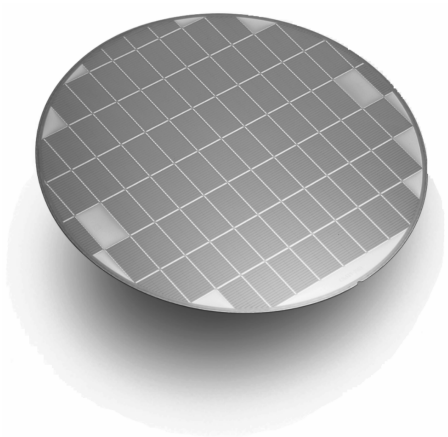
Digital Design Concepts

- 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 1.1 A sample of the International Technology Roadmap for Semiconductors.

	Year					
	2006	2007	2008	2009	2010	2012
Technology feature size	78 nm	68 nm	59 nm	52 nm	45 nm	36 nm
Transistors per cm^2	283 M	357 M	449 M	566 M	714 M	1,133 M
Transistors per chip	2,430 M	3,061 M	3,857 M	4,859 M	6,122 M	9,718 M

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

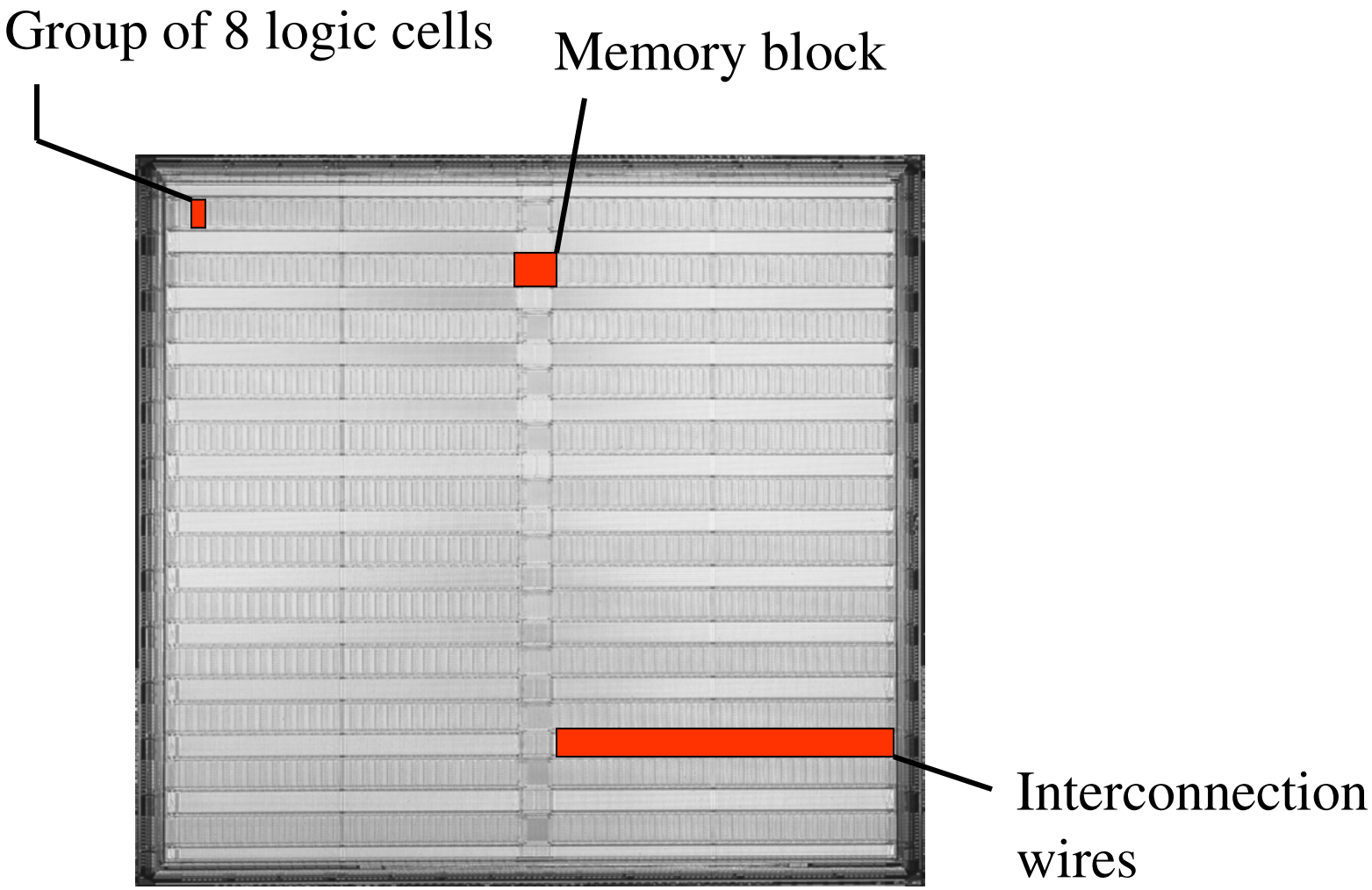


Figure 1.2. A field-programmable gate array chip (courtesy of Altera Corp.).

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

  $\Rightarrow$ 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

  $\Rightarrow$ Also known as Application Specific Integrated Circuits (ASICs).

  $\Rightarrow$ Optimized for a specific task, with better performance

  $\Rightarrow$ Larger circuits could be implemented in a single chip than possible with other technologies

  $\Rightarrow$ 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

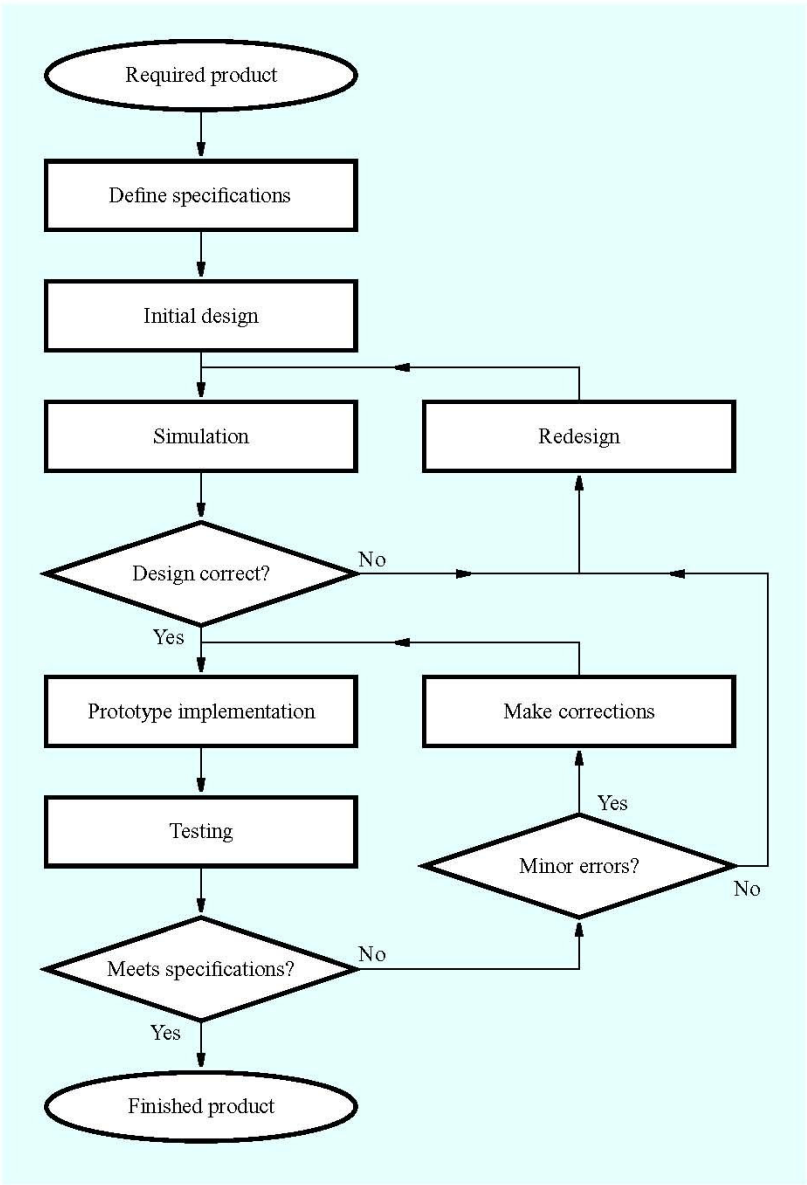


Figure 1.3. The development process.

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

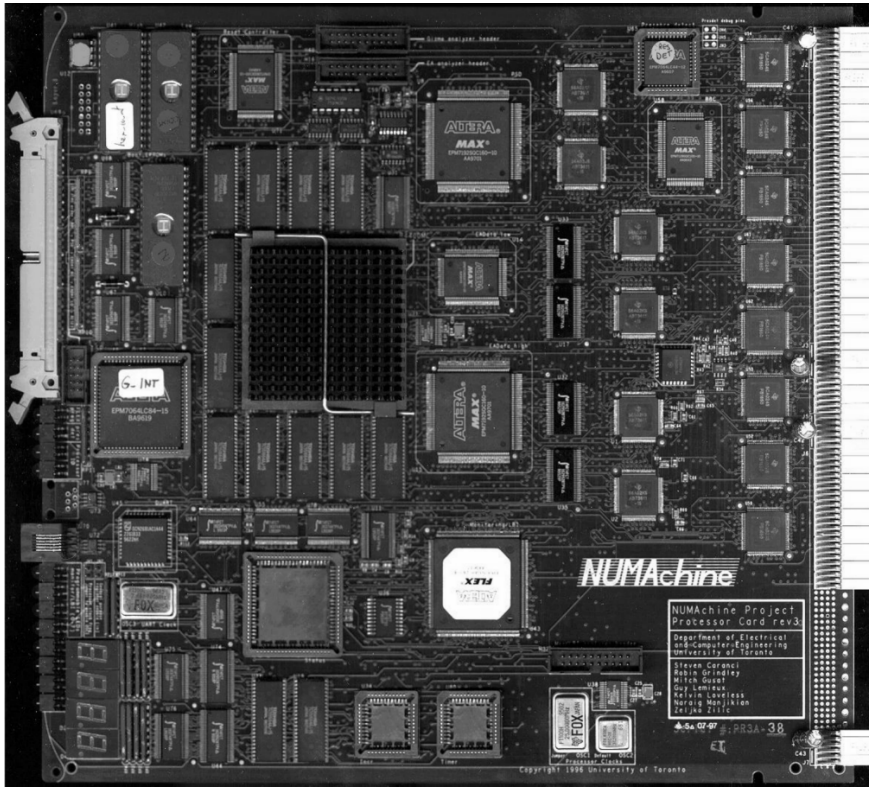


Figure 1.6. A printed circuit board.

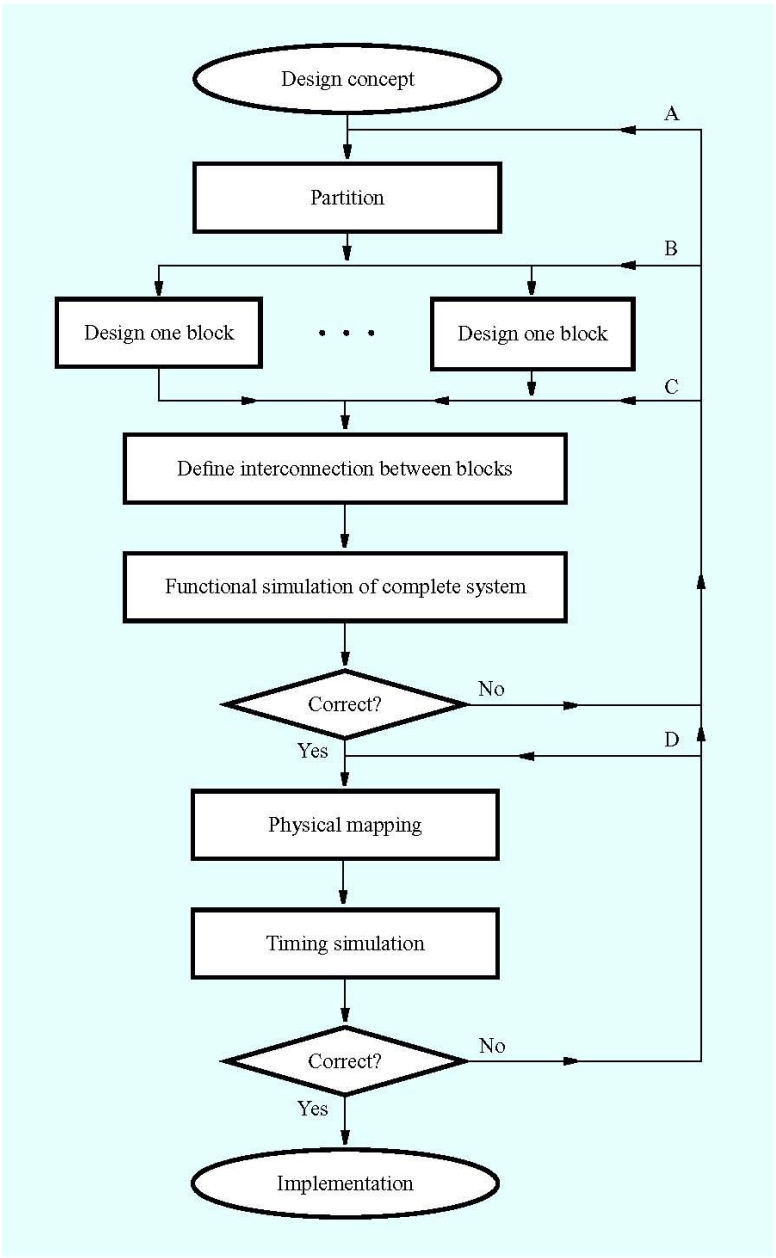


Figure 1.7. Design flow for logic circuits.

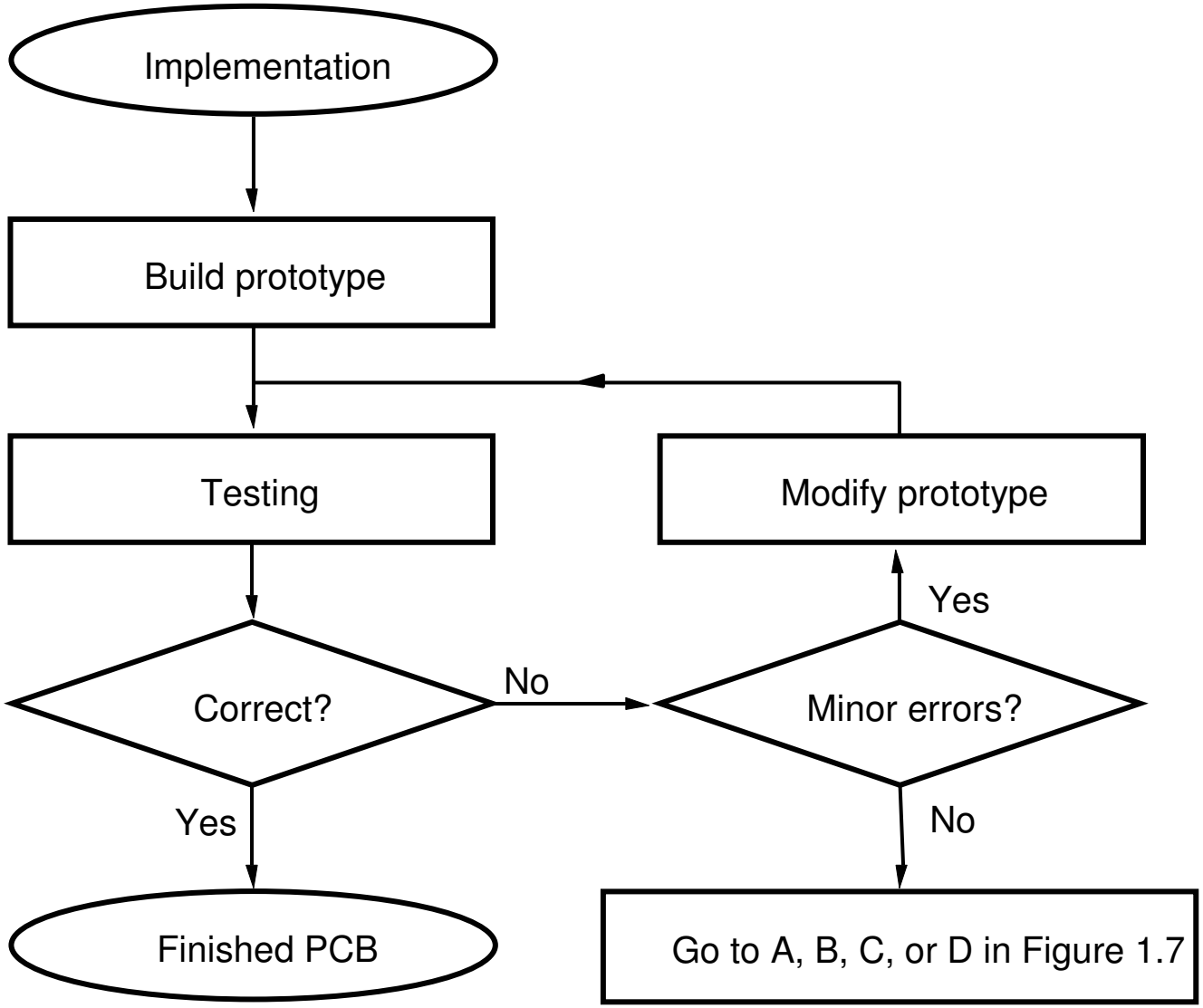


Figure 1.8. Completion of PCB development.