Problem Solving and Computer Organization

CSE 231, Bill Punch

The Problem is "Problem-Solving"

Remember, two parts to our goal:

- Understand the problems to be solved
- Encode the solution
  in a programming language, e.g. Python

Mix of both

- The goal in each class is to do a little of both: problem solving and Python
- Terribly important that we impress on you *to try and understand how to solve the problem **first** before you try and code it.*

Steps to problem solving

From "PProblem SSSolving", DeFranco & Vinsonhaler

- Be **P**roactive
- **S**ee it
- **S**implify it
- **S**tir it up
- **P**ause and Reflect

Steps to problem solving

My Paraphrase

- Engage/Commit
- Visualize/See
- Try it/Experiment
- Simplify
- Analyze/Think
- Relax

Engage

You need to commit yourself to addressing the problem.

- Don't give up easily
- Try different approaches
- Set the "mood"

Just putting in time does not mean you put in a real effort!!!

Visualize/See the problem

Find a way that works for you,
some way to make the problem tangible.

- draw pictures
- layout tables
- literally "see" the problem somehow

Everyone has a different way, find yours!

Try it/Experiment

For some reason, people are afraid to just "try" some solution. Perhaps they fear failure, but experiments, done just for you, are the best way to figure out problems.

Be willing to try, and fail, to solve a problem. Get started, don't wait for enlightenment!

Simplify

Simplifying the problem so you can get a handle on it is one of the **most powerful** problem solving tools.

Given a hard problem, make is simplier (smaller, clearer, easier), figure that out, then ramp up to the harder problem.

Think it over/Analyze

If your solution isn't working:

- stop
- evaluate how you are doing
- analyze and keep going, or start over.

People can be amazingly "stiff", banging their heads against the same wall over and over again. Loosen up, find another way!

One more thing, relax

Take your time. Not getting an answer right away is not the end of the world. Put it away and come back to it.

You'd be surprised how easy it is to solve if you let it go for awhile. That's why **starting early** is a luxury you should afford yourself.

Cryparithmetic problem

```
  E L F
+ E L F
-------
F O O L
```

E= ?
F = ?
L = ?
O = ?

Remember:

- Engage
- Visualize
- Try it
- Simplify
- Analyze
- Relax

What is a Computer?

Computer as a toaster

50 years ago when computers came into common existence, they were expensive, rare items used for research.

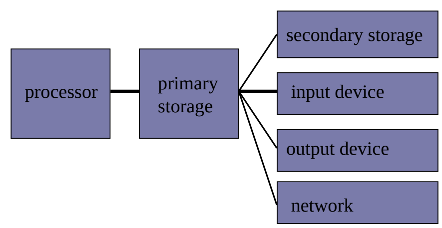
Today they are as common as a toaster (likely more common!)

Good to know a little bit about your toaster

Main Components

- People!!!
- Hardware
  - Physical Devices: processor, memory, keyboard, monitor, mouse, etc.
- Software
  - Executable Programs: word processor, spread sheet, internet browser, etc.

Hardware



Processor

- The processor is the “brain”of a computer.
- The processor controls the other devices as well as performing calculations

Processor Components

- Control Unit
  - fetches an instruction from primary storage
  - decodes it to decide which instruction it is
  - instructs the ALU to perform a calculation
- Arithmetic-Logic Unit (ALU)
  - performs arithmetic calculations
  - and logical calculations such as comparison

Processors: smaller, faster, more

One of the things that have made processors (and thus computers) so amazing over the last fifty years is:

- how much faster they are
- how much smaller they are
- how much more “stuff” are in each one

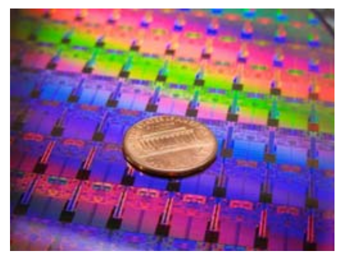
smaller

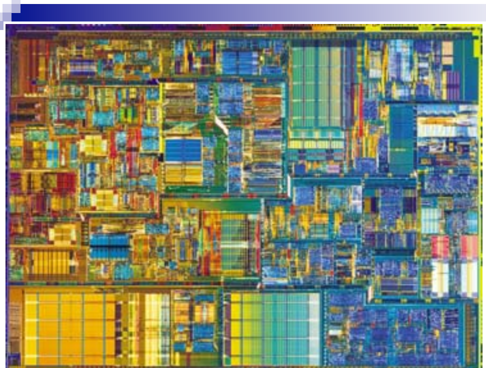
Little Processors

Processors like the Intel P4 have 55 million transistors in them

How about the newest Penryns

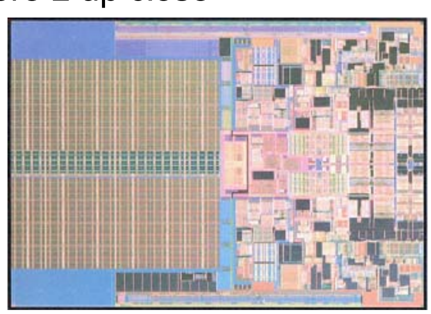
Very newest Intel processor, two CPUs on each die. Shown is a full ‘wafer’ of such processors as compared to a penny



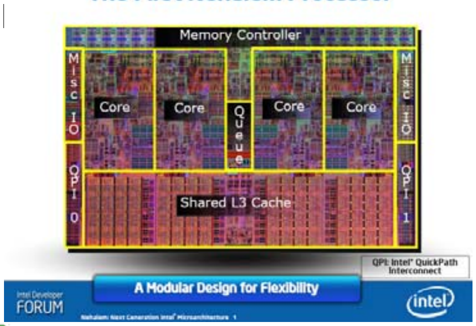


P4

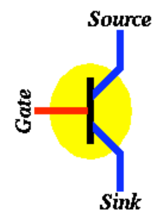
Core 2 up close



The First Nehalem Processor

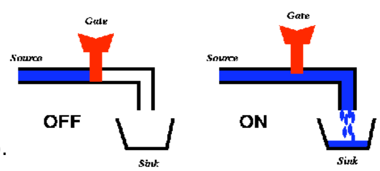


Transistors

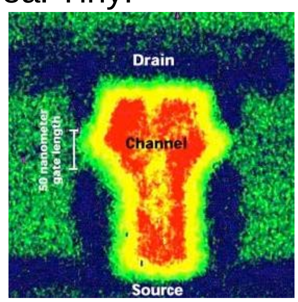


What are the transistors

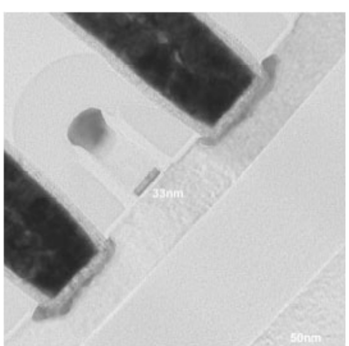
- Little electronic switches (only discovered in the 50's).



But Real Tiny!

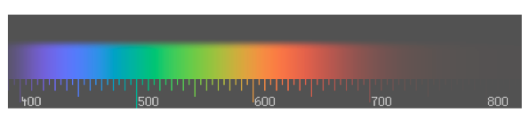


Penryn gate



How big is that?

color	wavelength interval	frequency interval
red	~ 630–700 nm	~ 480–430 THz
orange	~ 590–630 nm	~ 510–480 THz
yellow	~ 560–590 nm	~ 540–510 THz
green	~ 490–560 nm	~ 610–540 THz
blue	~ 450–490 nm	~ 670–610 THz
violet	~ 400–450 nm	~ 750–670 THz



how many

How many transistors?

Processor	Transistors		Date	Manufacturer
Intel 4004	2300		1971	Intel
Intel 8008	2500		1972	Intel
Intel 8080	4500		1974	Intel
Intel 8088	29 000		1979	Intel
Intel 80286	134 000		1982	Intel
Intel 80386	275 000		1985	Intel
Intel 80486	1 200 000		1989	Intel
Pentium	3 100 000		1993	Intel
AMD K5	4 300 000		1996	AMD
Pentium II	7 500 000		1997	Intel
AMD K6	8 800 000		1997	AMD
Pentium III	9 500 000		1999	Intel
AMD K6-III	21 300 000		1999	AMD
AMD K7	22 000 000		1999	AMD
Pentium 4	42 000 000		2000	Intel
Itanium	25 000 000		2001	Intel
Barton	54 300 000		2003	AMD
AMD K8	105 900 000	2003	AMD	
Itanium 2	220 000 000	2003	Intel	
Cell	241 000 000	2006	Sony/IBM	
Core 2 Duo	291 000 000	2006	Intel	
Core2 Quad	582 000 000	2006	Intel	
G80	681 000 000	2006	NVIDIA	
POWER6	789 000 000	2007	IBM	
Itanium 2	1 700 000 000		2006	Intel

By the way,
the latest Nehalem
has 731 million!

Moore's Law

- Gordon Moore is one of the founders of the chip maker Intel
- in 1965, he has observed (over that last 15 years or so) the growth rate of the number of transistors in a circuit
- Made a famous prediction

The "law"

"The complexity for minimum component costs has increased at a rate of roughly a factor of two per year ... Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years. That means by 1975, the number of components per integrated circuit for minimum cost will be 65,000. I believe that such a large circuit can be built on a single wafer"

Electronics Magazine 19 April 1965

What it means

- Roughly, since 1965, the number of transistors on a chip doubles every 18 months for approximately the same cost
- Often quoted as the speed of a cpu doubling every 18 months for the same cost
- speed and density were related

how fast

How fast

Typical processor this day runs at GHz speeds. That is 1 billion “operations” a second.

How fast is a nanosecond?

Nanoseconds

- Speed of light =186,000 miles/sec, $3x10^8$ meters/sec (actually 299,792,458)
- nanosecond = 10^{-9} seconds
- thus 30 centimeters or 11.8 inches

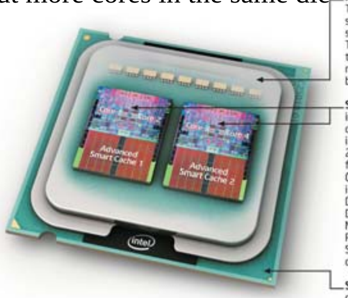
speed pushing up against physics

- the “clock” is like a drummer in the band. The faster it beats, the faster the operations.
- in 1 clock tick (at 1 GHz), electricity can travel 1 ft. 2GHz, 6 inches, 4GHz, 3 inches
- It becomes very difficult to get electricity across the board fast enough!

How to get around physics

- So if physics is getting in the way (and it is), you find a way to get around it.
- If you can’t make processors faster, what do you do?

Put more cores in the same die



Intel quad core “extreme”

Integrated Heat Spreader (IHS): The integrated metal heat spreader spreads heat from the silicon chips and protects them. The IHS acts as contact for the heatsink and provides more surface area leading to better cooling.

Silicon chips (dies): The two dies inside the Intel® Core™ 2 Extreme quad-core processor are 143 mm² in size and utilize a whopping 291 million transistors each. The four cores are based on the Intel® Core™ Microarchitecture with innovative features like Wide Dynamic Execution, Advanced Digital Media Boost, Smart Memory Access and Intelligent Power Capability. The Advanced Smart Caches have 4 MByte capacity each.

Substrate: The dies are mounted directly to the substrate which facilitates the contact to the motherboard and chipset of the PC via 775 contacts and electrical connections.

Heck, put a bunch on

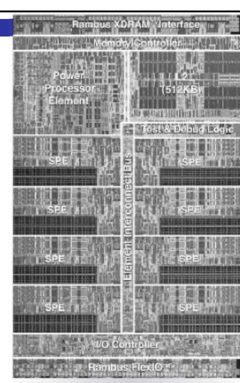
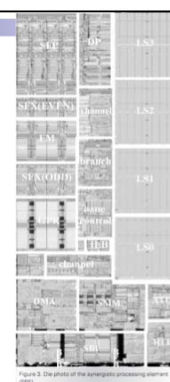
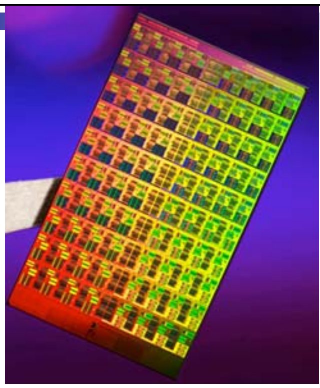


Figure 1. Die photo of the Cell processor.



IBM Cell Processor

Nah, even more than that!



Intel 80 core chip (not in production)

And multiple cpus gets me ...?

- That is the question. A blazingly fast quad core intel processor does not make your word processor faster, your AIM window brighter, your music louder or anything else except PERHAPS games, and right now that doesn't matter either
- It is hard to get multiple processors to work together on one problem.
- However, you can do all those things at once: now, be even more distracted than normal

the future

- One of the current big research questions is how to get multiple processors to work together more easily.
- Still plenty of research for CSE students like you.

Other Stuff

Primary Storage

- stores instructions and data for current program(s)
- other names: primary or main memory, RAM (Random Access Memory)
- memory is "dynamic" so it requires power to retain information
- often hundreds of Megabytes (million-bytes)

Peripheral Devices

- Secondary storage devices
  - disk (hard & floppy), tape, usb drives, flash drives, etc.
- Input devices
  - keyboard, mouse, camera, mic, etc.
- Output devices
  - monitor, printer, speaker, etc.
- Network
  - wireless, bluetooth, ethernet, etc.

Secondary Storage

- nonvolatile -- information is recorded magnetically so power is not needed
- disks hold Gigabytes (billions of bytes)
- cheap, but slow
  - RAM access is a hundred CPU clock ticks
  - disk access is a million CPU clock ticks
- not directly accessed by CPU

Software

- the programs available for execution
- simple classification
  - system software
  - application software

System Software

- operating system: manages system resources, e.g. DOS, UNIX
- user interface: interface with operating system, e.g. Windows, X
- combined: NT, MacOS

Application Software

- programs which perform specific tasks for the user (and use the operating system to interact with the hardware)
- examples: word processor, spreadsheet, internet browser, etc.

What is a program?

- A sequence of instructions written in machine language that tells the CPU to take certain actions in a specific order
- In this course we will learn to create programs

Storage

Program Storage

- machine language instructions are encoded as bit patterns (binary, remember our transistors)
- memory can only hold binary info.
- a bit is represented by two-states, e.g. L-R magnetism, high-low voltage
- it takes many bits to represent reasonable amounts of information

Binary

- byte = 8 bits
  e.g. 10110010
- storage devices come in large quantities
  1K (kilobyte)= 2^{10} bytes = 1024 bytes
  1M (megabyte)= 2^{20} bytes = 1,048,576 bytes
  1G (gigabyte)= 2^{30} bytes=1,073,741,824 bytes

Byte

Bytes(8 bits)

- 1 byte: A single character

Kilobyte (1000 bytes)

- 2 Kilobytes: A Typewritten page
- 10 Kilobytes: An encyclopedic page
- 50 Kilobytes: A compressed document
- 100 Kilobytes: A low-resolution photo

Megabyte (1 000 000 bytes)

- 1 MByte: A small novel **or** 3.5 inch floppy disk
- 2 MByte: A high resolution photograph
- 5 Mbyte: The complete works of Shakespeare
  or 30 seconds of video
- 100 Mbyte: 1 meter of shelved books
- 500 Mbyte: A CD-ROM

Gigabyte (1 000 000 000 bytes)

- 1 GByte: A pickup truck filled with paper
  or A symphony
  or A movie
- 20 GBytes: the works of Beethoven as sound
- 50 GBytes: A library floor of books

Terabyte (1 000 000 000 000 byte)

- 1 TByte: All X-rays in a large hospital
  or 50000 trees made into paper and printed
  or Daily rate of EOS data (1998)
- 2 TBytes: An academic research library
- 10 TBytes: The US Library of Congress
- 18 TBytes: www.terraserver.com
- 20 Tb, photos/month on facebook
- 530 Tb, all videos on youtube

Terabyte In Your Hand

- Terabyte = 1000 Gigabytes
  = 1500 music CD's
  = 200 DVD movies (16 days worth)
  = 1/10 of the Library of Congress
- Western Digital Caviar: 1 Terabyte, $269 (2006)
  - today, cost is $109
  - *Seagate Barracuda, 1.5 Tb, $129*
- History
  First disk by IBM in 1956 (4 MB on 50 24-inch platters)
  1GB in 35 years
  500 GB in 14 more years
  1000 GB = 1 TB in 2 more years

Petabyte = 1000 Terabytes*
= 1,000,000 Gigabytes

- EMC Symmetrix DMX-3
  1.2 PB = 2400 500GB drives
  - $4 million (2006)
- Kazza shared 54 Petabytes (2005)
- Google cluster has 4 Petabytes of RAM
- All data recorded in 2003: 2500 Petabytes
- Petabyte disk predicted for 2010

*(1,125,899,906,842,624 bytes = 2^{50})

Petabyte?

- **In round numbers, a book is a megabyte. If you read one book a day for every day of your life for 80 years, your personal library will amount to less than 30 gigabytes. Remember a petabyte is 1 million gigabytes so you will still have 999,970 gigabytes left over.**
- **How many pictures can a person look at in a lifetime (4 Mbytes each)? I can only guess, but 100 images a day certainly ought to be enough for a family album. After 80 years, that collection of snapshots would add up to 30 terabytes. So your petabyte disk will have 970,000 gigabytes left after a lifetime of high quality photos and books.**
- **What about music? MP3 audio files run a megabyte a minute, more or less. At that rate, a lifetime of listening--24 hours a day, 7 days a week for 80 years--would consume 42 terabytes of disk space. So with all your music and pictures and books for a lifetime you will have 928,000 gigabytes free on your disk.**
- **The one kind of content that might possibly overflow a petabyte disk is video. In the format used on DVDs, the data rate is about two gigabytes per hour. Thus the petabyte disk will hold some 500,000 hours worth of movies; if you want to watch them all day and all night without a break for popcorn, they will actually fill up your petabyte drive if you have a lifetime of video on it as it will give you 57 years of video**

Exabyte
(1 000 000 000 000 000 000 bytes)

- 5 Exabytes: All words ever spoken by human beings.