CS 3410: Computer System Organization and Programming

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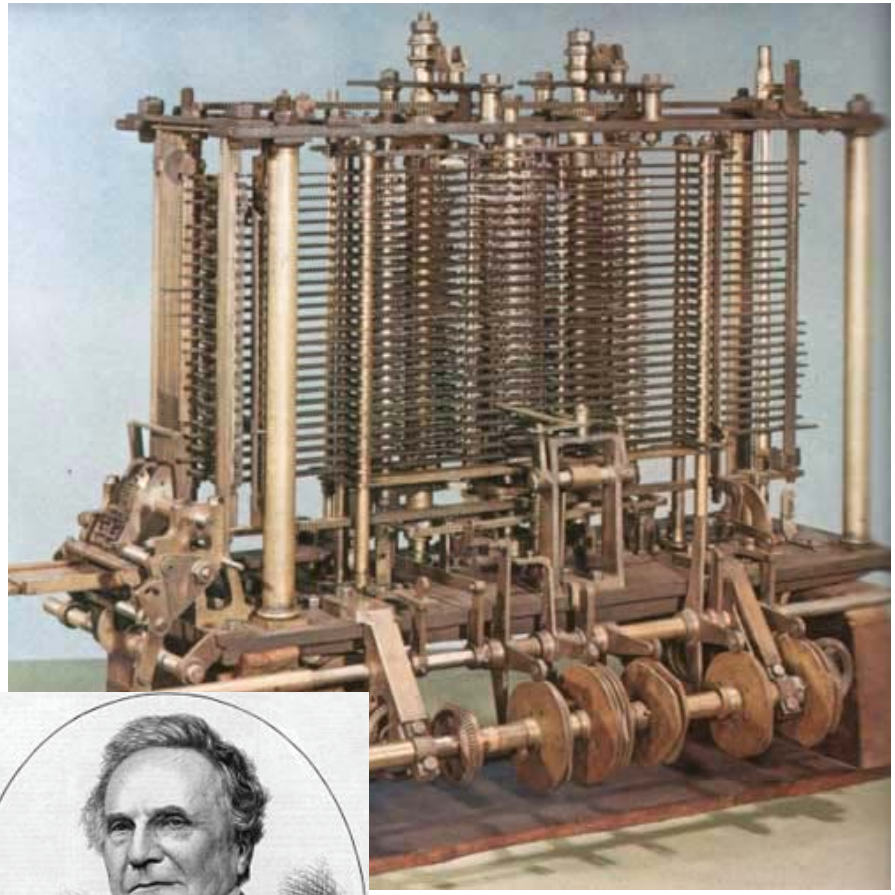
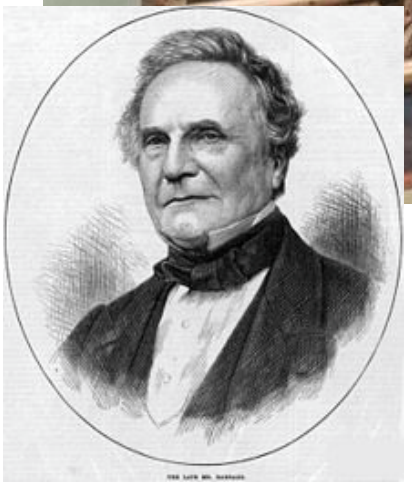
The slides are the product of many rounds of teaching CS 3410 by Professors Weatherspoon, Bala, Bracy, and Sirer.

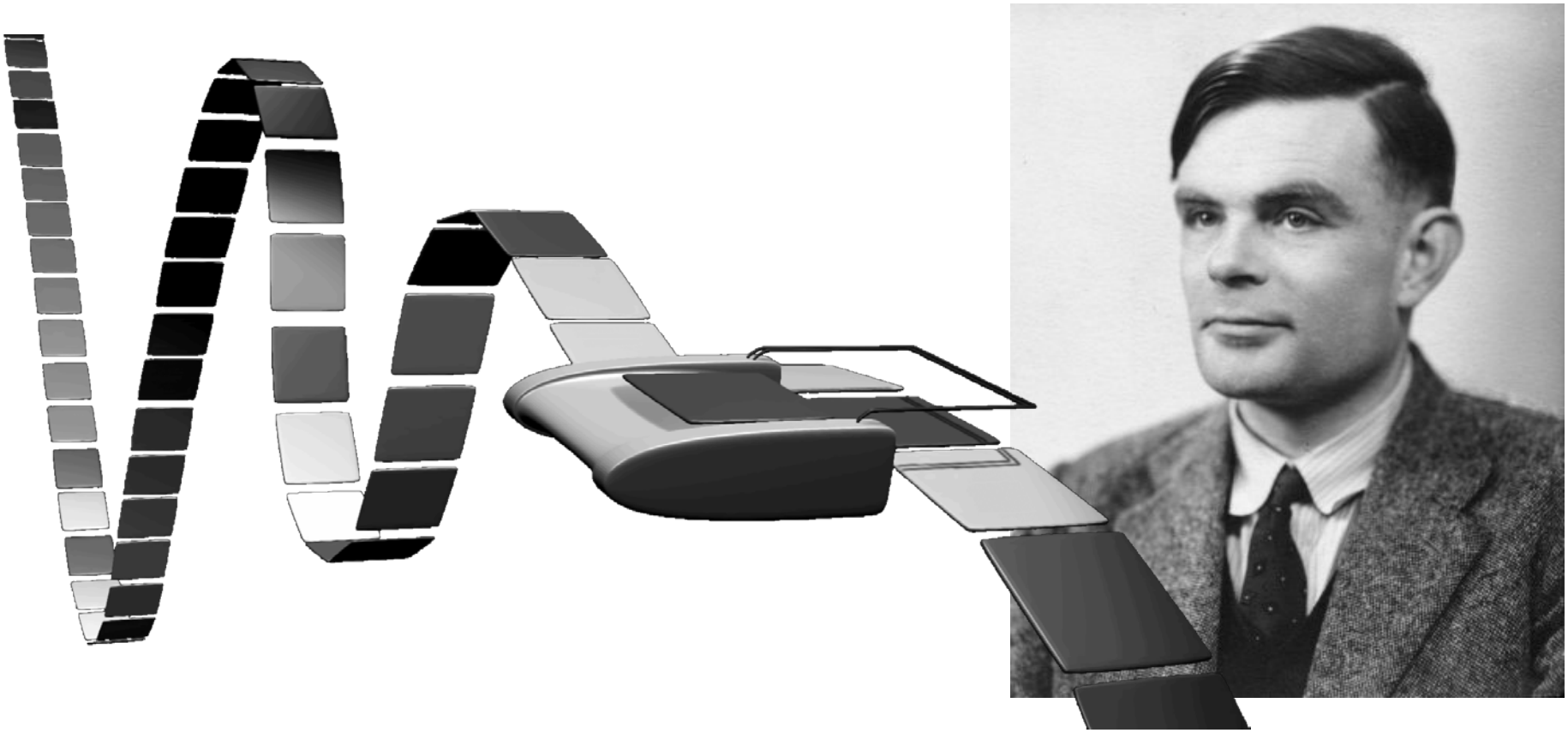
The Analytical Engine

- Designed by Charles Babbage from 1834 – 1871
- Considered to be the first digital computer
- Built from mechanical gears, where each gear represented a discrete value (0-9)
- Babbage died before it was finished





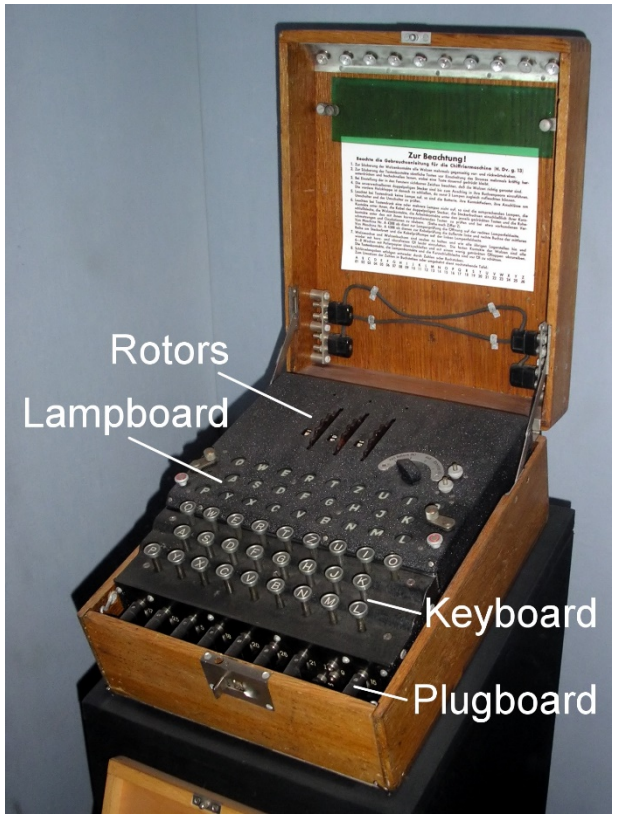
http://history-computer.com
http://wikimedia.com



Turing Machine
1936

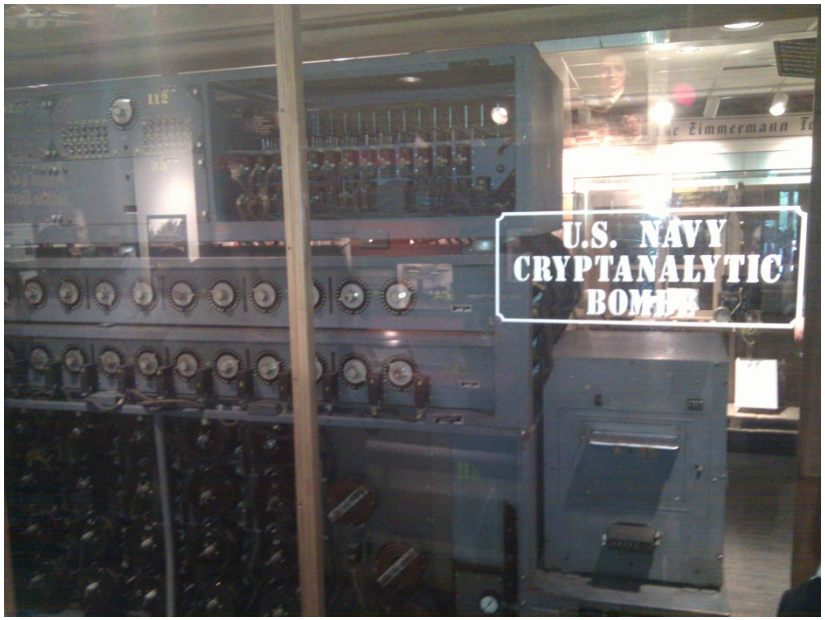
Alan Turing

= abstract model for CPU that can simulate any algorithm



Enigma machine

Used by the Germans during World War II to encrypt and exchange secret messages

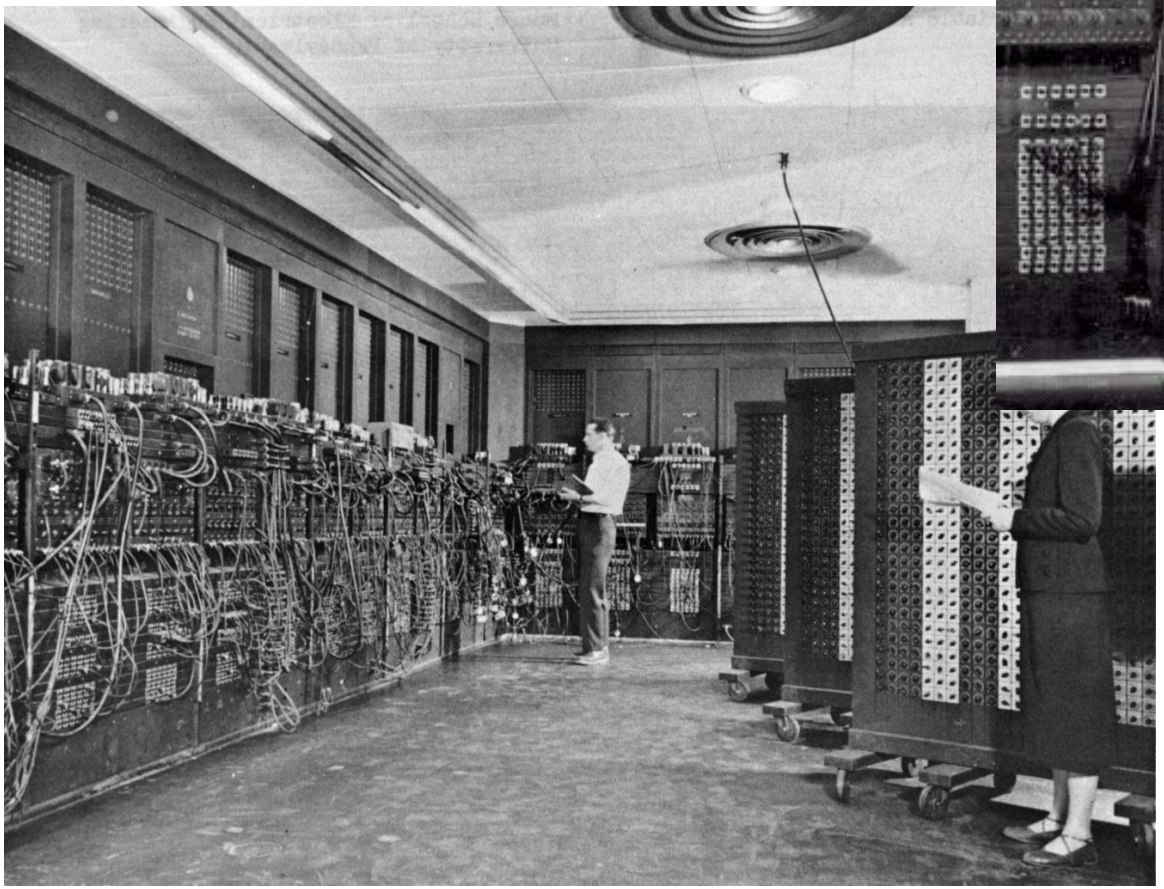


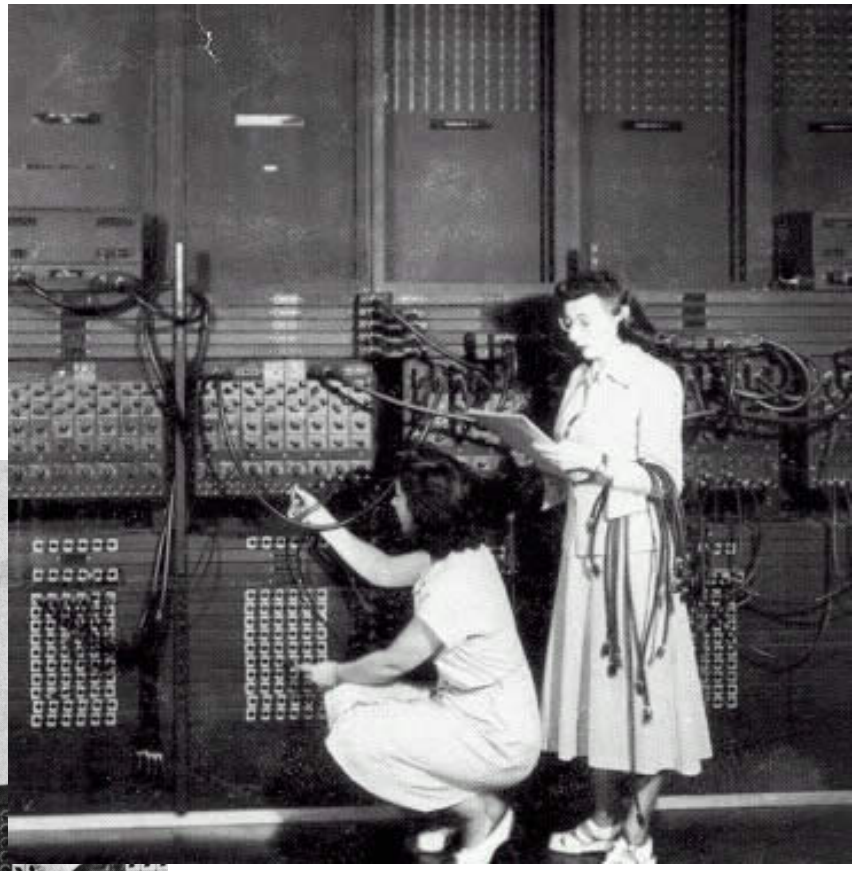
The Bombe

used by the Allies to break the German Enigma machine during World War II

ENIAC

Electronic Numerical Integrator And Computer





1946

John Mauchly

J. Presper Eckert

Who are you?

"Sometimes it is the people that no one imagines anything of who do the things that no one can imagine." – Alan Turing

- Turing Award Winners?
- Eckert Mauchly Award Winners?

Course Objective

- Understand the HW / SW interface software
  - How a processor works
  - How a computer is organized

- Establish a foundation for building applications
  - How to write a good program
    - Good = correct, fast, and secure
  - How to understand where the world is going

- Understand technology (past, present, future)

What is this?

```
#include <stdio.h>

int main() {
  printf("Hello world!\n");
  return 0;
}
```

How does it work?

I'm glad you asked…

15 weeks later and you'll know!

"I know Kung Fu."

Compilers & Assemblers

C

```
int x = 10;
x = 2 * x + 15;
```

compiler

r0 = 0

MIPS assembly language

```
addi r5, r0, 10
muli r5, r5, 2
addi r5, r5, 15
```

r5 = r0 + 10

r5 = r5 * 2

r5 = r5 + 15

assembler

MIPS machine language

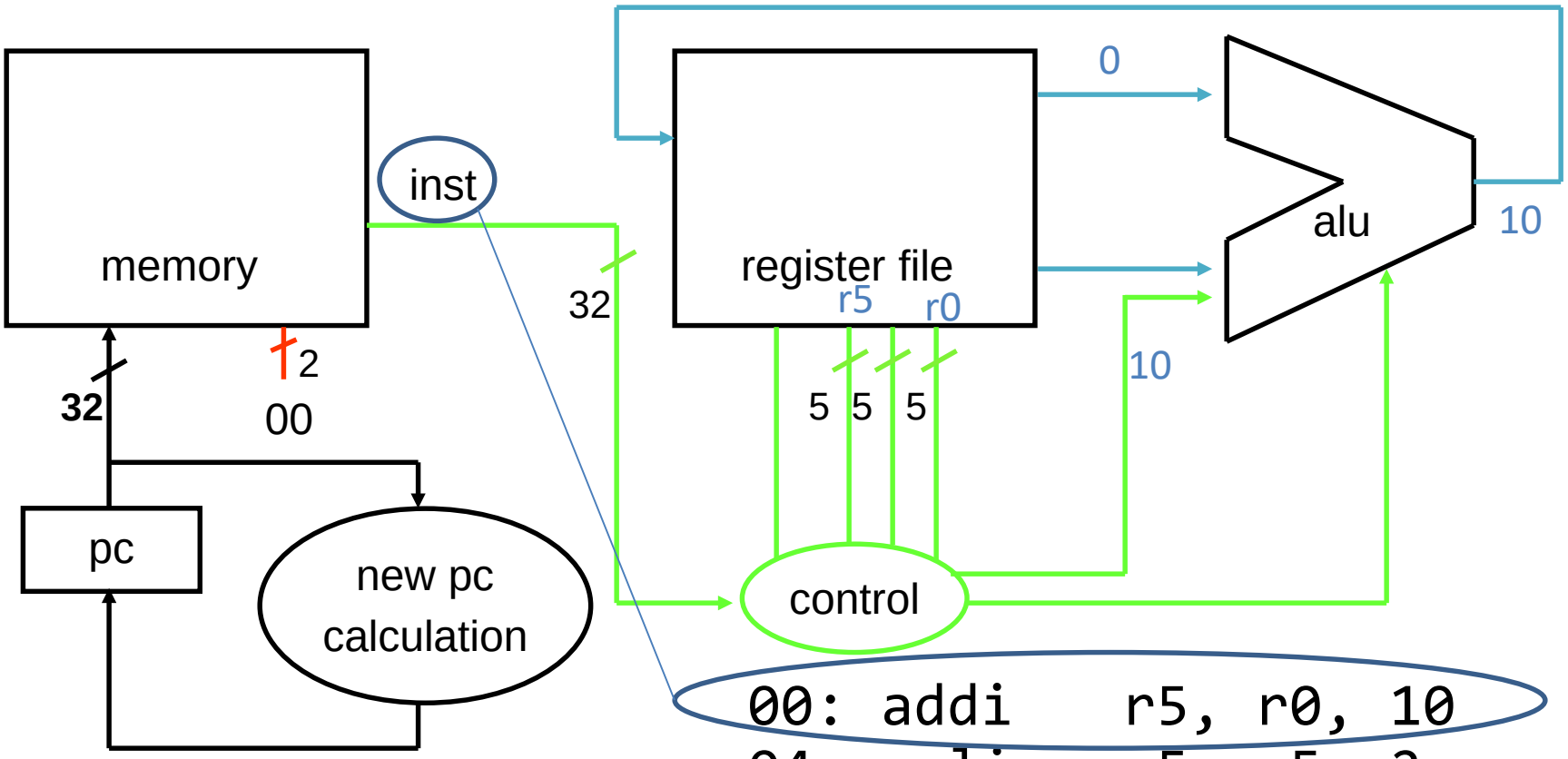
op = addi r0 r5 10

```
00100000000001010000000000001010
00000000000001010010100001000000
00100000101001010000000000001111
```

op = addi r5 r5 15

Everything is a number!

How to Design a Simple Processor




```
00: addi    r5, r0, 10
04: muli    r5, r5, 2
08: addi    r5, r5, 15
```

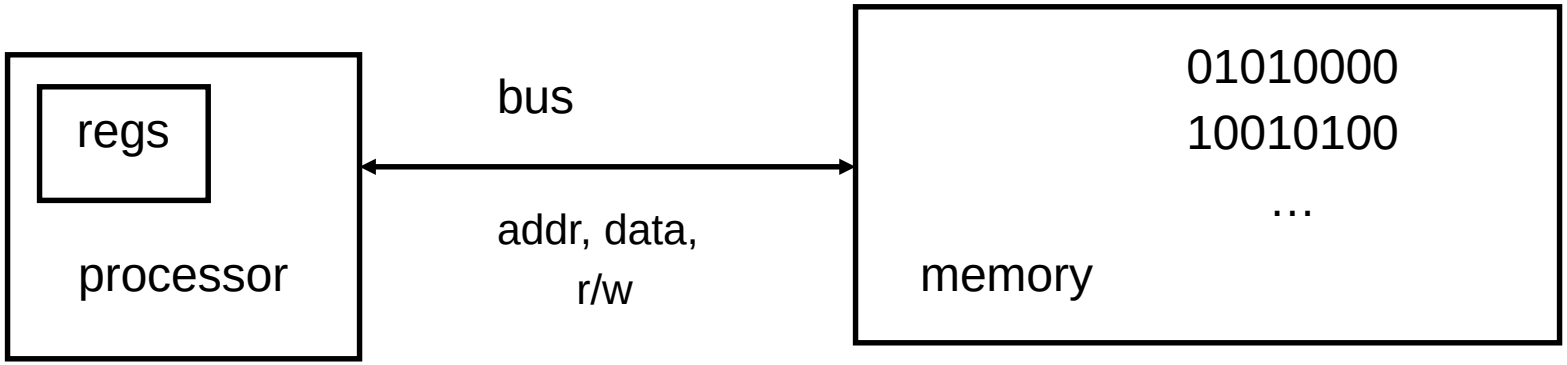
Instruction Set Architecture (ISA)

- abstract interface between hardware and the lowest level software

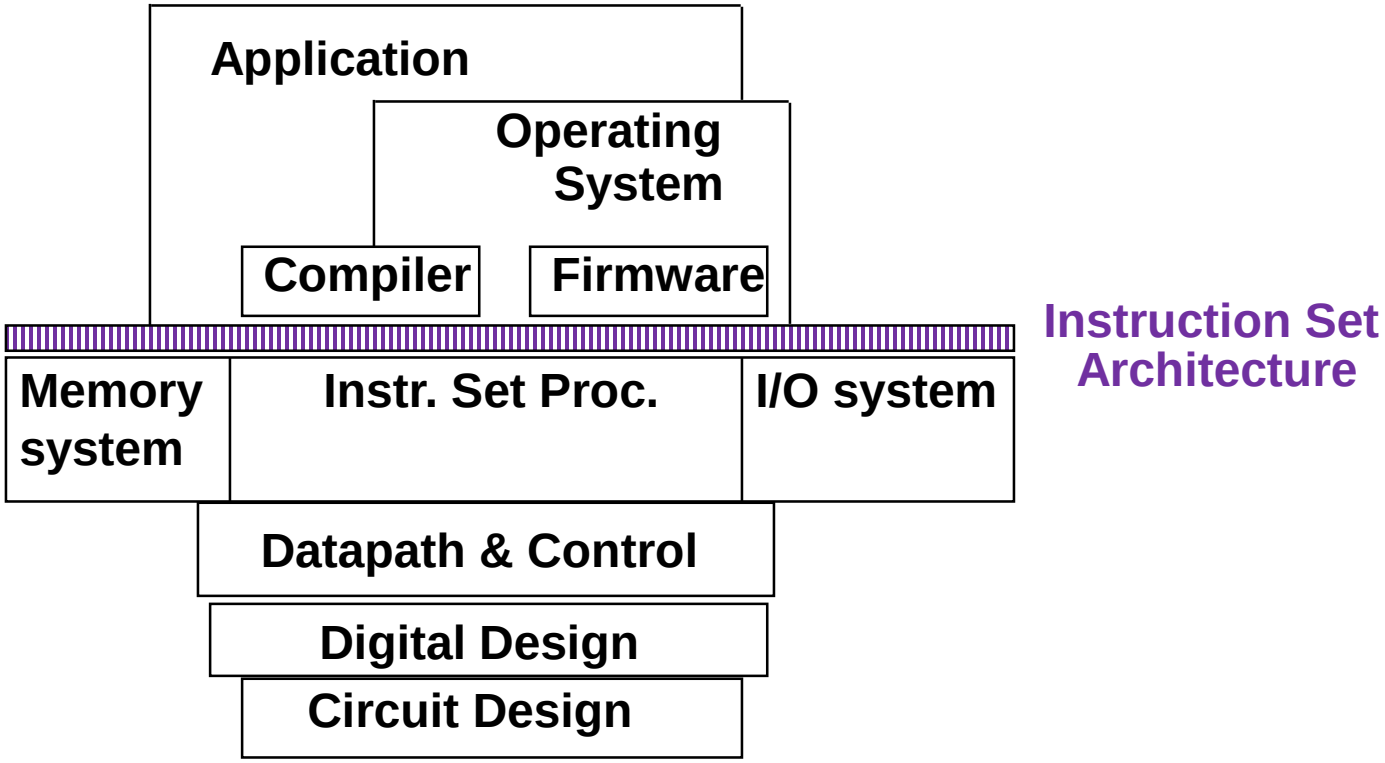
- user portion of the instruction set plus the operating system interfaces used by application programmers

Basic Computer System

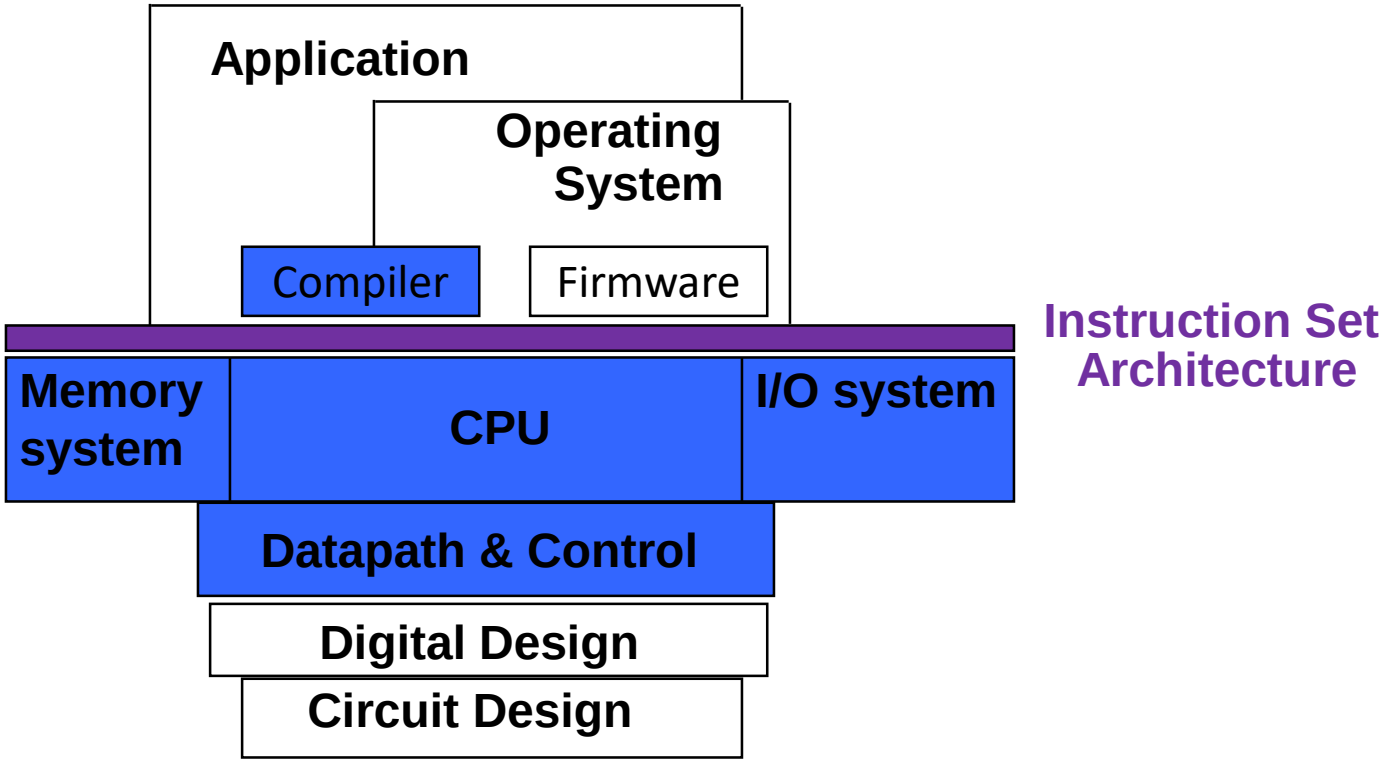
- A processor executes instructions
  - Processor has some internal state in storage elements (registers)
- A memory holds instructions and data
  - von Neumann architecture: combined inst and data
- A bus connects the two



Overview


Application
Operating System
Compiler
Firmware
Instruction Set Architecture
Memory system
Instr. Set Proc.
I/O system
Datapath & Control
Digital Design
Circuit Design

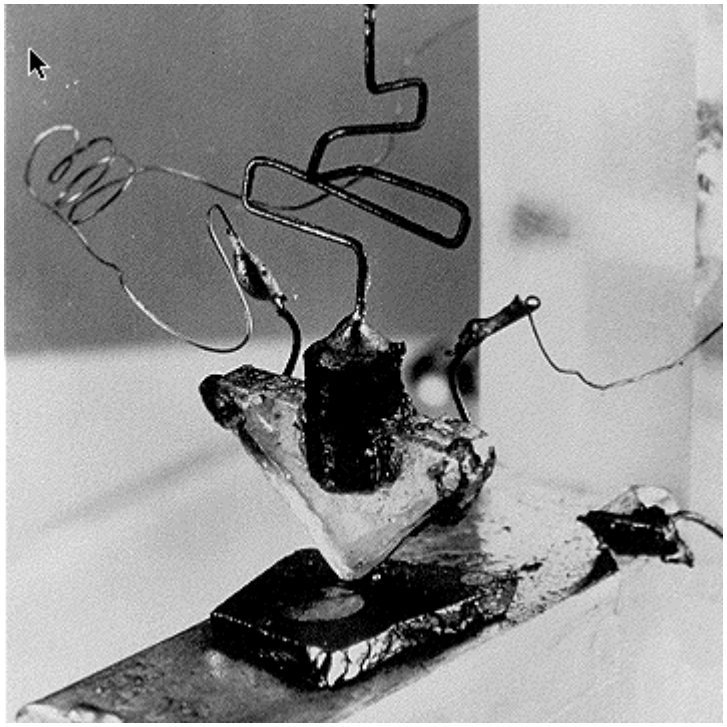
Covered in this course



Where did it begin?

- Electrical Switch
  - On/Off
  - Binary

- Transistor



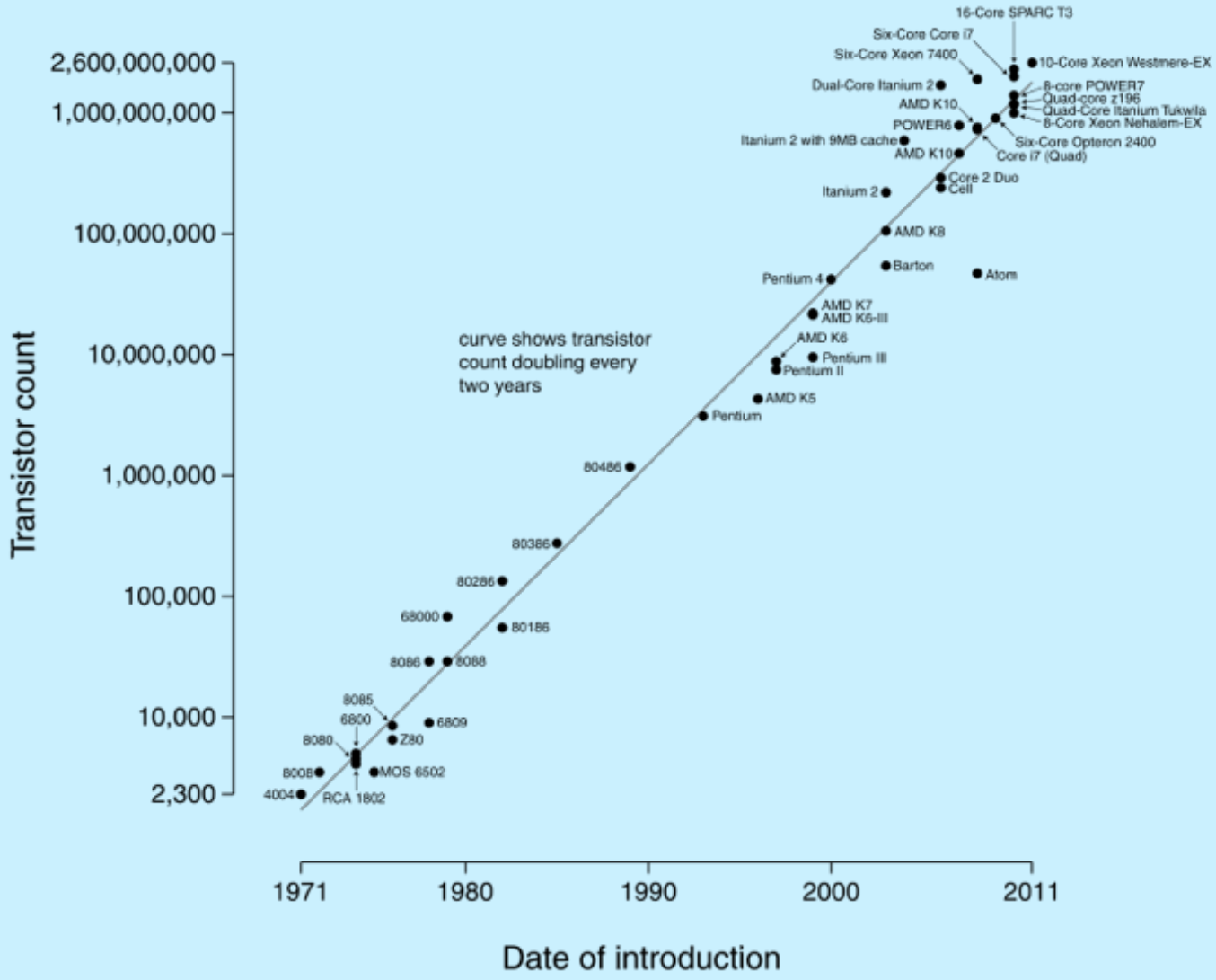
The first transistor on a workbench at AT&T Bell Labs in 1947

Moore's Law

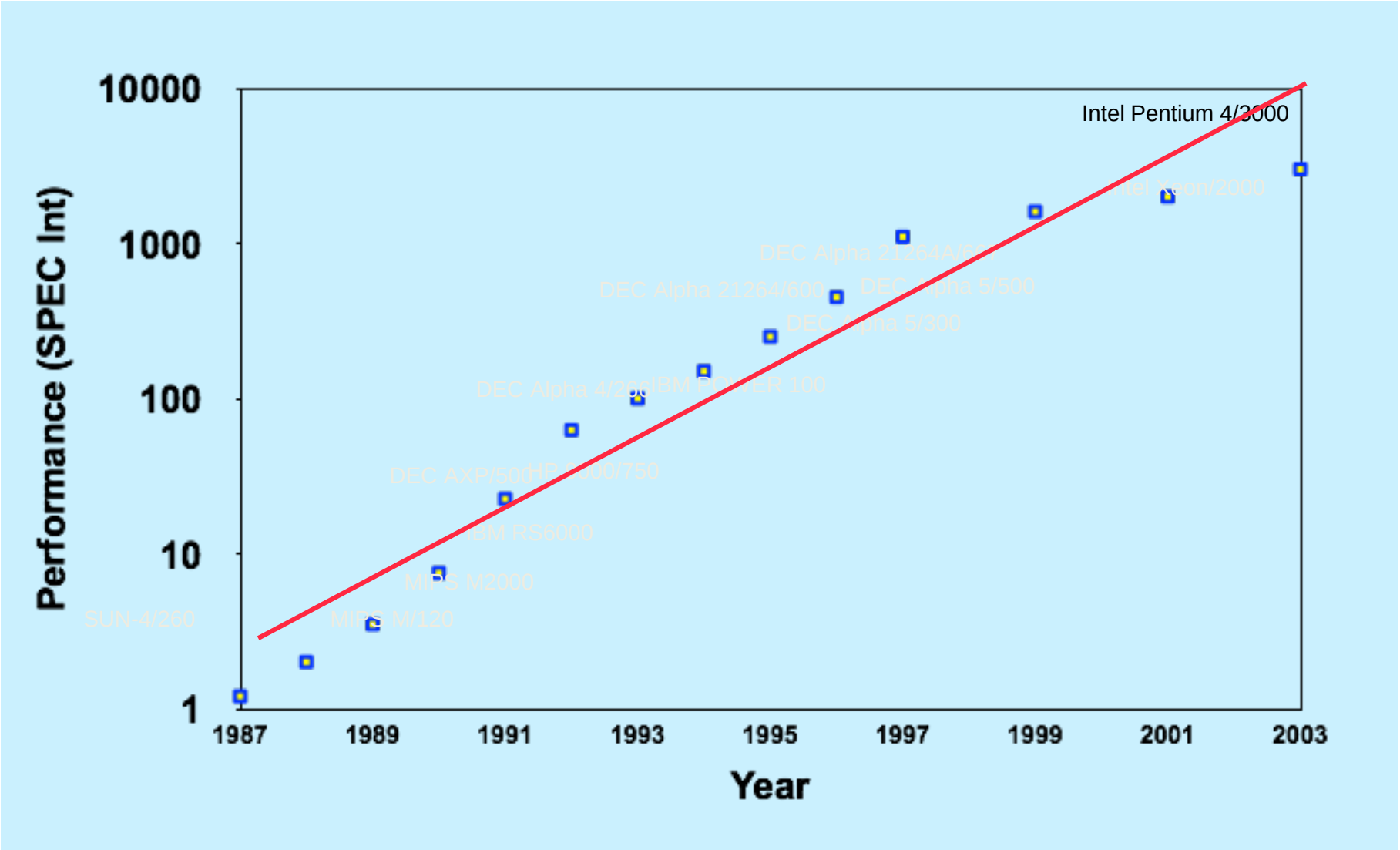
- 1965
  - # of transistors integrated on a die doubles every 18-24 months (*i.e.,* grows exponentially with time)

- 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
  - 721 Million transistors, 2 GHz (Nehalem) - 2009
  - 1.4 Billion transistors, 3.4 GHz Intel Haswell (Quad core) – 2013
  - 7.2 Billion transistors, 3-3.9 GHz Intel Broadwell (22-core) – 2016

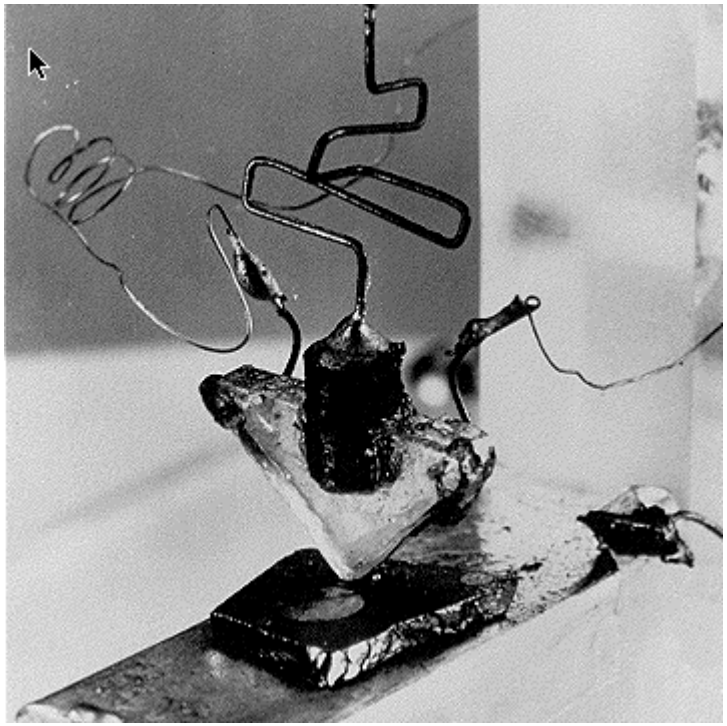
Microprocessor Transistor Counts 1971-2011 & Moore's Law

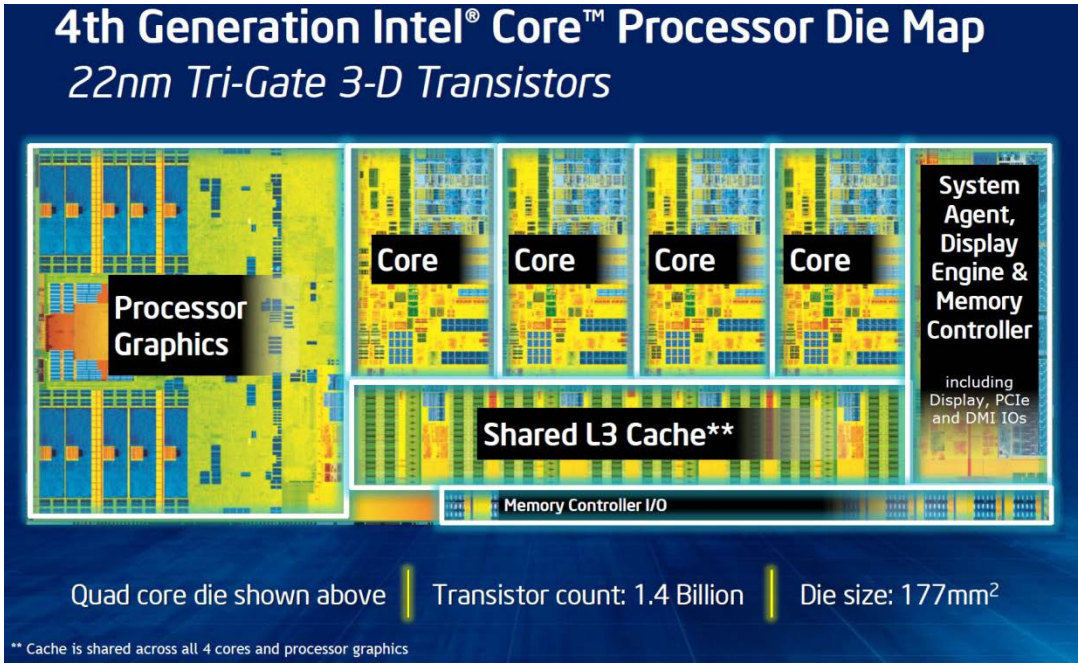


Processor Performance Increase



Then and Now





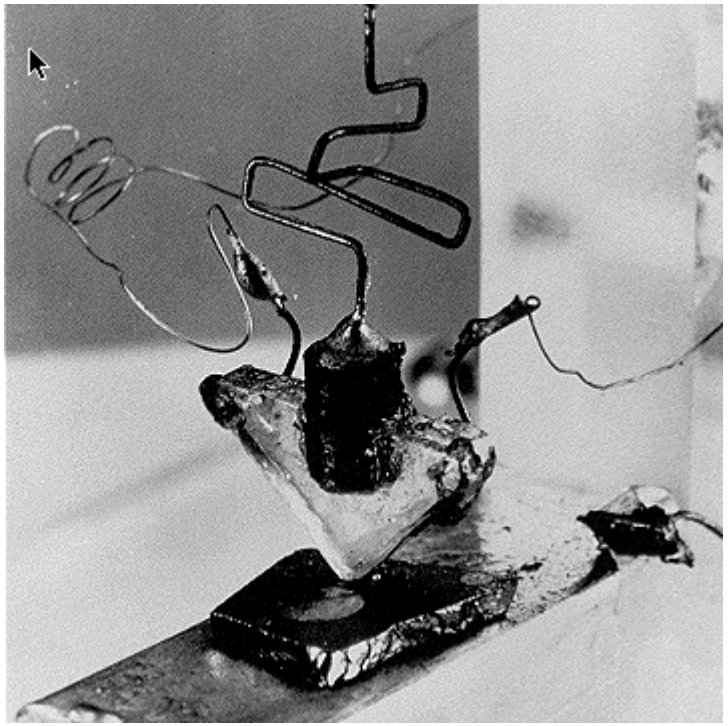
http://techguru3d.com/4th-gen-intel-haswell-processors-architecture-and-lineup/

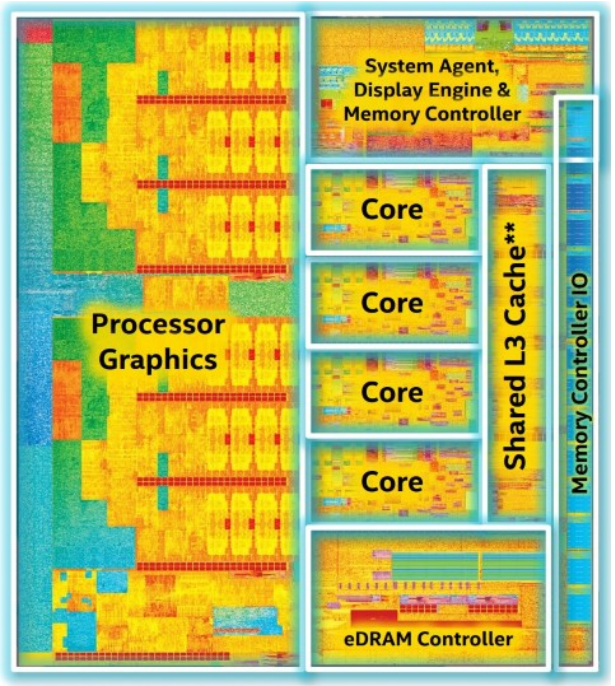
- The first transistor
  - One workbench at AT&T Bell Labs
  - 1947
  - Bardeen, Brattain, and Shockley
- Intel Haswell
  - 1.4 billion transistors, 22nm
  - 177 square millimeters
  - Four processing cores

What are we doing with all these transistors?

https://en.wikipedia.org/wiki/Transistor_count

Then and Now





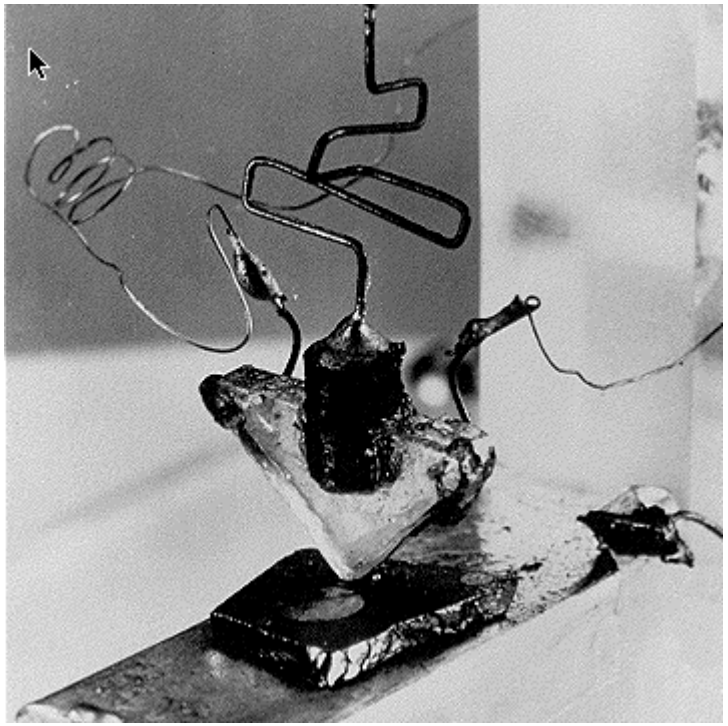
https://www.computershopper.com/computex-2015/performance-preview-desktop-broadwell-at-computex-2015

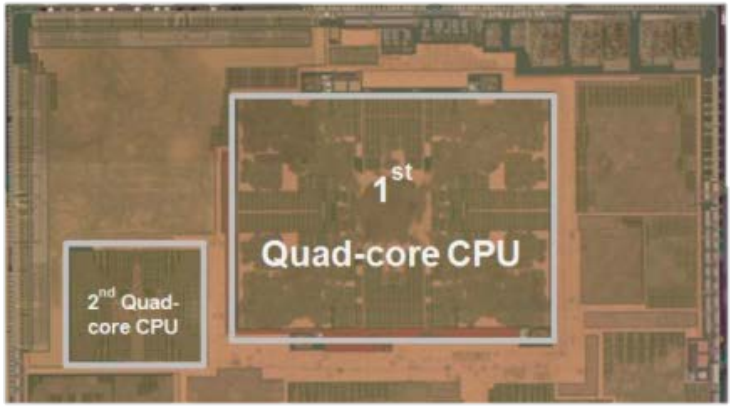
- The first transistor
  - One workbench at AT&T Bell Labs
  - 1947
  - Bardeen, Brattain, and Shockley
- Intel Broadwell
  - 7.2 billion transistors, 14nm
  - 456 square millimeters
  - Up to 22 processing cores

What are we doing with all these transistors?

https://en.wikipedia.org/wiki/Transistor_count

Then and Now





- The first transistor
  - One workbench at AT&T Bell Labs
  - 1947
  - Bardeen, Brattain, and Shockley
- Galaxy Note 8
  - 8 processing cores
  - Exynos 9 Octa 8895 processor

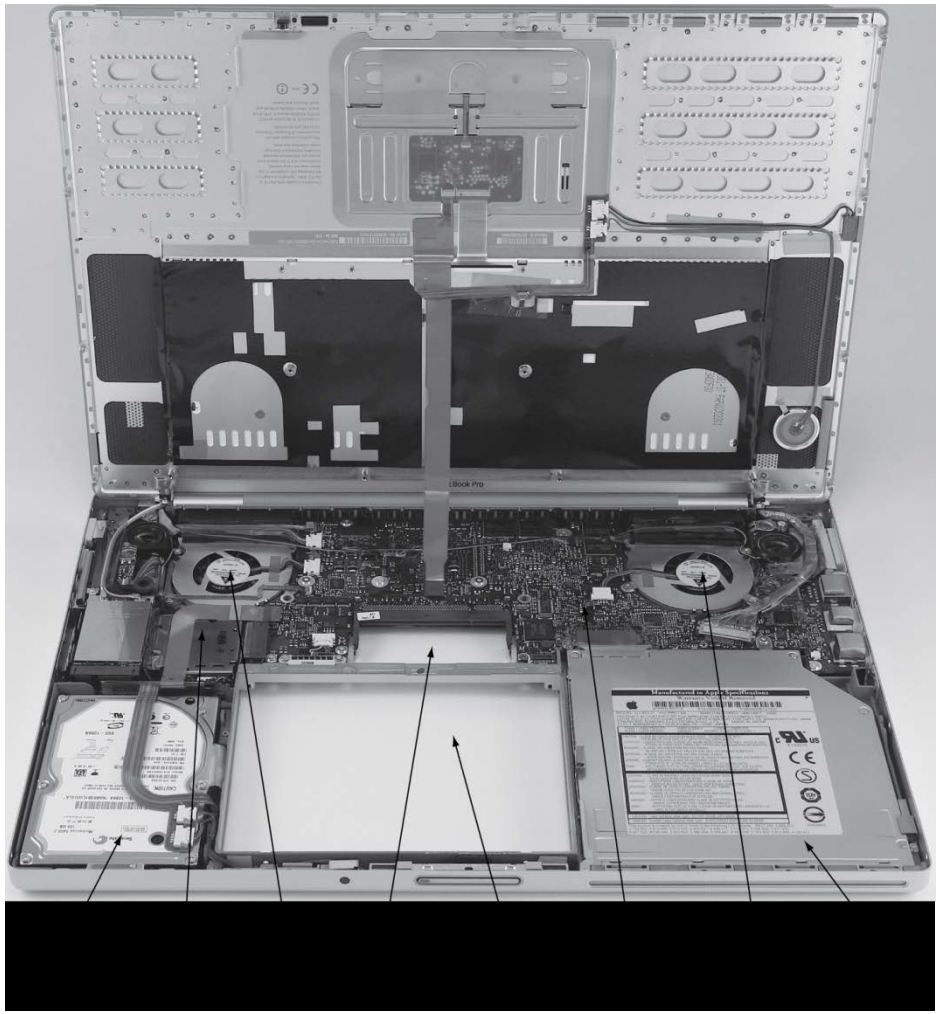
What are we doing with all these transistors?

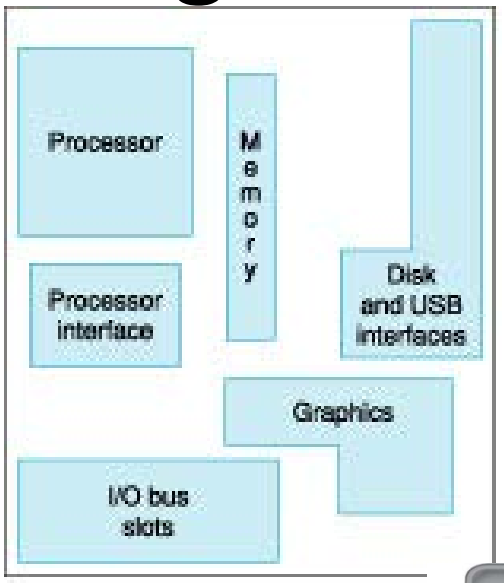
https://en.wikipedia.org/wiki/Exynos

What are we doing with all these transistors?

- Everything these days!
  - Phones, cars, televisions, games, computers,…

Computer System Organization





Reflect

Why take this course?

- Basic knowledge needed for *all* other areas of CS:
  - operating systems, compilers, ...
- Levels are not independent
  - hardware design ↔ software design ↔ performance
- Crossing boundaries is hard but important
  - device drivers
- Good design techniques
  - abstraction, layering, pipelining, parallel vs. serial, ...
- Understand where the world is going

The Mysteries of Computing will be revealed!