CS 316
Intro to Computer System Organization and Programming

Kavita Bala

Fall 2007

Computer Science

Cornell University

Information

- Instructor: Kavita Bala (kb@cs.cornell.edu)
- Tu/Th 1:25-2:40 Hollister B14

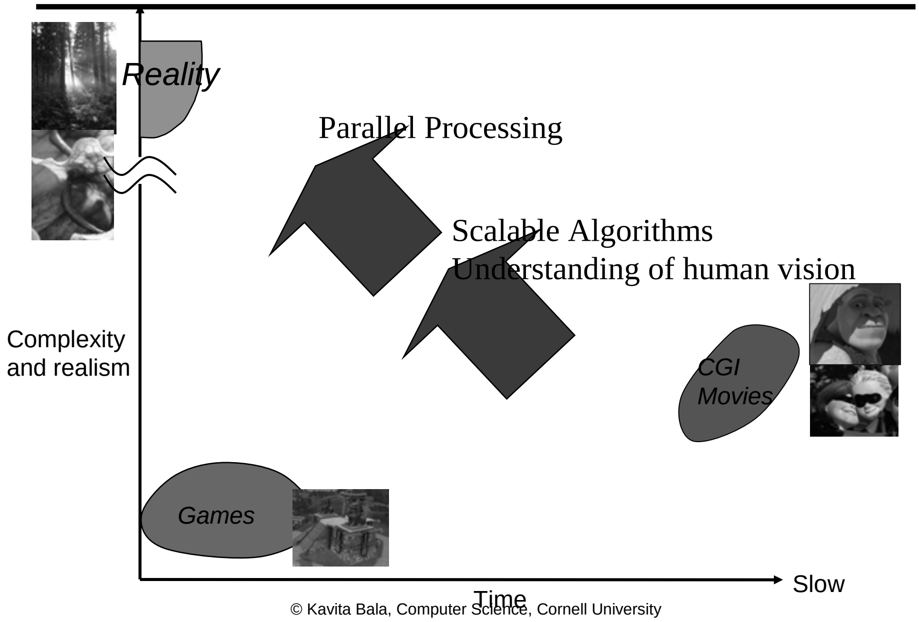
Course Objective

- Bridge the gap between hardware and software
  - How a processor works
  - How a computer is organized
- Establish a foundation for building higher-level applications
  - How to understand program performance
  - How to understand where the world is going

Who am I?

- Current life
  - Graphics
  - Parallel processing in graphics
- Previous life
  - Compilers
  - Operating Systems
  - Networks

Who am I?



Course Staff

- TAs
  - Adam Arbree (arbree@cs.cornell.edu)
  - Jed Liu (liujed@cs.cornell.edu)
  - Robert Burgess (burgess@cs.cornell.edu)

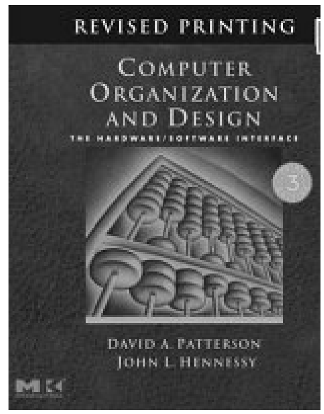
- Undergraduate consultants:
  - Daniel Margo, Matt Oliveri, Ben Pu

- AA: Amy Fish (amyfish@cs.cornell.edu)

- Sections:
  - Tu/Th/Fr 2:55-4:10
  - Wednesday section cancelled

Book

- Computer Organization and Design
  - The Hardware/Software Interface
- David Patterson, John Hennessy
  - Get revised printing from summer



Course

- Programming Assignments: 6-8
  - Work in groups of 2
- Homeworks: 4-5
  - Work alone
- 2 prelims, 1 final project

Grading

- Breakdown
  - 35-50% Projects (approx. 8 assignments)
  - 30-40% Prelims (2)
  - 15-20% Homeworks (approx. 4-5)
  - 5% Flexgrade (participation, attitude, improvement and effort)

Administrivia

- http://www.cs.cornell.edu/courses/cs316/2007fa
  - Updates
  - Schedule
  - Lecture notes
  - Office hours
  - Homeworks, etc.

Communication

- Email
  - cs316-l@cs.cornell.edu
  - The email alias goes to me and the TAs, not to whole class
- Mailing list for students
  - Sign up sheet

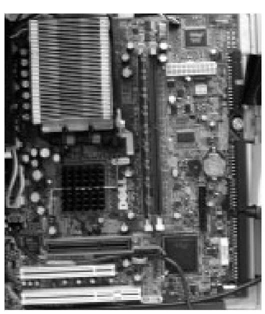
Sections & Projects

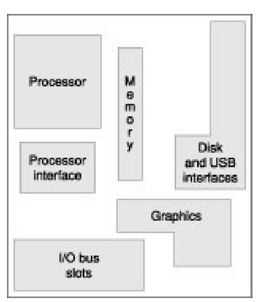
- Sections start next week
- Projects will be done in two-person teams
  - We will pair you up if you don't have a preferred partner
  - Start early, time management is key
  - Manage the team effort

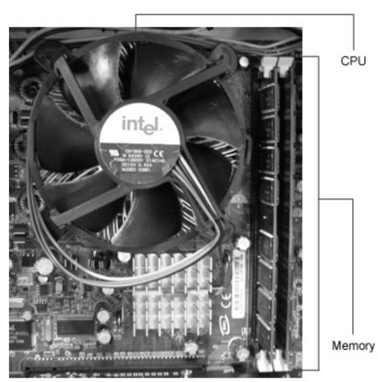
Academic Integrity

- All submitted work must be your own
  - OK to study together
  - Cannot share solutions however
- Project groups submit joint work
  - Same restrictions apply to projects at the group level
  - Cannot be in possession of someone else's solution
- Closed-book exams, no calculators

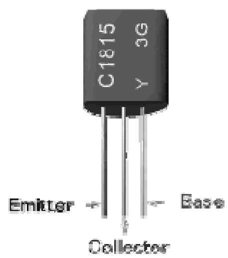
Computer System Organization

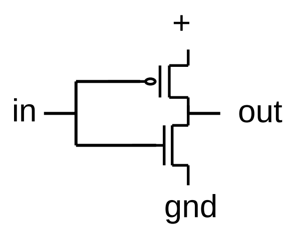






Transistors and Gates

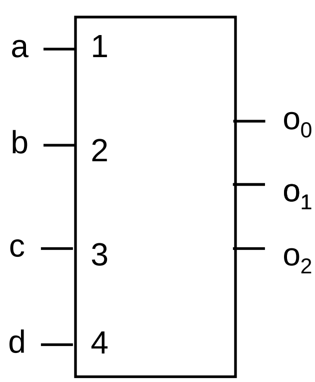


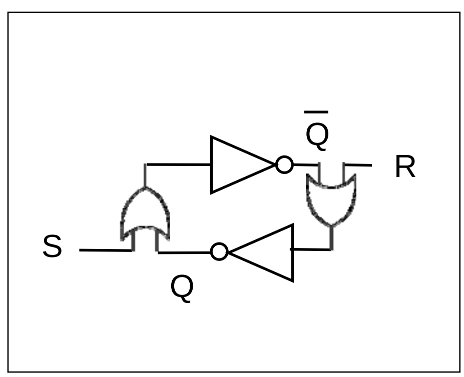


In	Out
0	1
1	0

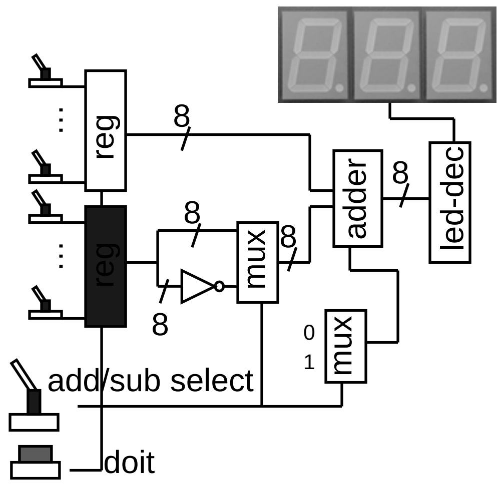
Truth table

Logic and State



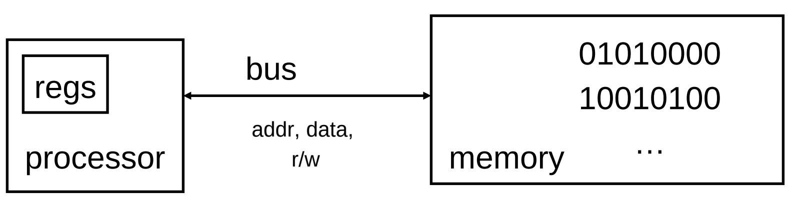


A Calculator

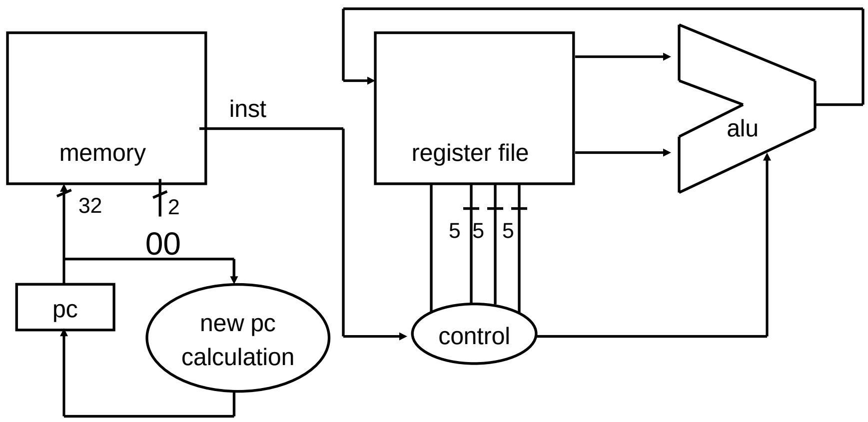


Basic Computer System

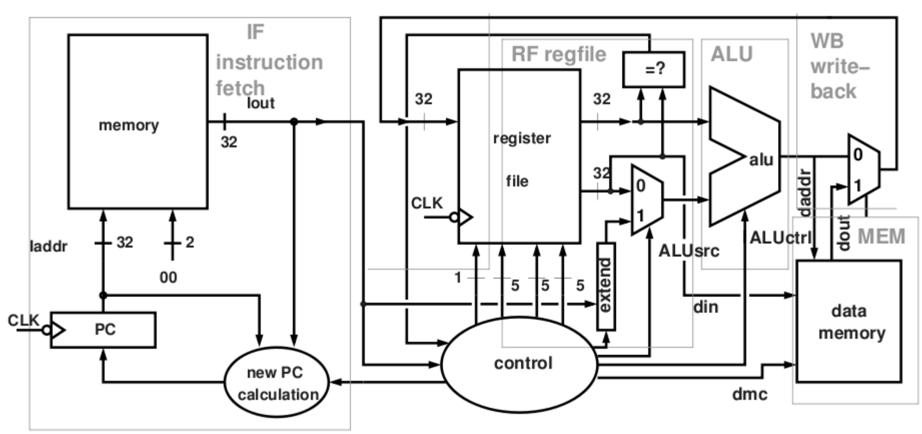
- A processor executes instructions
  - Processor has some internal state in storage elements (registers)
- A memory holds instructions and data
  - von Neumann architecture: combined inst and data
- A bus connects the two



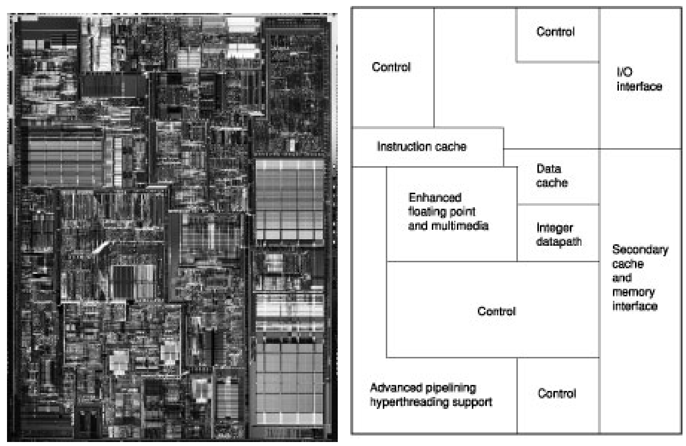
Simple Processor



MIPS Processor

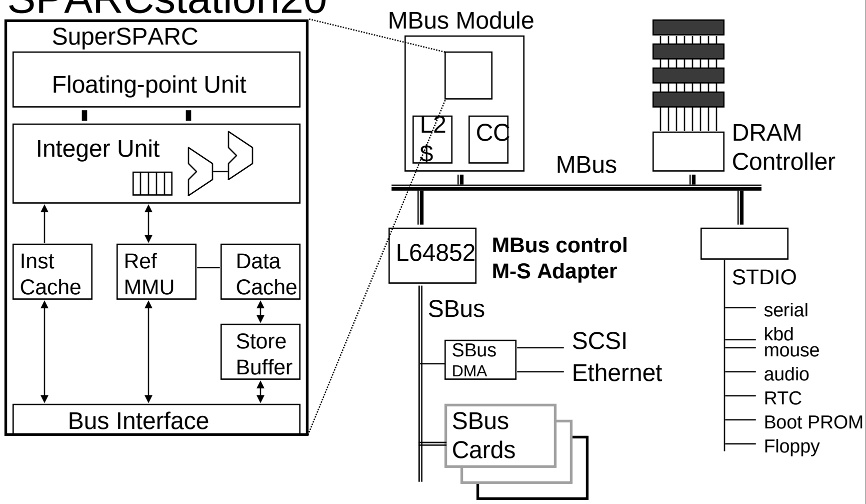


Computer System Organization



Example Machine Organization

- TI SuperSPARC^{tm} TMS390Z50 in Sun SPARCstation20



Why should you care?

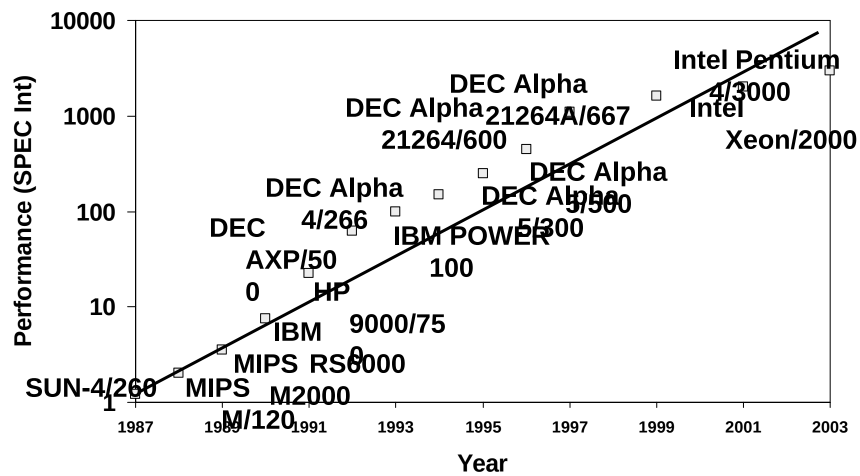
- Bridge the gap between hardware and software
  - How a processor works
  - How a computer is organized

- Establish a foundation for building higher-level applications
  - How to understand program performance
  - How to understand where the world is going

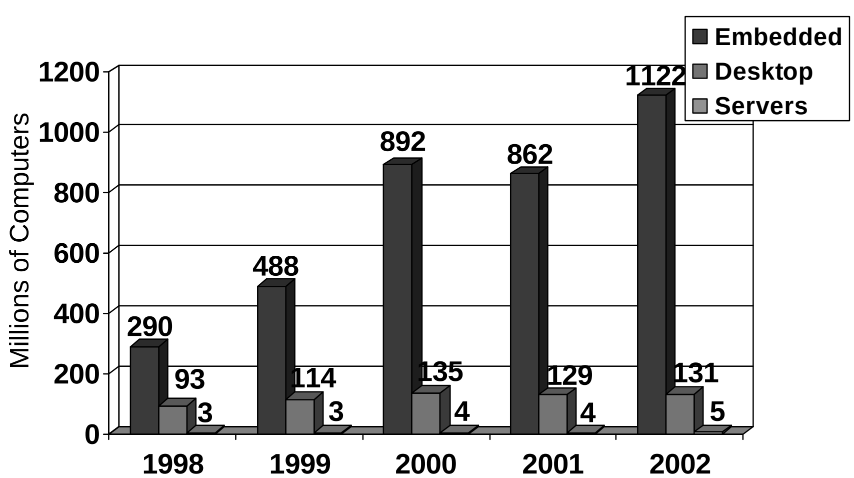
Moore's Law

- 1965
  - number of transistors that can be integrated on a die would double every 18 to 24 months (i.e., grow exponentially with time).
- Amazingly visionary
  - 2300 transistors, 1 MHz clock (Intel 4004) - 1971
  - 16 Million transistors (Ultra Sparc III)
  - 42 Million transistors, 2 GHz clock (Intel Xeon) – 2001
  - 55 Million transistors, 3 GHz, 130nm technology, 250mm^2 die (Intel Pentium 4) – 2004
  - 290+ Million transistors, 3 GHz (Intel Core 2 Duo) – 2007

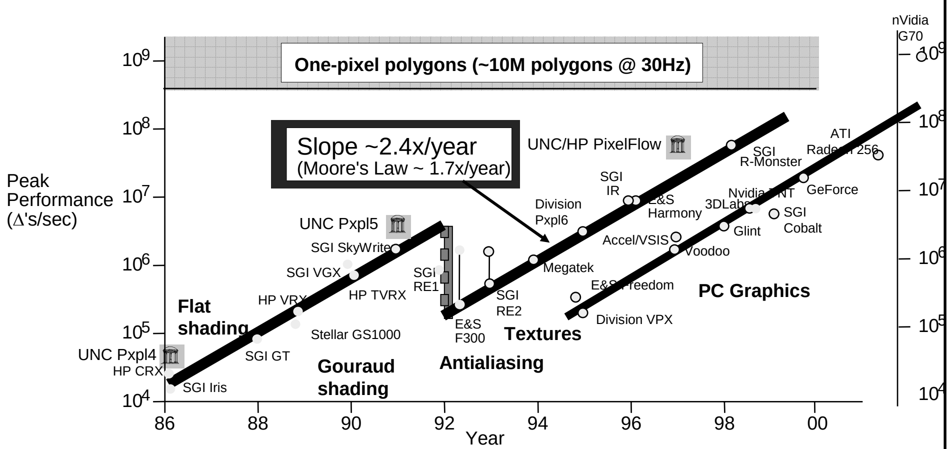
Processor Performance Increase



Where is the Market?

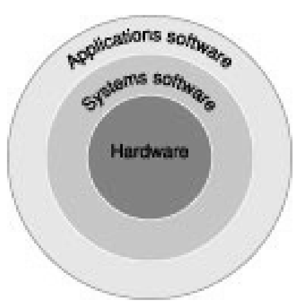


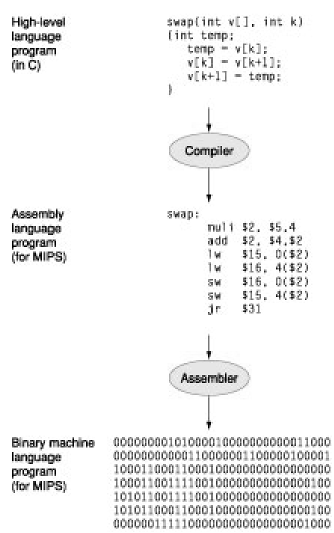
GPUs: Faster than Moore's Law



Graph courtesy of Professor John Poulton (from Eric Haines)

Computer System Programming

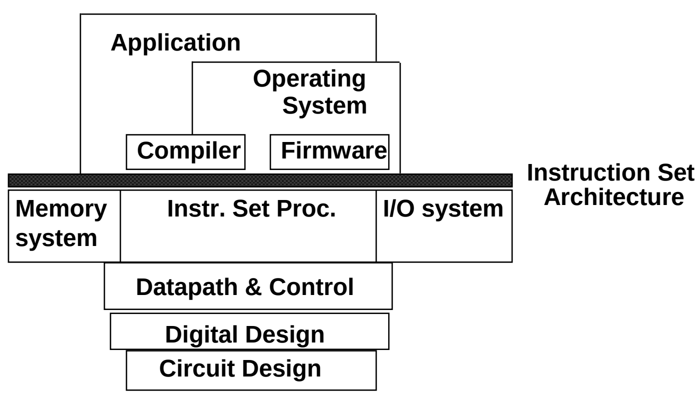




Instruction Set Architecture (ISA)

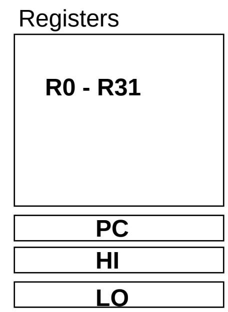
- ISA
  - – abstract interface between hardware and the lowest level software
  - – user portion of the instruction set plus the operating system interfaces used by application programmers

Overview



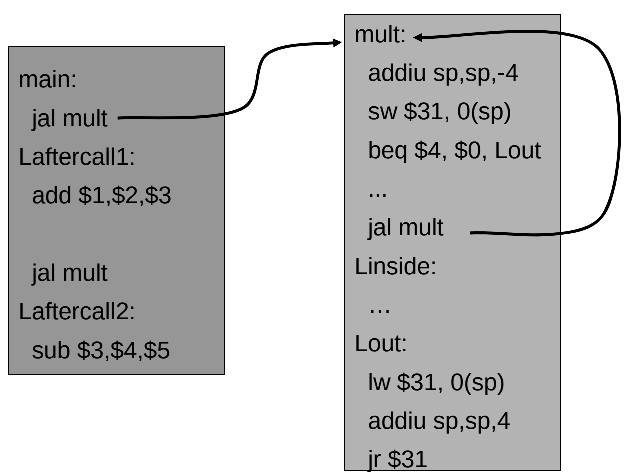
MIPS R3000 ISA

- Instruction Categories
  - Load/Store
  - Computational
  - Jump and Branch
  - Floating Point
    - coprocessor
  - Memory Management

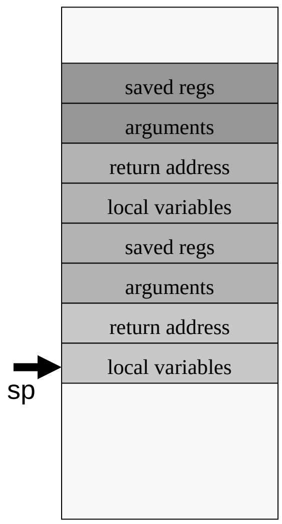


OP	rs	rt	rd	sa	funct
OP	rs	rt	immediate		
OP	jump target				

Calling Conventions

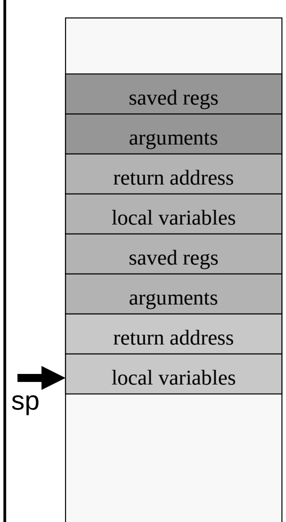


Data Layout




```
blue() {
   pink(0,1,2,3,4,5);
}
pink() {
    orange(10,11,12,13,14);
}
```


Buffer Overflows




```
blue() {
   pink(0,1,2,3,4,5);
}
pink() {
    orange(10,11,12,13,14);
}
orange() {
         char buf[100];
         gets(buf); // read string, no check
}
```

Parallel Processing

- Spin Locks
- Shared memory, multiple cores
- Etc.

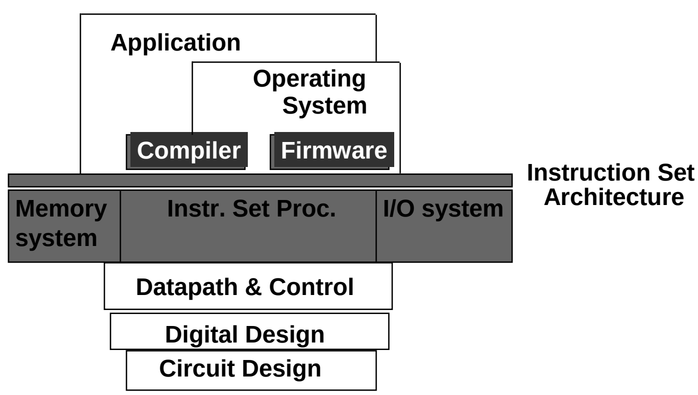
Can answer the question…..

- A: for i = 0 to 99
  - for j = 0 to 999
    - A[i][j] = Computation ()
- B: for j = 0 to 999
  - for i = 0 to 99
    - A[i][j] = complexComputation ()
- Why is B 15 times slower than A?

Applications

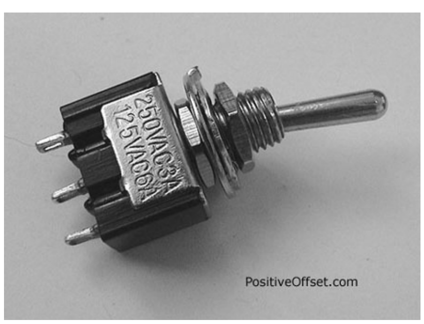
- Distributed ray tracer
  - Multiple cores running highly parallel application
  - Great images!
- Core war
  - Corrupt your neighbors context!

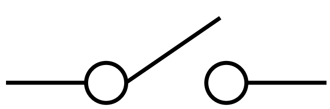
Covered in this course



Nuts and Bolts:
Switches, Transistors, Gates

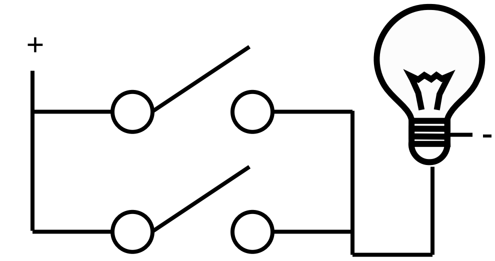
A switch



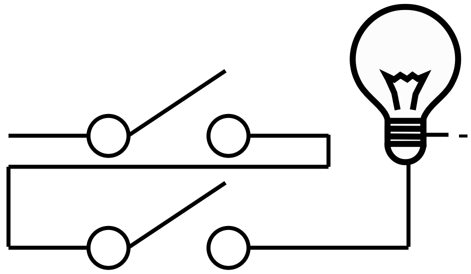


- A switch is a simple device that can act as a conductor or isolator
- Can be used for amazing things…

Switches

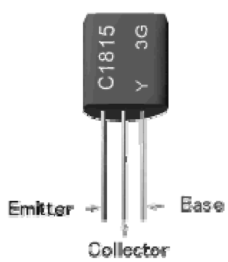


- Either (OR)

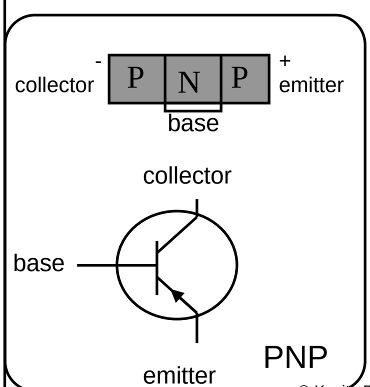


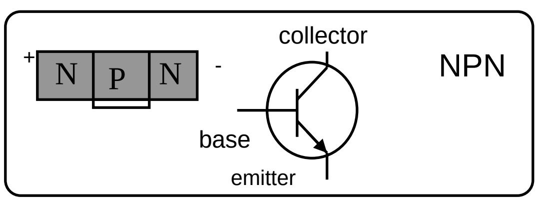
- Both (AND)
- But requires mechanical force

Transistors



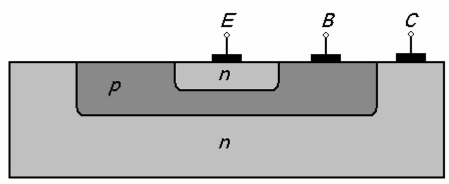
- Solid-state switch
  - The most amazing invention of the 1900s
- PNP and NPN

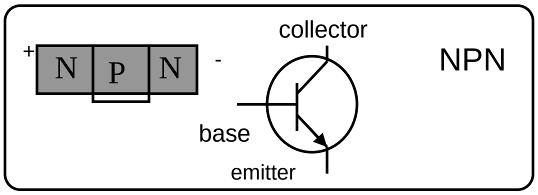




Transistors

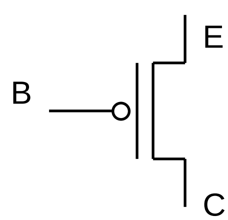
- Semi-conductor





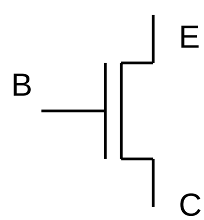
P and N Transistors

- PNP Transistor



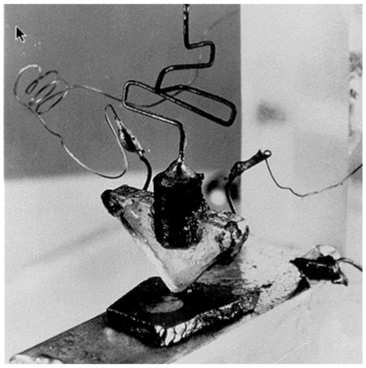
- Connect E to C when base = 0

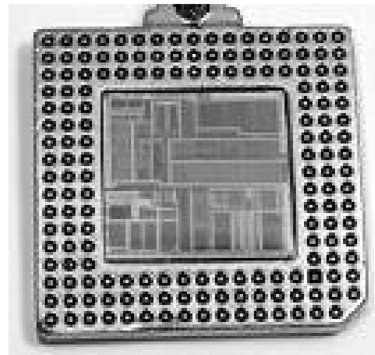
- NPN Transistor



- Connect E to C when base = 1

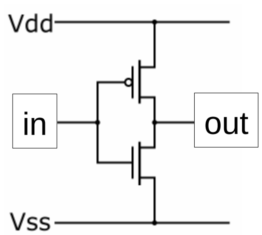
Then and Now



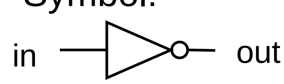


- The first transistor
  - on a workbench at AT&T Bell Labs in 1947
- An Intel Pentium
  - 125 million transistors

Inverter



- Function: NOT
- Called an inverter
- Symbol:



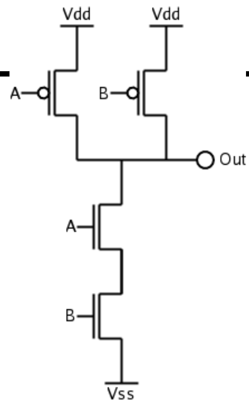
In	Out
0	1
1	0

Truth table

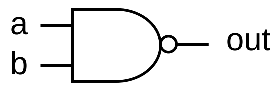
- Useful for taking the inverse of an input

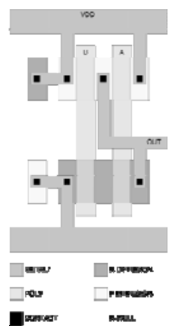
- CMOS: complementary-symmetry metal**–oxide–semiconductor**

NAND Gate



- Function: NAND
- Symbol:





A	B	out
0	0	1
1	0	1
0	1	1
1	1	0

NOR Gate

A	B	out
0	0	1
1	0	0
0	1	0
1	1	0

- Function: NOR
- Symbol: