Digital Design Concepts

- Digital Hardware Components
- The Design Process
Digital Hardware Components

- Discrete components: transistors, resistors, capacitors
- Integrated Circuits (ICs) manufactured from silicon wafers
- By 1970 it was possible to implement a complete microprocessor on a single chip

Moor’s law – doubling of number of transistors on a chip every 1.5 to 2 years
<table>
<thead>
<tr>
<th></th>
<th>Year</th>
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<tbody>
<tr>
<td></td>
<td>2006</td>
</tr>
<tr>
<td>Technology feature size</td>
<td>78 nm</td>
</tr>
<tr>
<td>Transistors per cm²</td>
<td>283 M</td>
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<tr>
<td>Transistors per chip</td>
<td>2,430 M</td>
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A sample of the International Technology Roadmap for Semiconductors.
Digital Hardware Components

• Standard chips
  – Realize commonly used simple logic functions (AND, OR, NOT, XOR, MUX, Adder, Comp, etc.)
  – A designer chooses & interconnects such chips to realize larger logic circuits
  – Had been popular till the 1980s
  – Drawbacks: inefficient use of valuable space on PCBs, and fixed (non-programmable) functionality
Digital Hardware Components

- **Programmable Logic Devices (PLDs)**
  - Contain circuitry that can be configured by the end user to implement wide range of circuits
  - Have general structure with *programmable switches*
  - Desired circuits implemented by appropriate configuration of the switches
  - PLDs are widely used today and could be one-time or multiple-time programmable, such as Electrically Erasable (EE), or in-system-programmable (ISP) devices
  - Available in a wide range of sizes, and can realize much larger logic circuits than a typical standard chip
  - Field Programmable Gate Array (FPGA) is most advanced type of PLDs, with large number of programmable logic elements and switches
Figure 1.2. A field-programmable gate array chip (courtesy of Altera Corp.).
Digital Hardware Components

• **Custom-Designed Chips**
  – The programmability feature of the off-the-shelf PLDs consume valuable chip area and limit the speed of operation of circuits
  – For some applications PLDs may not meet desired performance or cost objectives
  ➞ Design a *custom* or *semi-custom* chip from scratch and use an appropriate technology to implement it. The chip is then manufactured by a company with fabrication facilities
  ➞ Also known as Application Specific Integrated Circuits (ASICs).
  ➞ Optimized for a specific task, with better performance
  ➞ Larger circuits could be implemented in a single chip than possible with other technologies
  ➞ High initial cost and considerably longer time to manufacture. But when shipped in products with large volumes the amortized cost per chip may be lower than using off-the-shelf chips that may require larger PCBs.
The Design Process

- Steps of a general product development process:
  1) Define specification
  2) Initial Design
  3) Simulation
  4) If Design is not correct
     Redesign and go to step 3
  5) Prototype implementation
  6) Testing
  7) Is spec not met
     If minor errors
        Make corrections and go to step 5
     Else redesign and go to step 3
  8) finish
Figure 1.3. The development process.
Design of a Digital Hardware

Complex systems are first partitioned into smaller and more manageable parts:
⇒ divide-and-conquer approach

Individual parts are designed and simulated

The parts are put together for a *physical mapping* on PCB, PLD or custom-designed chip, with proper interconnections, using CAD tools to automate the task

*Timing simulation* used to reveal any potential performance problems of the physical design

Figure 1.6. A printed circuit board.
Figure 1.7. Design flow for logic circuits.
Figure 1.8. Completion of PCB development.