Introduction

Prof. Hakim Weatherspoon
CS 3410
Computer Science
Cornell University

[Weatherspoon, Bala, Bracy, and Sirer]
Turing Machine
1936

= abstract model for CPU that can simulate any algorithm

Alan Turing
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
IBM 7090
Human Computers
programming the IBM 7090

Mary Jackson

Hidden Figures
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?

```c
#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 and Assemblers

C

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

RISC-V assembly language

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

```
00000000101000000000010110010011
00000000000100101001001010010011
00000000111100101000001010010011
```

```
10 r0 r5 op = addi
```

Everything is a number!
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

Instruction Set Architecture

Memory system

Instr. Set Proc.

I/O system

Datapath & Control

Digital Design

Circuit Design

Compiler

Firmware

Operating System

Application
Covered in this course

- Memory system
- CPU
- I/O system
- Datapath & Control
- Digital Design
- Circuit Design

Application

Operating System

Compiler

Firmware

Instruction Set Architecture
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, 250mm² 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

The graph shows the transistor count doubling every two years.
Processor Performance Increase
Then and Now

• 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?
Then and Now

**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 9**
  - 8 processing cores
  - Exynos 9 Octa 8895 processor

*What are we doing with all these transistors?*
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!*