Introduction

CS 3410: Computer System Organization and Programming

[K. Bala, A. Bracy, E. Sirer, and H. Weatherspoon]
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
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;
```

MIPS assembly language

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

MIPS machine language

```
op = addi r0 r5 10
00100000000000000000000000001010
00000000000000000010010100001000000000
00100000101001010000000000001111

op = addi r5 r5 15
```

Everything is a number!
How to Design a Simple Processor

```
00: addi r5, r0, 10
04: multi 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
Overview

Instruction Set Architecture

Application

Operating System

Compiler

Firmware

Memory system

Instr. Set Proc.

I/O system

Datapath & Control

Digital Design

Circuit Design
Covered in this course

Application

Operating System

Compiler

Firmware

Memory system

CPU

I/O system

Datapath & Control

Digital Design

Circuit Design

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) - 1971
  • 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
Microprocessor Transistor Counts 1971-2011 & Moore’s Law

curve shows transistor count doubling every two years
Processor Performance Increase

- SUN-4/260
- MIPS M/120
- IBM RS6000
- DEC AXP/500
- HP 9000/750
- DEC Alpha 4/266
- DEC Alpha 5/300
- IBM POWER 100
- DEC Alpha 21264/600
- DEC Alpha 21264A/667
- DEC Alpha 5/500
- Intel Xeon/2000
- Intel Pentium 4/3000
- DEC Alpha 5/300
- DEC Alpha 21264A/667
- DEC Alpha 5/500
- Intel Xeon/2000
- Intel Pentium 4/3000
- DEC Alpha 5/300
- DEC Alpha 21264A/667
- DEC Alpha 5/500
- Intel Xeon/2000
- Intel Pentium 4/3000
• The first transistor
  • One workbench at AT&T Bell Labs
  • 1947
  • Bardeen, Brattain, and Shockley

• Intel Haswell
  • 1.4 billion transistors
  • 177 square millimeters
  • Four processing cores

What are we doing with all these transistors?
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!