get full credit since there seems to be some confusion

Electricity

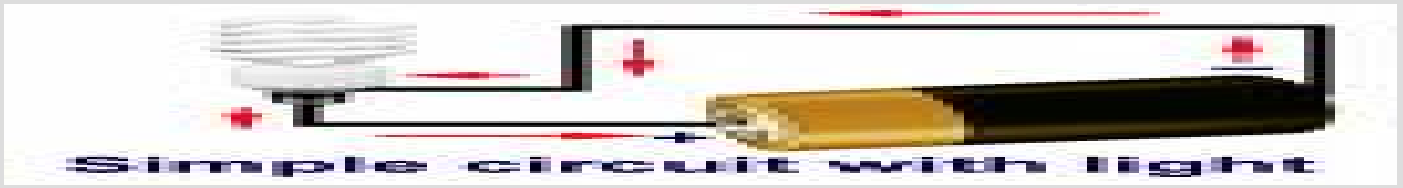
- Computers run on electricity
  - Key component of electricity: it's either on or off
  - Analogous numeric system: BINARY
    - Digit is either 0 or 1, where each 0 or 1 is called a **bit**
    - All data and program instructions represented in terms of binary numbers
    - Example: letter “G” represented as 01000111
      - This is a group of 8 bits, called a byte

Power Supply

- Electricity from standard wall outlet is alternating current (AC)
- Microcomputer runs on direct current (DC)
  - Power supply – device that converts AC to DC to run computer
- Electrical power from standard AC can be uneven
  - Sudden surge in AC voltage can burn out low-voltage DC circuitry in computer (called “fry the motherboard”)
  - Good idea to plug computer into power protection device
    - Surge protector, voltage regulator, and UPS
    - Rated in joules: higher # joules, more power protection

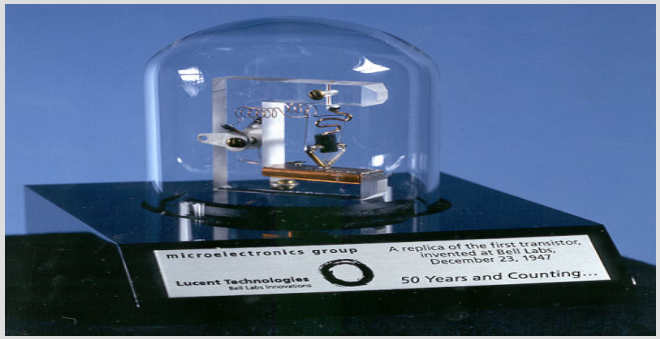
The Circuit

- **Definition**: closed path followed or capable of being followed by electric current
  - Needed to control electricity
- "Something" is needed to control the flow of electricity
  - At first, this something was vacuum tubes
  - Computers with vacuum tubes suffered from tube failure and it took time to replace faulty tubes
  - Early computers using vacuum tubes did beat manual computation in running time



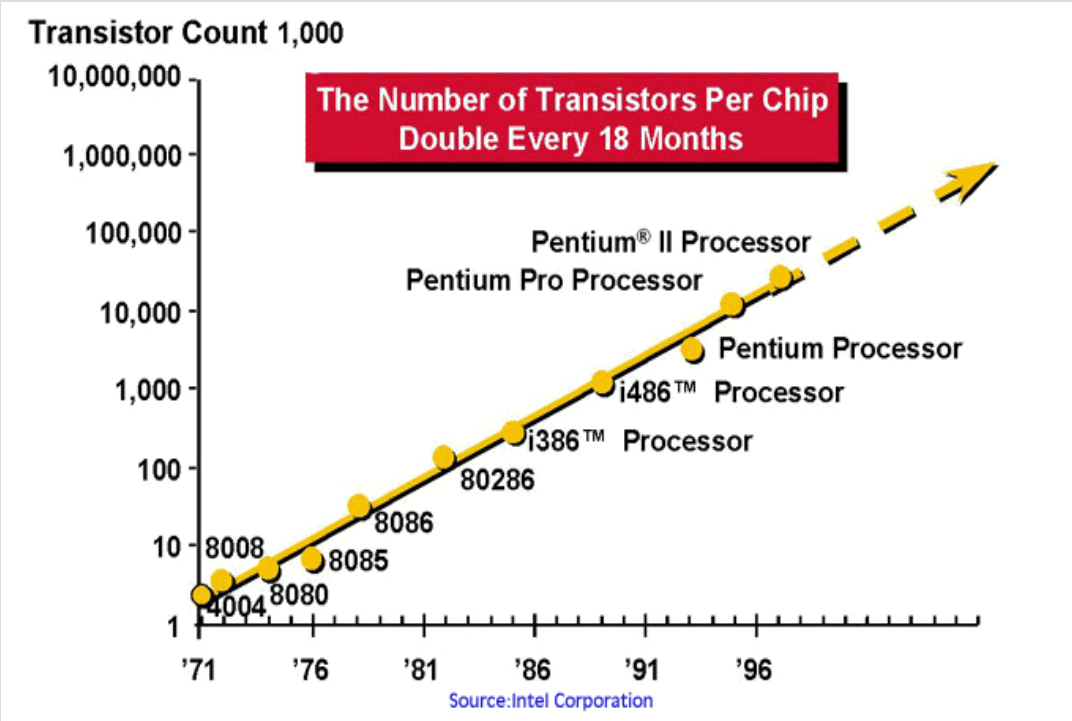
Then Came the Transistor...

- **Transistor**: a tiny electrically operated switch/gate that can alternate between “on” and “off” millions of times per second
  - Developed at Bell Labs in 1947
  - Replaced vacuum tubes
  - First transistors were “one-hundredth the size of a vacuum tube, needed no warm-up time, consumed less energy, and were faster and more reliable”
  - Size of transistors continues to decrease



Moore's Law

- Named for Intel cofounder Gordon Moore
  - Number of transistors that can be packed on a chip doubles every 18 months while price remains steady

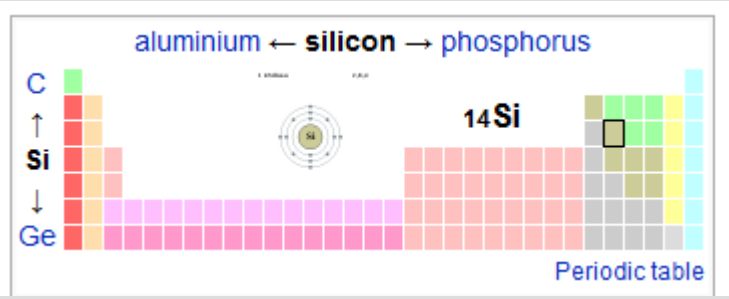


Electricity and Bits

- Remember that character “G” is represented as 01000111
  - In computer, character “G” represented by series of 8 transistors
    - Transistors in “off” position represent 0s, transistors in “on” position represent 1s

Silicon

- Silicon – element widely found in clay and sand
  - Critical properties of silicon
    - Cheap
    - Semiconductor – has partial resistance to electricity
      - Highly conducting materials can be overlaid on it
  - Silicon has no processor power by itself
    - Chip – piece of silicon that contains millions of integrated electronic circuits



The Microchip

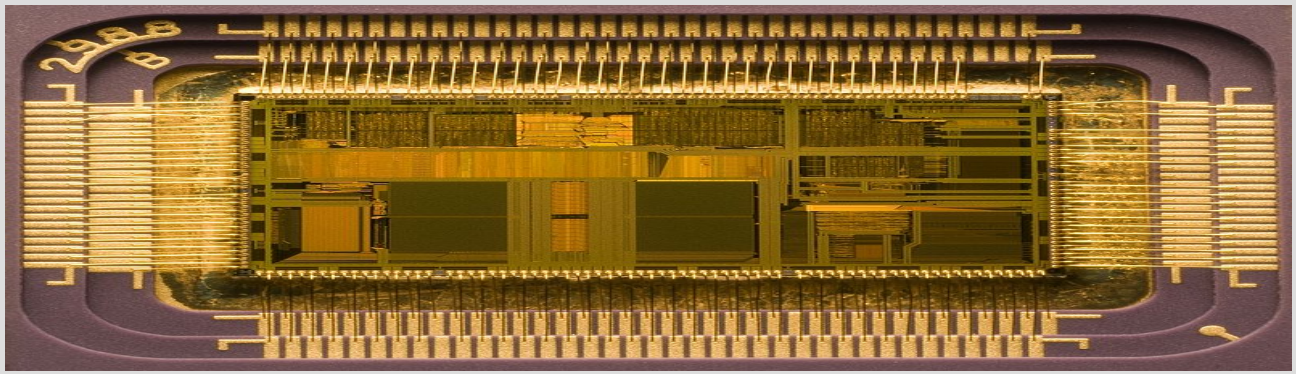
- Microchips – called “industrial rice” by Japanese
- Store and process data in electronic gadgetry
- Different kinds of microchips
  - Examples include microprocessor, memory, logic, communications, graphics, and math co-processor chips

The Microprocessor

- Microprocessor – miniaturized circuitry of a computer processor
  - Called microcontrollers/embedded computers when used in machines other than computers
- Called “The most important invention of the 20th Century” by Michael Malone, author of The Microprocessor: A Biography
  - “Just as (the human being) is an animal, yet transcends that state, so too the microprocessor is a silicon chip, but more”
- Portability of computing thanks to microprocessor generally taken for granted today

CPU (processor) Parts

- Processor also called CPU (central processing unit)
  - “brain” of computer
  - Works with “main memory” to perform processing
  - Follows instructions of software to manipulate data into information
  - Consists of control unit and arithmetic/logic unit (ALU)
  - Often hear about CPU in terms of size...such as 45 nm
    - Refers to size of transistor, which continues to shrink
  - Introduction to the CPU by Intel: http://www.youtube.com/watch?v=w6HMm-cBxp0



CPU Components

- **Control unit** – directs movement of electronic signals between main memory and ALU and also between main memory and input/output devices
- **Arithmetic/logic unit (ALU)** – performs arithmetic and logic operations and controls speed of operations
- **Registers** – high-speed storage areas that store data during processing
- **Buses** – electrical data roadways where bits are transmitted within the CPU and between the CPU and other motherboard components

Processing Speeds

- Processor contains a system clock
  - Controls speed of operations within a computer
  - Fixed vibrations from a quartz delivers a steady stream of “ticks” to the CPU
  - Microcomputer processor speeds generally given in gigahertz (GHz) – billions cycles per second
  - Intel's Pentium 4 as fast as 3.8 Ghz
  - Due to increasing power requirements and more heat emitted as the clock speed increases, Intel and AMD now focusing on multi-core rather than increasing clock speeds
    - Multicore processor – designed to let operating system divide work over multiple processors
    - Two or more processor cores on a single piece of silicon

Processing Speeds

Comparison of two top-of-the-line Intel processors:

Intel Core i7 Processor Extreme Edition

Compare Processor Numbers

Is faster always better? Yes, but it's not always what you should buy.

So as you evaluate the performance of the components below, don't analyze them in isolation from each other, but consider them interdependent partners that make up your projected system. And, keep in mind that your future needs—adding software from a growing family or a growing business—might be different later.

Processor Family	Processor Number	Cores/Threads	Clock Speed	Intel® QuickPath Interconnect	Intel® Smart Cache	Silicon	Intel® Turbo Boost Technology
intel Core i7 inside	i7-975	4 / 8	3.33 GHz	6.4 GT/sec	8 MB	45 nm	✓
	i7-965	4 / 8	3.2 GHz	6.4 GT/sec	8 MB	45 nm	✓

Challenges of Multicore

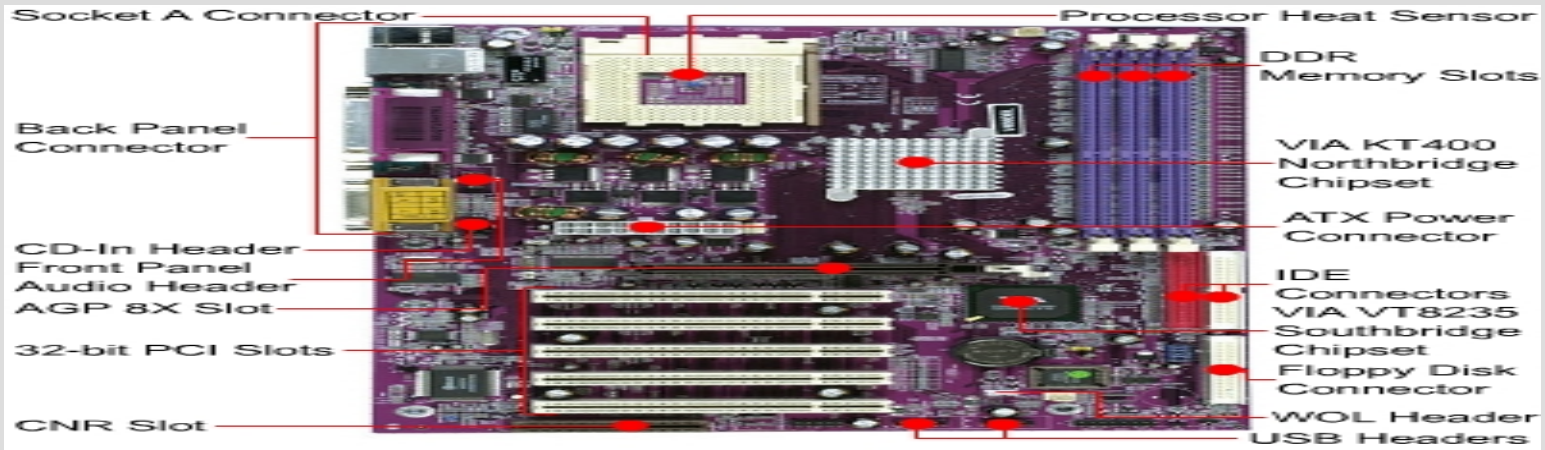
- Shift to multicore brings new programming challenges
  - With multicore, multiple instructions processed in parallel
  - However, sometimes one instruction (B) needs the result of a previous instruction (A), so instruction A must be processed before instruction B and they cannot be processed in parallel
    - **Can the following set of instructions run in parallel?**
      - Instruction A: x = 1 + 1;
      - Instruction B: y = 2 + 2;
    - **What about this set of instructions?**
      - Instruction A: x = 1 + 1;
      - Instruction B: y = x + 2;

Machine Cycle

- Method by which instructions are executed on the CPU
  - Consists of 4 steps:
    1. Fetches an instruction from memory
    2. Decodes the instruction (is it add?...multiply?...)
    3. Executes the instruction (initially result stored in register...this is temporary)
    4. Stores the result in memory on computer to be used as desired

The Motherboard

- Main circuit board in system unit
  - Flat board that fills one side of case
  - Contains removable and nonremovable computer components
    - Removable components allows for the capability of expand/upgrade computer system
- Motherboard can be thought of as computer's central nervous system
  - Microprocessor is the “brain” in this analogy



Computer Storage

- Storage types
  - **Primary storage** – internal computer circuitry that temporarily holds data waiting to be processed
  - **Secondary storage** – devices/media which stores data/information permanently

Computer Storage

- Primary storage
  - Temporary/working storage
  - Often called memory/main memory
  - Random access memory (RAM) chips used for main memory
    - Holds software instructions and data before and after it is processed by the CPU
    - Primary workspace inside computer
    - Example:
      - When file opened, copy transfers from hard disk to RAM
      - RAM copy of file changes as you work with file
      - When “save” command activated, RAM copy is transferred back to hard drive
  - RAM is volatile – contents lost when power of computer turned off

Types of RAM

- DRAM
  - Dynamic RAM – must be constantly refreshed by the CPU or will lose contents
- SDRAM
  - Synchronous dynamic RAM – synchronized by the system clock; faster than DRAM; expressed in megahertz/gigahertz
- SRAM
  - Static RAM – faster than DRAM; retains contents without being refreshed by CPU
- DDR-SDRAM
  - Double-data rate synchronous dynamic RAM
  - Newest type of RAM chip, most commonly used in PCs and Apple computers today (according to book...now DDR2 and DDR3 are available and sold in modern computers)

RAM on the modern computer

- Dell computer:
  - 4GB Shared Dual Channel DDR2 at 800MHz
    - Shared refers to sharing the system memory with the graphics card
    - Dual channel describes technology that doubles the speed of the memory using two RAM memory modules
    - DDR2 “employs an I/O buffer between the memory and the data bus so that the data bus can be run at the twice the speed of the memory clock. The two factors combine to achieve a total of 4 data transfers per memory clock cycle.”
    - DDR3 available on some computers which is double the speed of DDR2

Importance of RAM

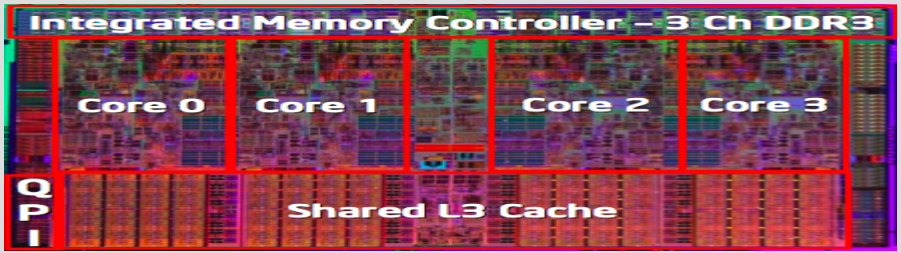
- More RAM -> computer performs better
  - If not enough RAM on the computer, then some processes must be stored on hard drive, which is much slower
    - Concept is called virtual memory; hard-disk space used to extend RAM capacity

Cache

- Pronounced “cash”
  - What do you know about cache regarding computers?

Cache

- CPU usually faster than system RAM
  - Needs to wait for information it retrieves from RAM
- Introducing...cache!
  - Cache temporarily stores instructions and data, just like RAM
    - Cache is faster than RAM, but there is less of it
    - Ideally used for instructions and data that the processor is likely to use frequently
    - Not possible to upgrade cache like RAM; set by processor purchased
- Types of cache
  - L1 cache – fastest, part of microprocessor chip
  - L2 cache – usually referred to in computer ads, outside of processor chip and consists of SRAM chips
  - L3 cache – separate from processor chip on motherboard



Other Method of Speeding up Processing

- Speed at which data can travel between memory and CPU critical to performance
  - This can be a bottleneck in the computer performance
- Multiple methods used to speed up data traveling between the memory and the CPU
  - **Interleaving**: CPU alternates communication between two or more memory banks
  - **Bursting**: CPU grabs a block of information from memory each time since it's likely that the nearby memory will be requested
  - **Pipelining**: Divides a task into a series of stages; large tasks are divided into smaller overlapping ones...work on other tasks can be performed when waiting for data from RAM
  - **Superscalar architecture**: computer has ability to execute multiple instructions per clock cycle
  - **Hyperthreading**: microprocessor treated as though it's two microprocessors; lets processor handle two sets of instructions (as opposed to one)

Computer Storage

- Secondary Storage
  - Also called permanent storage
  - Hard-disk drive – storage device in computer
    - Stores word documents, game high-scores, anti-viral software on computer, etc...
    - New computers often have around 100 GB or more hard drive space
  - Removable secondary storage
    - Floppy disk
    - Zip drive – has 70-500 times capacity of floppy
    - Rewritable CD/DVD
    - Now, it seem that USB flash drive have taken over as the choice removable secondary storage

Secondary Storage

- Secondary storage on both floppy disks and the hard disk is stored in tracks, sectors, and clusters
  - Cluster is the smallest unit of disk space that holds data
  - Operating systems keeps track of hard-disk sectors according to clusters
  - Windows assigns a unique number to each cluster and keeps track of files using Virtual File Allocation Table (VFAT)
    - Method for storing and keeping track of files according to cluster on disk they use
    - Includes entry for each cluster that describes where on disk cluster located
    - Operating system may number a cluster as used when it is not assigned to a file; waste of disk space
    - Called a lost cluster, can be freed using ScanDisk utility

Ports

- Port – connecting socket or jack outside system unit where different kinds of cables are plugged
  - Dedicated ports
    - Used for special purposes, such as keyboard/mouse, monitor, audio, etc.
  - Serial port – used for transmitting slow data over long distances
    - Used to connect devices that don't need fast transmission, such as keyboards
  - Parallel ports – used for transmitting fast data over short distances
    - Used to connect devices needing faster transmission since more data is being sent, such as printers and external disks

USB Standard

- USB (universal serial bus) port used for many types of peripherals, include flash drives, mice, digital cameras, etc.
- Goals of the USB standard
  - Be low-cost so it could be used in cheap peripherals such as mice/game controllers
  - Able to connect lots of devices and have sufficient speed to replace different ports on computers with single standard
  - Be “hot swappable” - allow USB devices to be connected or disconnected while PC is running
  - Permit plug and play – allow peripheral devices and expansion cards to be automatically configued while installed
- Expected that soon microcomputers will only have USB ports; replacing the various varieties of dedicated, serial, and parallel ports

Specialized Expansion Ports

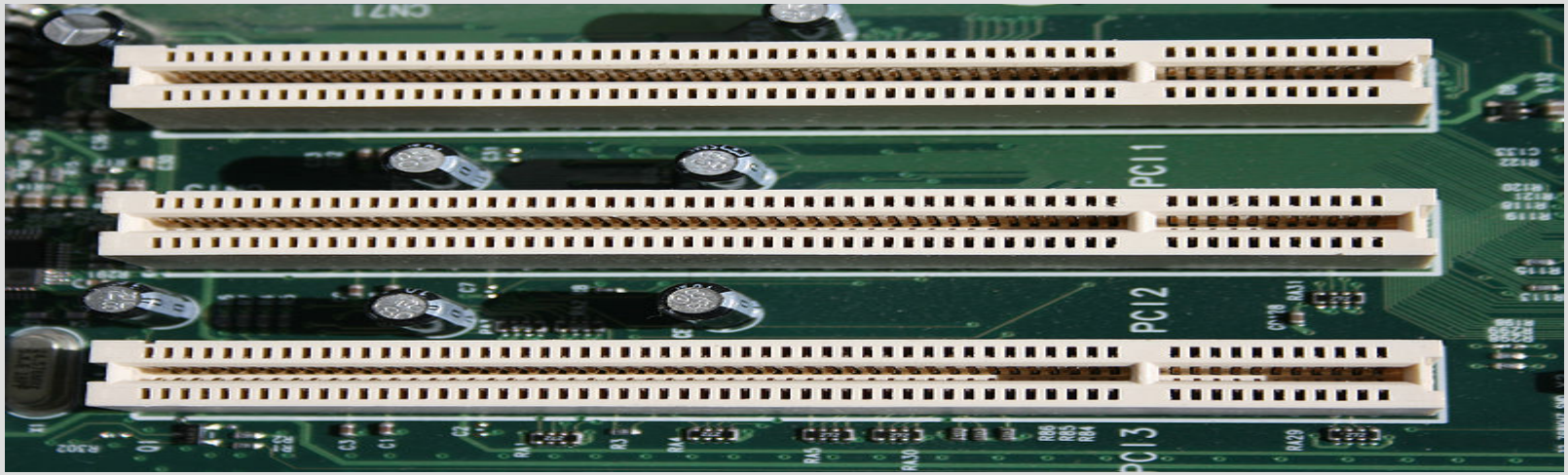
- Firewire
  - Created by Apple
  - Came before USB and with similar goals
  - Intended for devices working with lots of data such as digital video recorders, DVD payers, gaming consoles, and digital audio equipment
- Bluetooth
  - Consists of short-range radio waves that transmit data up to 30 feet
  - Used to connect computers to cellphones, printers, keyboards, etc.
- Multmedia ports
  - “Trend toward multimedia notebooks has introduced a whole slew of port types you may not be familiar with, but that you might need”
  - Includes ports for connecting computer to gaming consoles, TVs, speakers, etc.

Expanding the computer: buses & cards

- Capabilities of microcomputer system can be expanded
  - Expansion of the system involves both expansion cards and buses
    - Expansion cards connect with different types of buses on the motherboard

Expansion Buses

- Important expansion buses
  - **PCI bus**
    - Used to connect PC graphics cards, sound cards, modems, and high-speed network cards
  - **AGP bus**
    - Developed to meet the high-performance demands of graphics cards
    - Transmits data at twice the speed of PCI bus
    - Currently being phased out in favor of PCI express



Expansion Cards

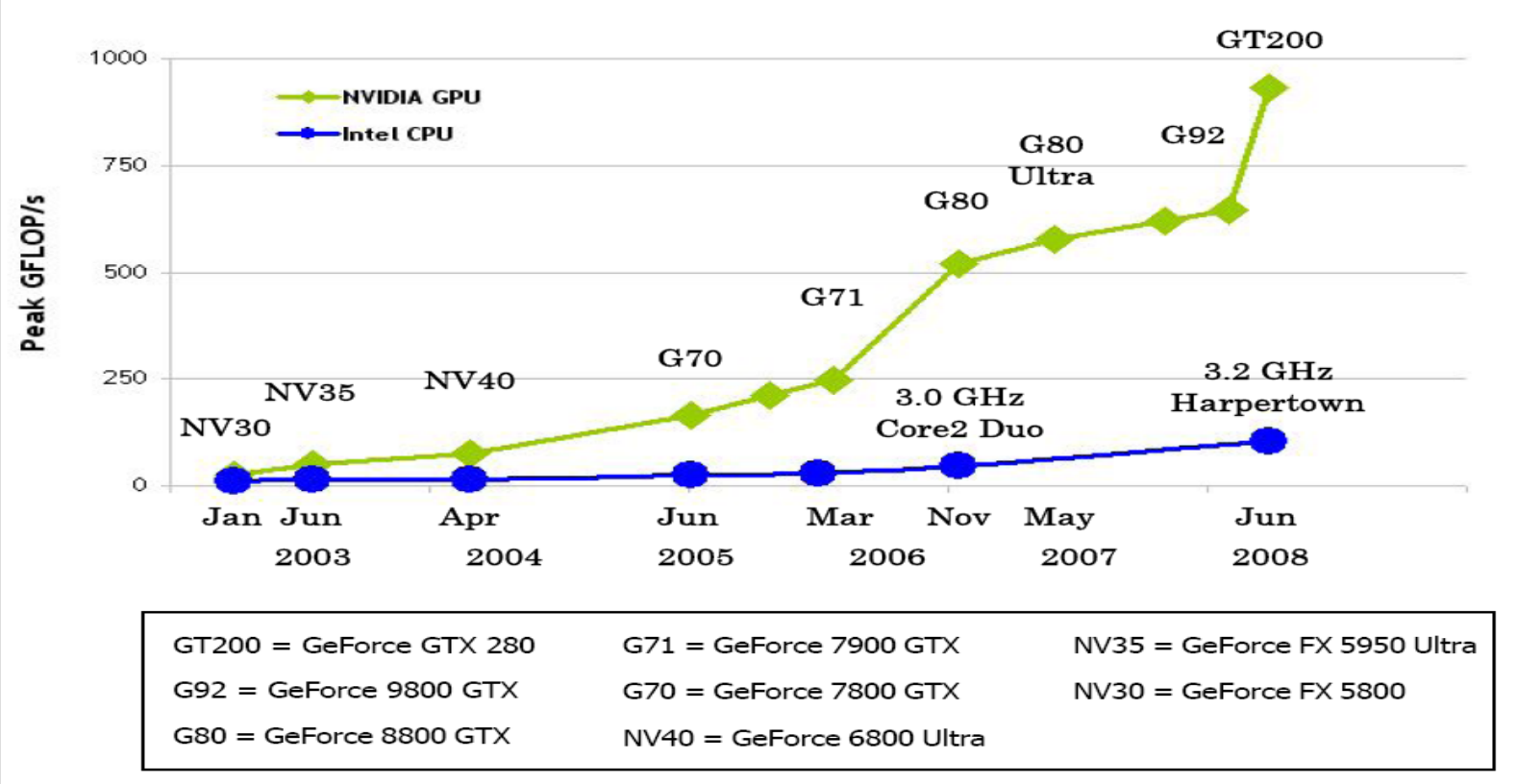
- Graphics card
  - Converts signals from the computer into video signals that can be displayed as images on a monitor
- Sound Card
  - Converts and transmits digital sounds through analog speakers, microphones, and headsets
- Network Card
  - Allows a computer to communicate over a network

Graphics Cards

- Two types: integrated and dedicated
  - Integrated graphics cards
    - Integrated into motherboard
    - Generally don't have own memory, borrow from computer RAM
    - Limited multimedia powers
  - Dedicated graphics cards
    - Come with own video RAM
    - Processing power of dedicated graphics cards is currently increasing faster than CPUs
      - Graphics cards can now be used to speed up general-purpose (non-graphics) computing...faster than CPU for certain tasks
    - Can be easily replaced/upgraded since not part of motherboard

Power of graphics cards

Processing power of top-of-the-line CPUs and graphics cards in recent years



Next operating system from Apple will contain technology known as OpenCL to take advantage of this processing power for any application

OpenCL and the new Mac

OpenCL

With graphics processors surpassing speeds of a trillion operations per second, they're capable of considerably more than just drawing pictures. OpenCL in Snow Leopard is a technology that makes it possible for developers to tap the vast computing power currently in the graphics processor and use it for any application.

The exploding power of GPUs.

Over the last few years the performance of graphics processing units (GPUs) has grown exponentially as measured in gigaflops. Today's fastest GPUs are capable of over one teraflop, as much as the room-size ASCI RED supercomputer of just 12 years ago.

A graphic shift in performance.

Now a new technology in Mac OS X Snow Leopard called OpenCL takes the power of graphics processors and makes it available for general-purpose computing. No longer will graphics processors be limited to graphics-intensive applications such as games and 3D modeling. Instead, once developers begin to use OpenCL in their applications, you'll experience greatly improved speed in a wide spectrum of applications.

For example, sophisticated financial modeling techniques can be incorporated into desktop accounting software and personal finance

Optimized for the task.

OpenCL automatically optimizes for the kind of graphics processor in the Mac, adjusting itself to the available processing power. OpenCL provides consistent numeric precision and accuracy, fixing a problem that has hampered GPU-based programming in the past.

NVIDIA. AMD intel

Familiar, C-based language with industry support.

OpenCL stands for Open Computing Language. It's a C-based programming language with a structure that will be familiar to programmers, who can simply use Xcode developer tools to adapt their programs to work with OpenCL. They don't have to completely rewrite applications to use OpenCL. They need only rewrite the most performance-intensive parts of their application in

Bits In the Computer System

- How many “bits” was the original Nintendo game system...?
- How many “bits” was the Sega Genesis game system...?
- How many “bits” was the Atari Jaguar game system...? (this is actually debatable...)
- How many “bits” was the Nintendo 64 game system...?
- What does all this mean...?

Bits In the Computer System

- Recall that a bit is either a 0 or 1
  - A computer's **word size** -> number of bits the processor can process at any one time
  - More bits in a word -> faster computer
  - Example: 32 bit computer will transfer data in the microprocessor chip in 32-bit chunks
  - Currently, we are in the midst of a transition from 32 bit computers to 64 bit computers
    - One major reason for this is that 32 bit computers are limited to 4 GB of RAM, while 64 bit computers can theoretically have up to 17.2 billion GB of RAM

Bits in the Atari Jaguar

- First, let's watch a couple commercials...
- http://www.youtube.com/watch?v=hjRjyCiBzHU
- http://www.youtube.com/watch?v=EQaro-yjBqI&feat
- Note the “stress” of 64 bits, but they don't actually say what a bit is...
- Now let's look at this 1995 thread about the number of bits in the Jaguar: http://groups.google.com/group/rec.games.video.atari/browse_thread/thread/49a45b71cbcc0b9e/0bebc8c724042860?lnk=st&q=#0bebc8c724042860

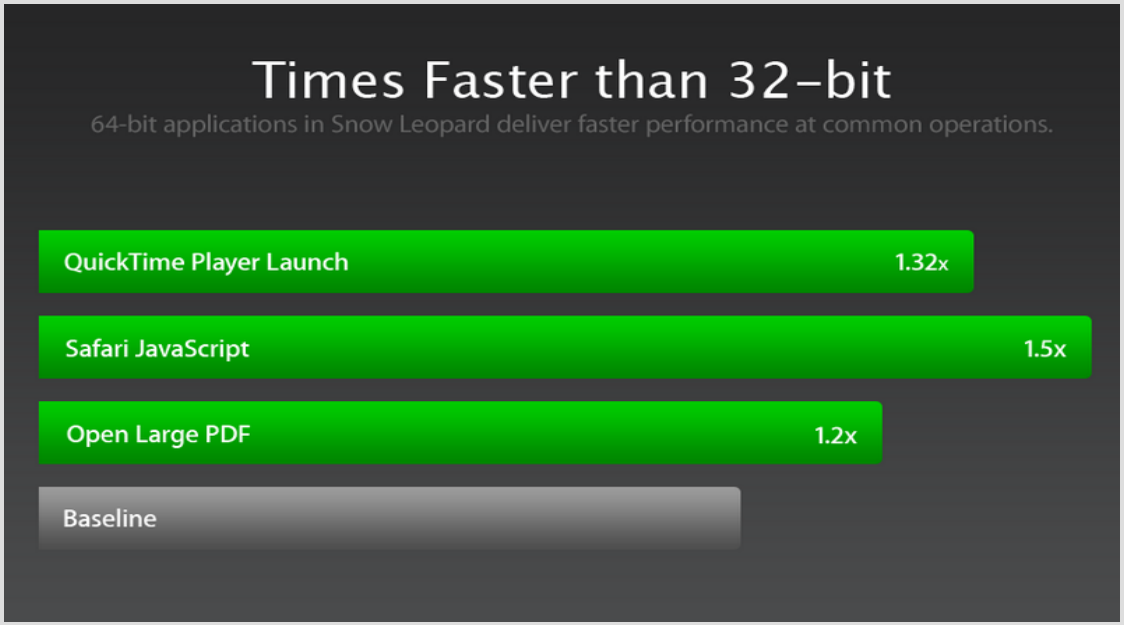
The Sega Genesis/32X

- How many bits was the Sega Genesis?
- Then there was the 32X add-on:
  - http://www.youtube.com/watch?v=2xHmGaKs0Do
- Virtua Racing for the 32X (state-of-the-art graphics in 1994): http://www.youtube.com/watch?v=mF_bwH76HUk
- What do you think the processor speed/RAM of the Sega Genesis and 32X are?

64 Bits and the New Mac

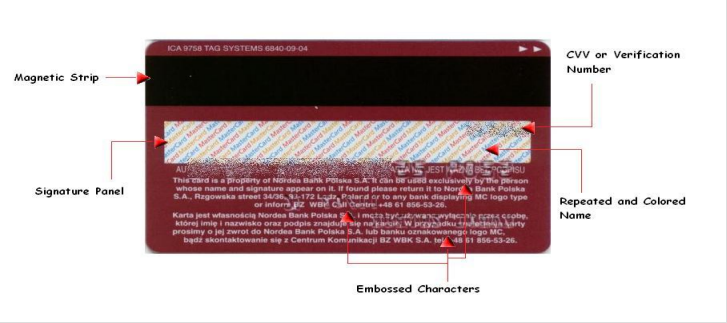
The 64-bit transition.

The entire computing industry is moving from 32-bit to 64-bit technology, and it's easy to see why. Today's Mac computers can hold up to 32GB of physical memory, but the 32-bit applications that run on them can address only 4GB of RAM at a time. 64-bit computing shatters that barrier by enabling applications to address a theoretical 16 billion gigabytes of memory, or 16 exabytes. It can also enable computers to crunch twice the data per clock cycle, which can dramatically speed up numeric calculations and other tasks. Earlier versions of Mac OS X have offered a range of 64-bit capabilities. Now Snow Leopard takes the next step in the transition from 32-bit to 64-bit.



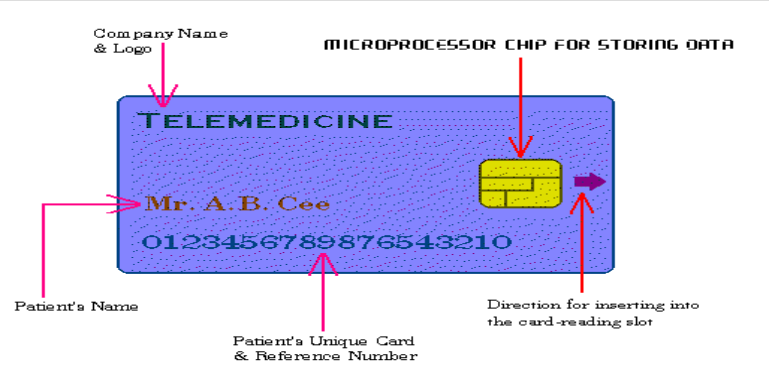
Smart Cards

- Most credit cards in US are magnetic-strip cards
  - Contains strip of magnetically encoded data
  - Holds 0.2-0.9 KB of data
  - Might include name, account number, and PIN needed to use card
  - Weaknesses of magnetic strip card
    - Degrades over time
    - Magnetic strip doesn't hold much info
    - Data on magnetic strip may be easy to access, risk of freud



Smart Cards

- Looks like a credit card
- Has microprocessor and memory chips embedded in it
  - Holds more information than magnetic strip cards (8-40 Mb of data)
  - Transfers data to and from a central computer when inserted into reader
  - Can be programmed to self-destruct if wrong password entered too many times
  - Well-suited for prepaid, disposable applications such as cash cards or telephone debit cards



Future Developments In Processing

- **How long will Moore's law hold true?**
  - Recall Moore's law: number of transistors on silicon chip doubles every 18 months while price remains steady
  - Smaller circuits get, chip manufacturers up against material limits
  - Have been advances in chip technology that some experts believe will allow Moore's law to hold true until at least 2016
    - IBM has developed transistor one-tenth size of most advanced transistors at the time the book came out...
    - Would allow 100 times more transistors to be put into computer chip than currently possible

Future Developments In Processing

- Nanotechology
  - Start with nanometer measurement; billionth of a meter
    - Operating at level of atoms and molecules
    - Molecules used to create tiny machines for holding data or performing task
    - Nanostructures build one atom/molecule at a time
    - Field called nanoelectronics when applied to chips and other electronic devices
    - Scientists trying to simulate on/off of transistors by creating switches that manipulate a single electron
    - A trillion electrons could be put on chip size of fingernail
    - Carbon nanotubes rather than silicon used for these chips
    - IBM has built working nanocircuits, likely won't be made in large quantities till 2015

Future Developments In Processing

- Optical Computing
  - Optical technology uses lasers, lenses, and mirrors to represents on/off codes of data via light pulses
  - Light is faster than electricity
  - Already used in fiber-optic networks such as those on the internet backbone as well as Fios
  - Signal slowed by when processed by silicon chips
  - Optical chips could potentially remove this bottleneck

Future Developments In Processing

- DNA Computing
  - Biotechnology could be used to grow cultures of bacteria that emit small electrical charge when exposed to light
    - This “biochip” could represent on/off digital signals in computing
  - String of synthetic DNA could represent information as pattern of molecules
    - Info could be manipulated by subjecting it to chemical reactions that could mark or lengthen the strand
      - Four nucleic acids (represented by A, T, C, G) could be manipulated rather than using binary
      - Nondigital ways of thinking about computing...

Future Developments In Processing

- Quantum Computing
  - Has been called the “ultimate computer”
    - Based on quantum mechanics
      - Physics theory that explains “erratic world of the atom”
    - Stores information using states of elementary particles
    - Energized and relaxed states of individual atoms could be used to represent data
      - Example: “hydrogen atoms could be made to switch off and on like a conventional computer's transistors by moving from low energy states (off) to high energy states (on)”

Homework

- Find specs of at least 4 Nintendo game systems
- Create an HTML page (or add to the current one) with the following:
  - A table with NO border and at least two columns and at least two rows
  - Each “cell” of the table will be dedicated to a single game system and will contain
    - Name of system formatted in such a way that it is more “important” than the text below
    - The specs of each system are to be placed in a separate “cell” within the table using a list of some sort
    - An image that makes sense
  - Either put the page online or send me a zip file containing the folder with the page (can't just send HTML page since there are image)
  - HTML questions?...let me know
- Look up the Nintendo Wiimote and Nintendo Wii MotionPlus and how they work
  - Incorporate info about this (at least a paragraph total) into the page in some manner
  - Will give some extra credit for good presentation of page that goes beyond basic requirements (feel free to add more stuff/HTML components as well!)