CIS 407/507
Introduction to Digital Design
Part II

Prof. Michel A. Kinsky
In this class we will focus on FPGA-based design as a sub-domain of digital design.
Programmable Logics

- Field Programmable Gate Arrays (more on it later)
  - Each cell in array contains a programmable logic function
  - Array has programmable interconnect between logic functions

![Diagram showing Logic Block, I/O Block, and Interconnect]
The Design Process

- Functional specification
  - What is the function performed by the object?
  - Constraints: How fast? How much area? How much cost?
  - Refine abstract functional blocks into more concrete realizations
The Design Process

- Functional specification
- Implementation
  - Assemble primitives into more complex building blocks
  - Composition via wiring
  - Choose among alternatives to improve the design

Debugging
The Design Process

- Functional specification
- Debugging
  - Faulty systems: design flaws, composition flaws, component flaws
  - Design to make debugging easier
  - Hypothesis formation and troubleshooting skills
The Design Process

Functional Specification

- Functional specification
  - A fire sprinkler system should spray water if high heat is sensed and the system is set to enabled
The Design Process

- **Functional specification**
  - A fire sprinkler system should spray water if high heat is sensed and the system is set to enabled

- **Implementation**
  - Let Boolean variable $h$ represent “high heat is sensed,” $e$ represent “enabled,” and $F$ represent “spraying water.” Then an equation is: $F = h \text{ AND } e$
The Design Process

• Functional specification
  ‣ A car alarm should sound if the alarm is enabled, and either the car is shaken or the door is opened
The Design Process

- **Functional specification**
  - A car alarm should sound if the alarm is enabled, and either the car is shaken or the door is opened.

- **Implementation**
  - Let a represent “alarm is enabled,” s represent “car is shaken,” d represent “door is opened,” and F represent “alarm sounds.” Then an equation is: F = a AND (s OR d).
The Design Process

- **Functional specification**
  - A car alarm should sound if the alarm is enabled, and either the car is shaken or the door is opened

- **Implementation**
  - Alternatively, assuming that our door sensor $d$ represents “door is closed” instead of open (meaning $d=1$ when the door is closed, $0$ when open), we obtain the following equation: $F = a \text{ AND } (s \text{ OR NOT}(d))$. 
Boolean Algebra to Digital Design

Symbol

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Truth table</th>
<th>Transistor circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT</td>
<td>x</td>
<td>0</td>
</tr>
<tr>
<td>OR</td>
<td>x y</td>
<td>0 0</td>
</tr>
<tr>
<td>AND</td>
<td>x y</td>
<td>0 0</td>
</tr>
</tbody>
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Computer Architecture and Embedded Systems Laboratory (CAES Lab)
Our First Digital Circuit!

- Motion sensor example
  - Turn on lamp (F=1) when motion sensed (a=1) and no light (b=0)
    - F = a AND NOT(b)
  - Build using logic gates, AND and NOT, as shown
Computer Design

- Has all the design elements mentioned in previous slides

Digital Computer

- Memory System
- Central Processing Unit

- Instruction
- Data
- Address

- Input
- Output

Clock
Little Bit of History

• The theory of everything
  ‣ The First Computer

The Babbage Difference Engine (1832)

25,000 parts

cost: £17,470
ENIAC - The first electronic computer (1946)
The Transistor Revolution

First transistor
Bell Labs, 1948
The First Integrated Circuits

Bipolar logic
1960’s

ECL 3-input Gate
Motorola 1966
Intel 4004 Micro-Processor

1971
1000 transistors
1 MHz operation
Intel Pentium (IV) microprocessor
Next Class

• Verilog Fundamentals