1. Layer Cakes
2. Computers are translators
3. Switches and Wires

(in Chapter 1)
First, we have a TA!

Micah Taylor

Office: SN045
Phone: TBA
Office hours: TBA
Duties:

Answer questions on PSs
Grade problem sets
Lead Quiz study sessions
Be your best friend!
Computers Everywhere

• The computers we are used to
  - Desktops
  - Laptops
  - Embedded processors
    • Cars
    • Mobile phones
    • Toasters, irons, wristwatches, happy-meal toys
A Computer System

- What is a computer system?
- Where does it start?
- Where does it end?

\begin{verbatim}
Compiler
for (i = 0; i < 3; i++)
    m += i*i;

Assembler and Linker
addi $8, $6, $6
sll $8, $8, 4
\end{verbatim}
Computer Layer Cake

- Applications
- Systems software
- Shared libraries
- Operating System
- Hardware – the bare metal

Computers are digital Chameleons

<table>
<thead>
<tr>
<th>Apps</th>
<th>Systems S/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Libraries</td>
<td></td>
</tr>
<tr>
<td>Operating System</td>
<td></td>
</tr>
<tr>
<td>Hardware</td>
<td></td>
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</tbody>
</table>
Computers are Translators

- **User-Interface (visual programming)**
- **High-Level Languages**
  - Compilers
  - Interpreters
- **Assembly Language**
- **Machine Language**

```c
int x, y;
y = (x-3)*(y+123456)
```

```assembly
x: .word 0
y: .word 0
c: .word 123456

lw $t0, x
addi $t0, $t0, -3
lw $t1, y
lw $t2, c
add $t1, $t1, $t2
mul $t0, $t0, $t1
sw $t0, y
```
Computers are Translators

- User-Interface (visual programming)
- High-Level Languages
  - Compilers
  - Interpreters
- Assembly Language
- Machine Language

```
x: .word 0
y: .word 0
c: .word 123456

... lw $t0, x
     addi $t0, $t0, -3
     lw $t1, y
     lw $t2, c
     add $t1, $t1, $t2
     mul $t0, $t0, $t1
     sw $t0, y
```

0x04030201 0x08070605 0x00000001 0x00000002 0x00000003 0x706d6f43
Why So Many Languages?

- **Application Specific**
  - Historically: COBOL vs. Fortran
  - Today: C# vs. Java
    - Python vs. Matlab

- **Code Maintainability**
  - High-level specifications are easier to understand and modify

- **Code Reuse**

- **Code Portability**

- **Virtual Machines**
Under the Covers

- **Input**
- **Output**
- **Storage**
- **Processing**
  - Datapath
  - Control
Under the Covers

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_Cathode Ray Tube (CRT)_

The “last vacuum tube”
Now nearing extinction
Under the Covers

- **Input**
- **Output**
- **Storage**
- **Processing**
  - Datapath
  - Control

Liquid Crystal Displays (LCDs)
Under the Covers

- Input
- Output
- Storage
- Processing
  - Datapath
  - Control
Under the Covers

- Input
- Output
- Storage
- Processing
- Datapath
- Control

<table>
<thead>
<tr>
<th>Size</th>
<th>Year</th>
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<tr>
<td>64 Kb</td>
<td>1980</td>
</tr>
<tr>
<td>256 Kb</td>
<td>1983</td>
</tr>
<tr>
<td>1 Mb</td>
<td>1986</td>
</tr>
<tr>
<td>4 Mb</td>
<td>1989</td>
</tr>
<tr>
<td>16 Mb</td>
<td>1992</td>
</tr>
<tr>
<td>64 Mb</td>
<td>1996</td>
</tr>
<tr>
<td>256 Mb</td>
<td>1999</td>
</tr>
<tr>
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<td>2002</td>
</tr>
<tr>
<td>4 Gb</td>
<td>2004</td>
</tr>
</tbody>
</table>
Under the Covers

- Input
- Output
- Storage
- Processing
  - Datapath
  - Control

Intel® Pentium® Core 2
Extreme processor die

The hottest chip you can get???
Issues for Modern Computers

- GHz Clock speeds
- Multiple Instructions per clock cycle
- Multi-core
- Memory Wall
- I/O bottlenecks
- Power Dissipation

Will I ever understand all this stuff?

- Technology Changes

Courtesy Troubador
Implementation Technology

- Relays
- Vacuum Tubes
- Transistors
- Integrated Circuits
  - Gate-level integration
  - Medium Scale Integration (PALs)
  - Large Scale Integration (Processing unit on a chip)
  - Today (Multiple CPUs on a chip)
- Nanotubes??
- Quantum-Effect Devices??
Implementation Technology

- Common Links?
- A controllable switch
- Computers are *wires* and *switches*
Chips

- **Silicon Wafers**
  - Chip manufacturers build many copies of the same circuit onto a single wafer. Only a certain percentage of the chips will work; those that work will run at different speeds. The yield decreases as the size of the chips increases and the feature size decreases.
  - Wafers are processed by automated fabrication lines. To minimize the chance of contaminants ruining a process step, great care is taken to maintain a meticulously clean environment.
Field Effect Transistors (FETs)

- Modern silicon fabrication technology is optimized to build a particular type of transistor. The flow of electrons from the source to the drain is controlled by a gate voltage.
Chips

- **Silicon Wafers**
  IBM photomicrograph (Si has been removed!)
How Computers WERE Designed

• 20 years ago
  ▪ I/O Specification
    • Truth tables
    • State diagrams
  ▪ Logic design
  ▪ Circuit design
  ▪ Circuit Layout
How Computers ARE Designed

• Today (with software)
• High-level hardware specification languages
  - Verilog
  - VHDL

Verilog (One-Hot)
Following is the Verilog code for a 1-of-8 decoder.

```verilog
module mux (sel, res);
    input [2:0] sel;
    output [7:0] res;
    reg [7:0] res;

always @(sel or res)
    begin
        case (sel)
            3'b000 : res = 8'b00000001;
            3'b001 : res = 8'b00000010;
            3'b010 : res = 8'b00000100;
            3'b011 : res = 8'b00001000;
            3'b100 : res = 8'b00010000;
            3'b101 : res = 8'b00100000;
            3'b110 : res = 8'b01000000;
            default : res = 8'b10000000;
        endcase
    end
endmodule
```

VHDL (One-Hot)
Following is the VHDL code for a 1-of-8 decoder.

```vhdl
library ieee;
use ieee.std_logic_1164.all;

entity dec is
    port (sel: in std_logic_vector (2 downto 0);
        res: out std_logic_vector (7 downto 0));
end dec;
architecture archi of dec is
begin
    res <= "00000001" when sel = "000" else
        "00000010" when sel = "001" else
        "00000100" when sel = "010" else
        "00001000" when sel = "011" else
        "00010000" when sel = "100" else
        "00100000" when sel = "101" else
        "01000000" when sel = "110" else
        "10000000";
end archi;
```
Reconfigurable Chips

- **Programmable Array Logic (PALs)**
  - Fixed logic / programmable wires
- **Field Programmable Gate Arrays (FPGAs)**
  - Repeated reconfigurable logic cells
Next Time

• Computer Representations

• How is $X$ represented in computers?
  - $X = \text{text}$
  - $X = \text{numbers}$
  - $X = \text{anything else}$

• Encoding Information