ECE 3534
Microprocessor System Design

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Blackboard Site: http://learn.vt.edu
What we expect of you . . . 

- An understanding of the basics of
  - Combinational and sequential logic
  - Binary representations and arithmetic
  - Assembly language
  - Computer organization

- A desire to do some work:
  - Laboratory assignments
    - Technical content and “Writing intensive” content
  - Homework
  - Online quizzes
  - A mid-semester exam
  - A final exam
What you can expect from us . . .

- Develop an in-depth understanding of the operation and design of microprocessors in general, to include:
  - Hardware
  - Software
  - Integrated systems
- Develop a thorough understanding of the Xilinx MicroBlaze microcontroller as a learning vehicle
- Ultimate goal: be able to apply this knowledge to more advanced microprocessors
Major, Measurable Learning Objectives

- Compare alternative microprocessor and microcontroller features and select features appropriate for a given application task.
Major, Measurable Learning Objectives

- Design hardware and software, and compare alternative designs for one or more specific microprocessors and/or microcontrollers considering:
  - address, data, and control signals
  - input/output hardware and control software
  - interrupt hardware and control software
  - external read-only and read/write memory
  - system buses
  - external device addressing
Major, Measurable Learning Objectives

- Implement microprocessor-based systems, including both hardware and software, using a specific microprocessor or microcontroller considering application-oriented software and hardware interfaces.
  - application-oriented software
  - hardware interfaces
Major, Measurable Learning Objectives

- Write and revise technical reports
Course Logistics

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QOTD
MWF
QUESTION: The Sony Playstation 3 features the IBM Cell processor, which has 234 million transistors, measures 235 square millimeters (mm²) in size, can run at speeds of more than 4 gigahertz (GHz), has a memory bandwidth of 25.6 gigabytes per second (GBps), and has an input/output (I/O) bandwidth of 76.8 Gbps. This is a multi-core processor featuring nine separate processors. One of the processor cores is most similar to which of the following processors:

a) ARM  
b) PowerPC  
c) Motorola HC11  
d) Intel Core Solo  
e) PIC18  
f) Intel 8051
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Course Introduction

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Common Computer Organization

- **Memory**  - Stores programs and data
- **CPU**  - Central Processing Unit
- **ALU**  - Arithmetic & Logic Unit
- **Control Unit**  - Sequences data transfers and other operations
- **I/O Unit**  - Communicates with the “outside world”

![Diagram of computer organization](image)
Computer Architecture

- Classic **von Neumann** computer organization:
  - Store programs as codes that can be changed easily, rather than using special wiring
  - “General-purpose”
  - Instructions and data can share the same memory space
  - One instruction is executed at a time

- A system's architecture is determined by both its hardware and its software
Computer Programming before von Neumann
Course Focus

SOFTWARE

HARDWARE
Course Focus

SOFTWARE

HARDWARE

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ECE4534 Embedded Systems

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SOFTWARE

HARDWARE
Course Focus

SOFTWARE

ECE4534 Embedded Systems

HARDWARE

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ECE4514 Digital II
Hardware Design Levels
Hardware Design Levels

SYSTEM:
Processors, memory, I/O
Hardware Design Levels

SYSTEM:
Processors, memory, I/O

PROCESSOR:
Instruction sets, interfaces, data representation
Hardware Design Levels

SYSTEM:
Processors, memory, I/O

PROCESSOR:
Instruction sets, interfaces, data representation

REGISTER:
ALUs, data path control
Hardware Design Levels

**SYSTEM:**
Processors, memory, I/O

**PROCESSOR:**
Instruction sets, interfaces, data representation

**REGISTER:**
ALUs, data path control

**GATE:**
Boolean equations, timing, fanout, etc.
Software Design Levels
Software Design Levels

APPLICATION:
Excel, Matlab, Spice
Software Design Levels

APPLICATION: Excel, Matlab, Spice
HIGH-LEVEL LANGUAGE: C, C++, Java, FORTRAN
Efficiency and Portability
Software Design Levels

APPLICATION: Excel, Matlab, Spice

HIGH-LEVEL LANGUAGE: C, C++, Java, FORTRAN

Efficiency and Portability

ASSEMBLY: Access to machine-specific resources.
Software Design Levels

**APPLICATION:** Excel, Matlab, Spice

**HIGH-LEVEL LANGUAGE:** C, C++, Java, FORTRAN

Efficiency and Portability

**ASSEMBLY:**
Access to machine-specific resources.

**MACHINE:**
Not meant for human consumption
## Microprocessor Progression (Intel)

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Transistors</th>
<th>Microns</th>
<th>Clock speed</th>
<th>Data width</th>
<th>MIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8080</td>
<td>1974</td>
<td>6,000</td>
<td>6</td>
<td>2 MHz</td>
<td>8 bits</td>
<td>0.64</td>
</tr>
<tr>
<td>8086</td>
<td>1978</td>
<td>29,000</td>
<td>3</td>
<td>5 MHz</td>
<td>16 bits</td>
<td></td>
</tr>
<tr>
<td>80286</td>
<td>1982</td>
<td>134,000</td>
<td>1.5</td>
<td>6 MHz</td>
<td>16 bits</td>
<td>1</td>
</tr>
<tr>
<td>80386</td>
<td>1985</td>
<td>275,000</td>
<td>1.5</td>
<td>16 MHz</td>
<td>32 bits</td>
<td>5</td>
</tr>
<tr>
<td>80486</td>
<td>1989</td>
<td>1,200,000</td>
<td>1</td>
<td>25 MHz</td>
<td>32 bits</td>
<td>20</td>
</tr>
<tr>
<td>Pentium</td>
<td>1993</td>
<td>3,100,000</td>
<td>0.8</td>
<td>60 MHz</td>
<td>32 bits 64-bit bus</td>
<td>100</td>
</tr>
<tr>
<td>Pentium II</td>
<td>1997</td>
<td>7,500,000</td>
<td>0.35</td>
<td>233 MHz</td>
<td>32 bits 64-bit bus</td>
<td>~300</td>
</tr>
<tr>
<td>Pentium III</td>
<td>1999</td>
<td>9,500,000</td>
<td>0.25</td>
<td>450 MHz</td>
<td>32 bits 64-bit bus</td>
<td>~510</td>
</tr>
<tr>
<td>Pentium 4</td>
<td>2000</td>
<td>42,000,000</td>
<td>0.18</td>
<td>1.5 GHz</td>
<td>32 bits 64-bit bus</td>
<td>~1,700</td>
</tr>
<tr>
<td>Pentium 4 &quot;Prescott&quot;</td>
<td>2004</td>
<td>125,000,000</td>
<td>0.09</td>
<td>3.6 GHz</td>
<td>32 bits 64-bit bus</td>
<td>~7,000</td>
</tr>
</tbody>
</table>

Source: [http://computer.howstuffworks.com/microprocessor2.htm](http://computer.howstuffworks.com/microprocessor2.htm)
(Compiled from The Intel Microprocessor Quick Reference Guide and TSCP Benchmark Scores)
Putting 0.065 Microns in Perspective

Transistor for 90 nm process

Influenza virus
Source: CDC
What happened to the 10 GHz Goal?

1. Why did Pentiums stall out at about 4 GHz?

2. How is performance being addressed now?
Answers:

1. 

2.
Microprocessors

- High performance, general purpose "brains" for PCs and workstations
- Instruction decode and control, arithmetic/logic operations, registers, timing, external control
- Typical cost: $75 -- $500
- Annual demand: 10s of millions
Devices with high levels of integration for embedded control

- Microprocessor functions plus on-chip memory and peripheral functions (e.g. ports, timers)
- "Swiss army knife" of the technology
- Typical cost: $1-- $25
- Annual demand: billions!
Typical Baseline Microcontroller
Microprocessors have evolved in two directions:

- High-end Microprocessors
  - Increasing circuit integration
- Microcontrollers
  - Architectural Complexity
  - On-chip Functions
Microprocessor vs. Microcontroller

- Not always a clear distinction
- Today’s microprocessor may be tomorrow’s microcontroller

Microprocessor

- Includes memory management unit
- Lots of cache
- Performance is most important feature (cost is important, but secondary)
- Used mainly in desktop machines
Microprocessor vs. Microcontroller

- **Microcontroller**
  - Integrated RAM and ROM
  - No cache
  - Includes lots of peripherals
  - Used mainly in “embedded” applications
  - Often involves real-time control

- Important features include
  - Low cost
  - Low power consumption
  - Number of integrated peripherals
  - Interrupt response time
  - Amount of RAM and ROM
Some Microcontroller Applications

"When we sell it we have no idea whether it will end up in a toaster or the space shuttle" [article in Financial World, 1995]

- Pocket pagers
  (low-power, interprets characters, user interface)

- Cameras
  (low-power, exposure and focus control, user interface)

- Keyboard controllers
  (scanning, debounce, autorepeat, diagnostics)

- Modems
  (one for data transmission, one for command processing)

- Printers / copiers
  (paper positioning, color exposure, sensors)

- Charge card pay phones
  (card reading, dialing, carrier access)

- Lawn sprinkler controller
  (timer, valve control, user interface)

- Instrumentation
  (user interface, GPIB interface)
Higher-level View

- Sensors
- User Input
- Other Sources

Microcontroller
- Processing
- Timing
- Storage

- Actuators
- User Output
- Other Output
The Instruction Cycle

- **Fetch**
  - Control unit gets next instruction from memory

- **Decode**
  - Control unit figures out what instruction it has

- **Execute**
  - Control unit carries out the instruction by transferring data to/from appropriate places, possibly specifying ALU micro-operations and possibly involving I/O hardware.
Coming Soon . . .

- MicroBlaze hardware
- MicroBlaze software