011361 COMPUTER HARDWARE

DIGITAL DESIGN AND CAD TOOLS

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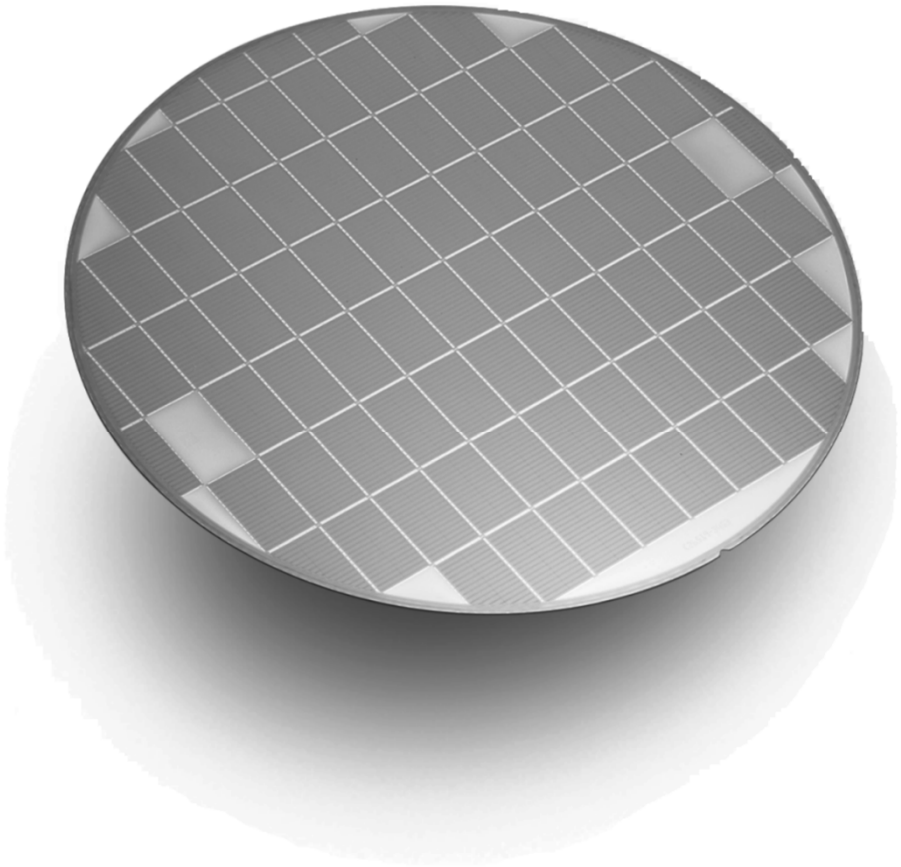
DIGITAL HARDWARE

- Integrated circuit chips are manufactered on a silicon wafer.
- The wafer is cut to produce the individual chips, which are then placed inside a special type of chip package



A silicon wafer

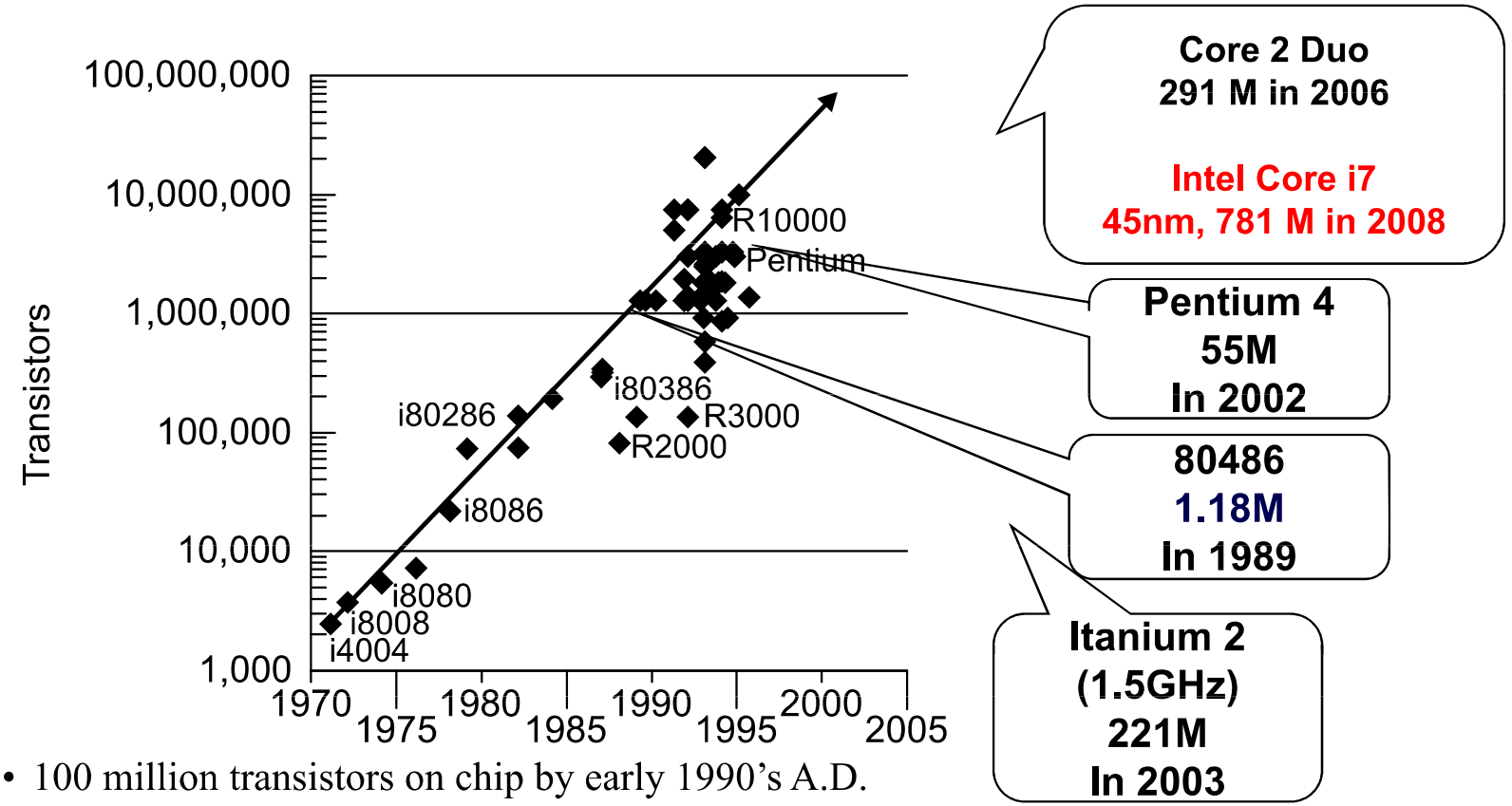
Digital Hardware

- Moore's Law: Chip density–doubling the 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

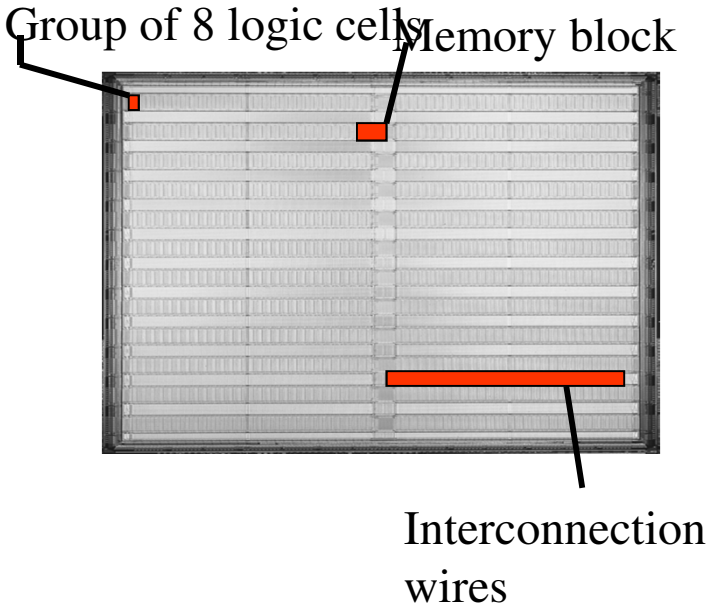
Transistor Count Growth Rate



- 100 million transistors on chip by early 1990's A.D.
- Transistor count grows much faster than clock rate
  - 40% per year, order of magnitude more contribution in 2 decades

Types of Chips

- Standard Chips
  - 7400, 7408, etc.
- Programmable Logic Devices
  - Programmable logic devices (PLDs)
  - Field-programmable gate array (FPGA)
- Custom-Designed Chips
  - Custom or semi-custom chips
  - Application-specific integrated circuits(ASICs)

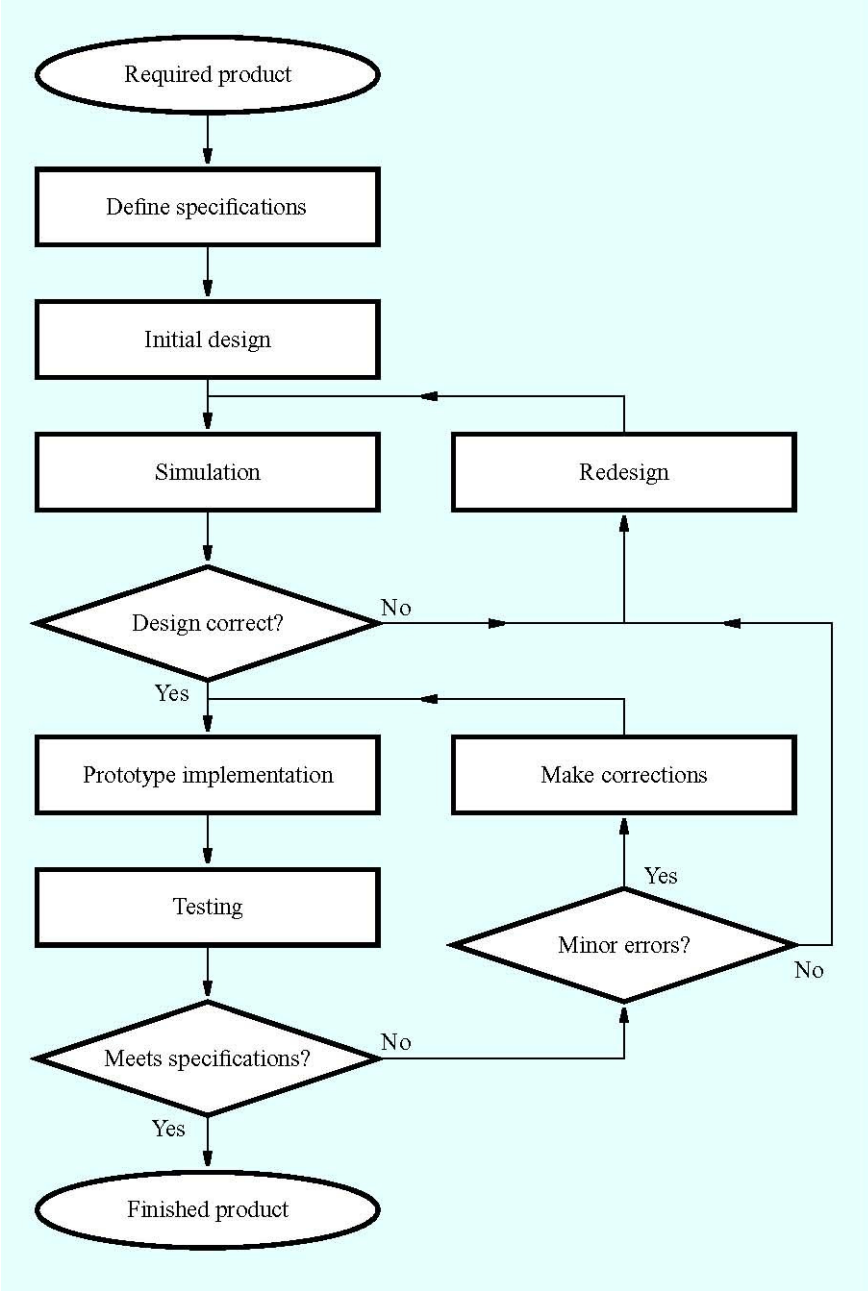


A field-programmable gate array chip.

The Design Process

- Design
  - Given a specification of a problem
  - come up with a way of solving it
    - choosing appropriately from a collection of available components
- The process is to develop a product that meets certain expectations. The product must
  - function properly
  - meet an expected level of performance
  - meet some criteria for size, cost, power, etc.

The Development Process



Design Process

- **Define specifications:** essential features of the product are identified.
  - Specifications must be tight enough to ensure that the developed product will meet the general expectations, but not be unnecessarily constraining.
- **Initial design:** is generated from the design specifications
  - This step is usually performed by a human designer.
  - It requires considerable design experience and intuition.

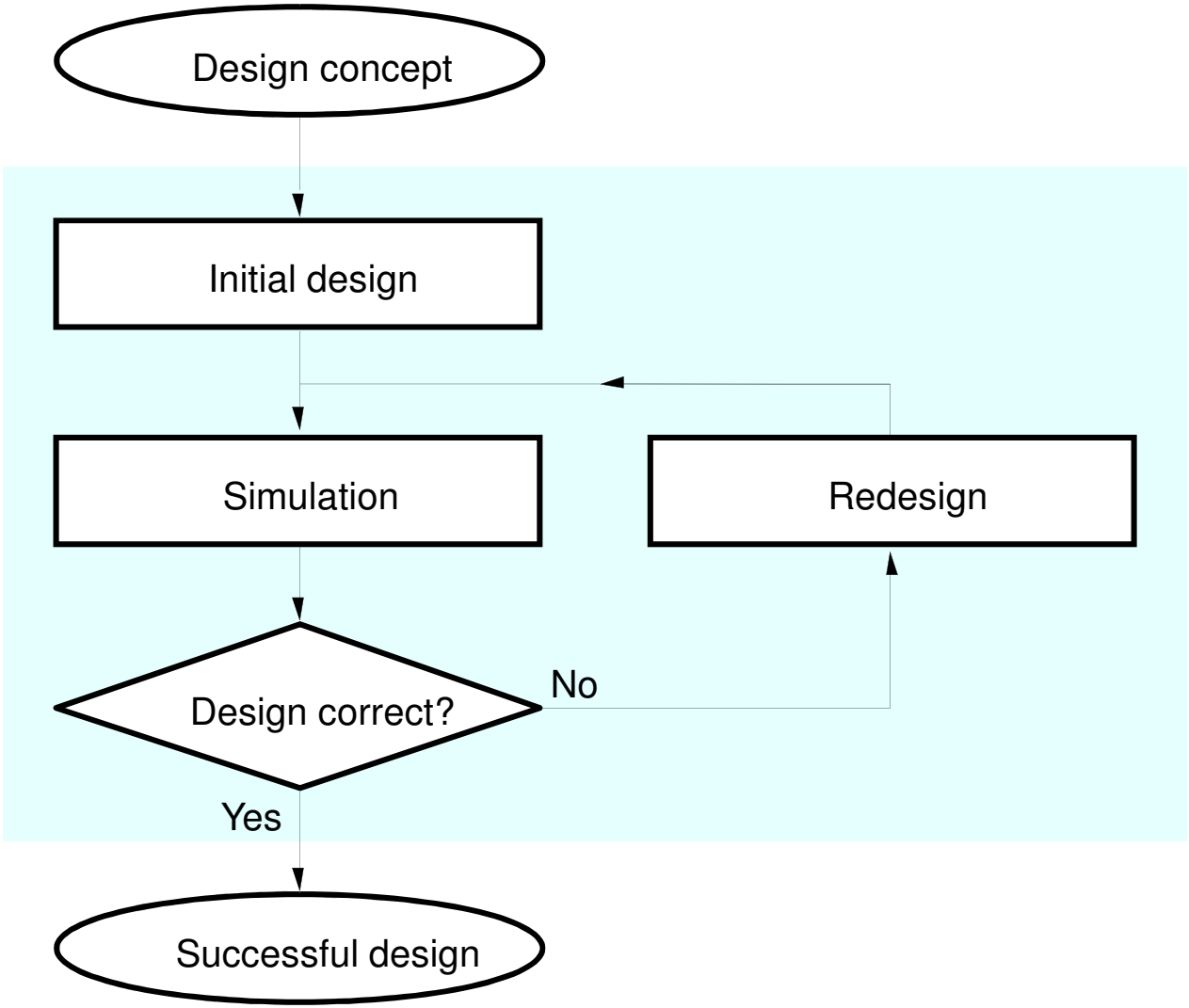
Design Process

- **Simulation:** CAD tools are used to simulate the behavior of the initial design to determine whether the obtained design meets the required specifications.
  - If errors are found appropriate changes are made and verification is repeated through simulation.
  - Usually all except subtle problems are discovered in this way.
- **Prototype implementation:** When simulation indicated that the design is correct, a prototype of the product is constructed.

Design Process

- **Testing:** The prototype is thoroughly tested for conformance with the specifications.
  - Minor errors are often eliminated by making small corrections directly on the prototype.
  - In the case of large errors, it is necessary to redesign the product.

Basic Design Loop



Structure of a Computer

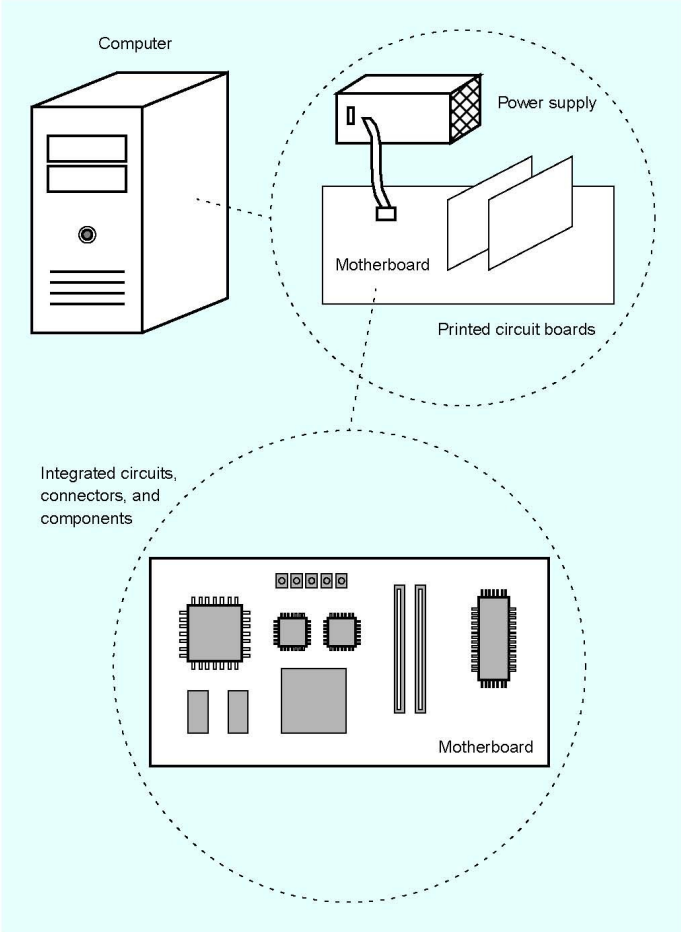


Figure 1.5. A digital hardware system (Part *a*).

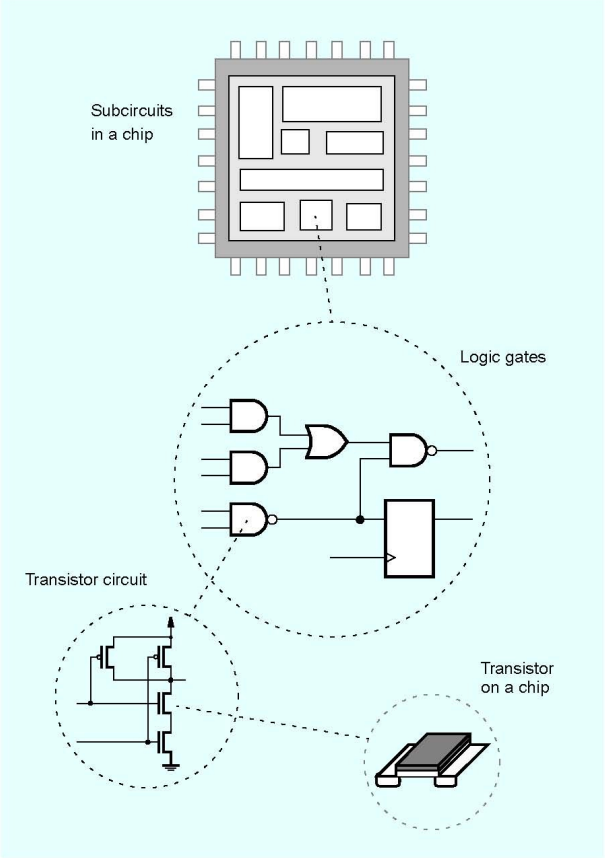
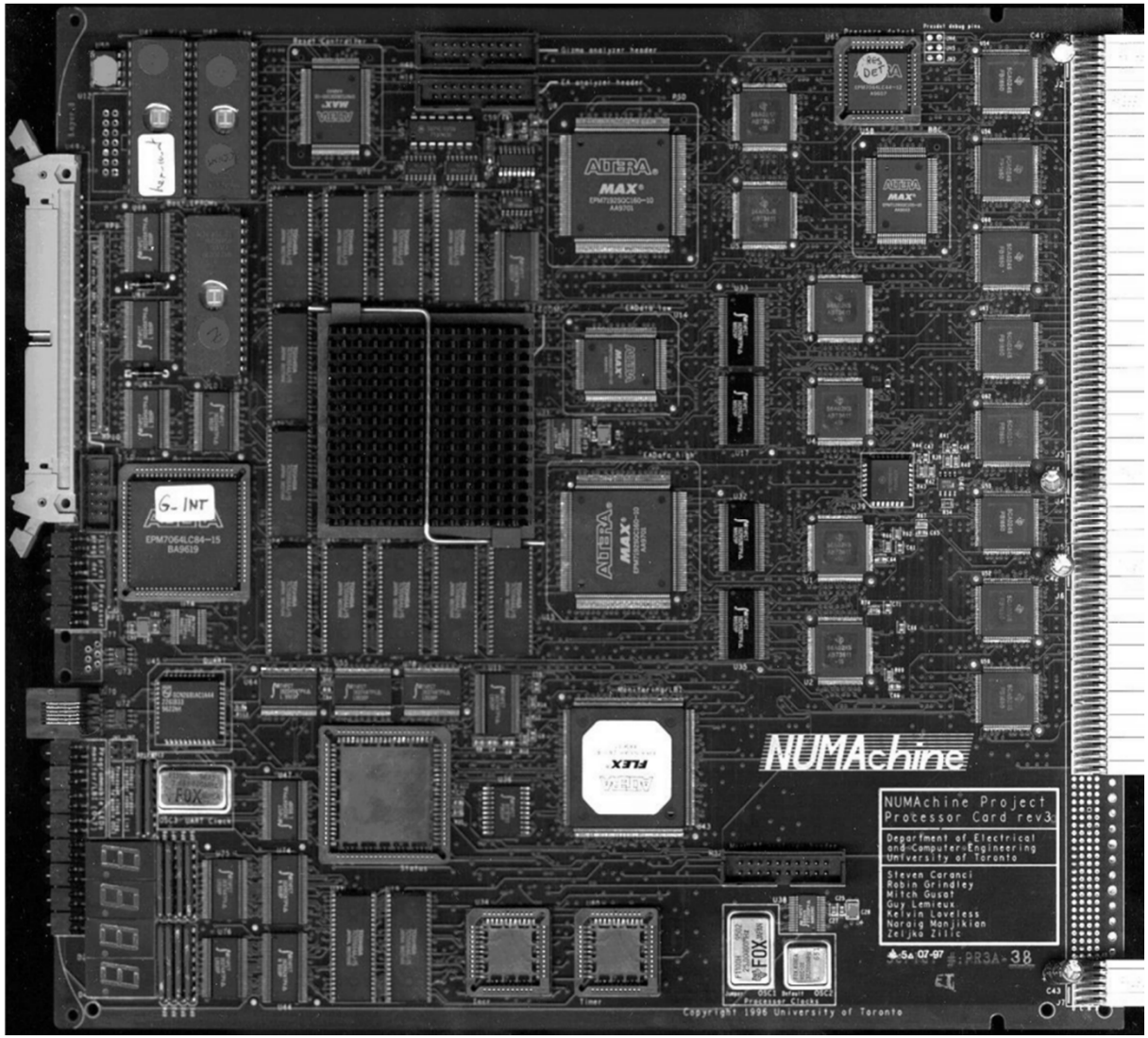


Figure 1.5. A digital hardware system (Part *b*).

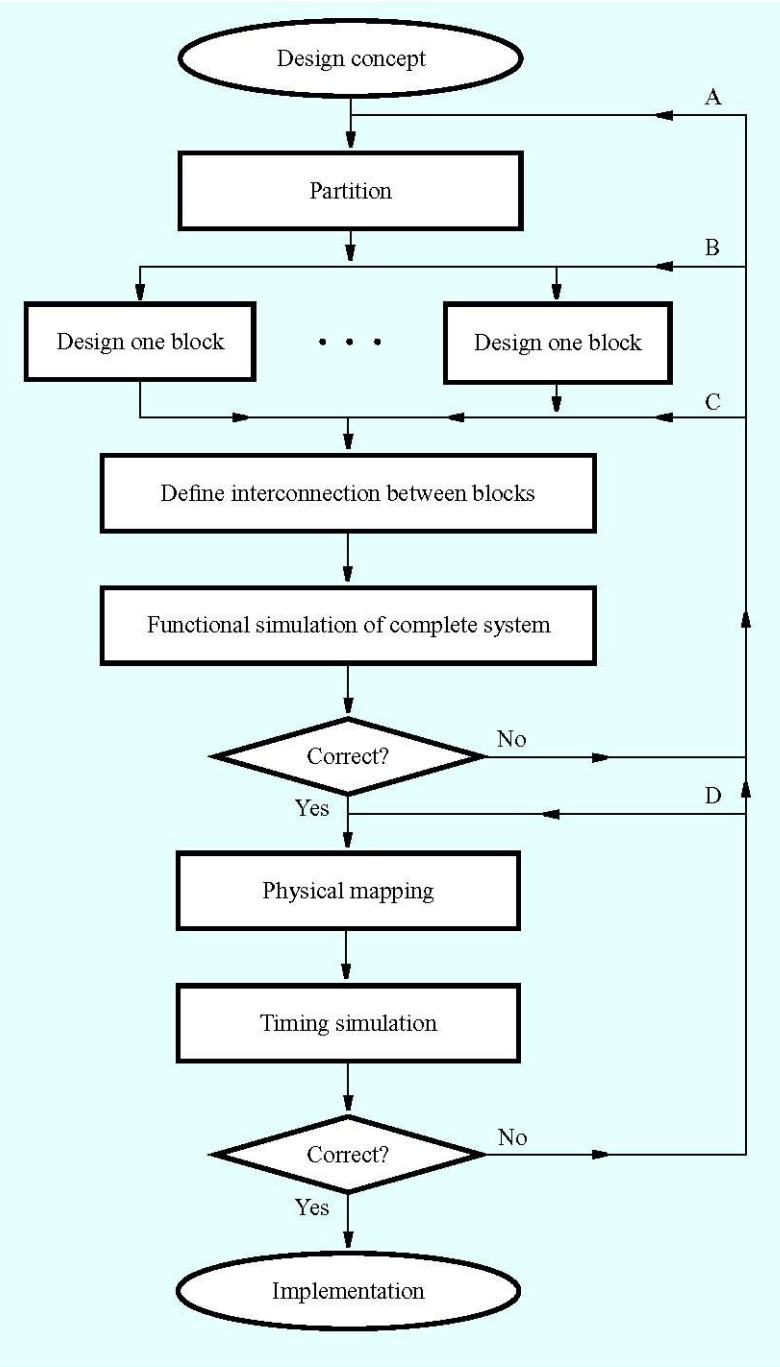
Design of a Digital Hardware Unit



A printed circuit board (PCB). NUMAachine is a multiprocessors.

Logic Design

- Logic design
  - determining the collection of digital logic components to perform specified functions
  - which logic components to choose
    - many implementation technologies
  - Design may need to be optimized
- Application of logic design
  - Computer system: CPU, Register files, Busses, Peripherals
  - Embedded products: phones, cars, toys, appliances, etc.



Design flow for logic circuits

Design of digital hardware

- A common way of dealing with complexity in digital hardware is to **partition** the circuit into smaller blocks and **design** each block separately.
- Having successfully designed all blocks, the **interconnection** between blocks must be defined.
- **Functional Simulation:** The complete circuit is simulated and errors are corrected
  - Errors caused by incorrect connections: connections are redefined (path C)
  - Some blocks have not been designed correctly: erroneous blocks are redesigned (path B)
  - Some functionality missing: incorrect partitioning (path A)

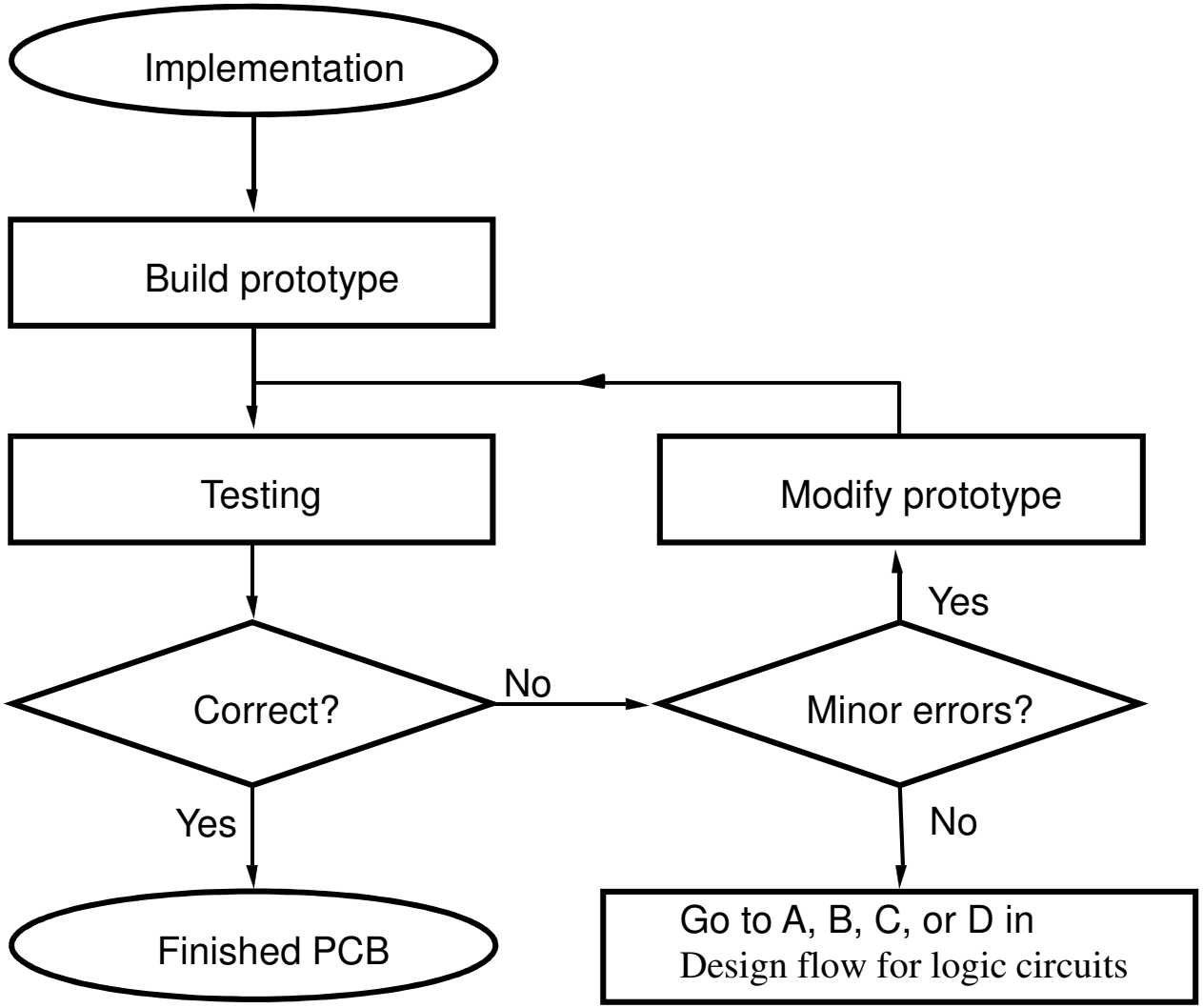
Design of digital hardware

- **Physical mapping:** physical location of each chip on the board and wiring pattern
  - CAD tools are relied on
  - Does the physical layout affect the performance of the circuit (even though the functional behavior of complete system is correct)?
  - Physical wiring introduce resistance and capacitance. It may have an impact on the speed of operation.
- **Timing simulation** is used to check the performance of the circuit after wiring.
  - It is customary to use *functional* and *timing* simulation
  - A timing simulation may reveal potential performance problems.

Design of digital hardware

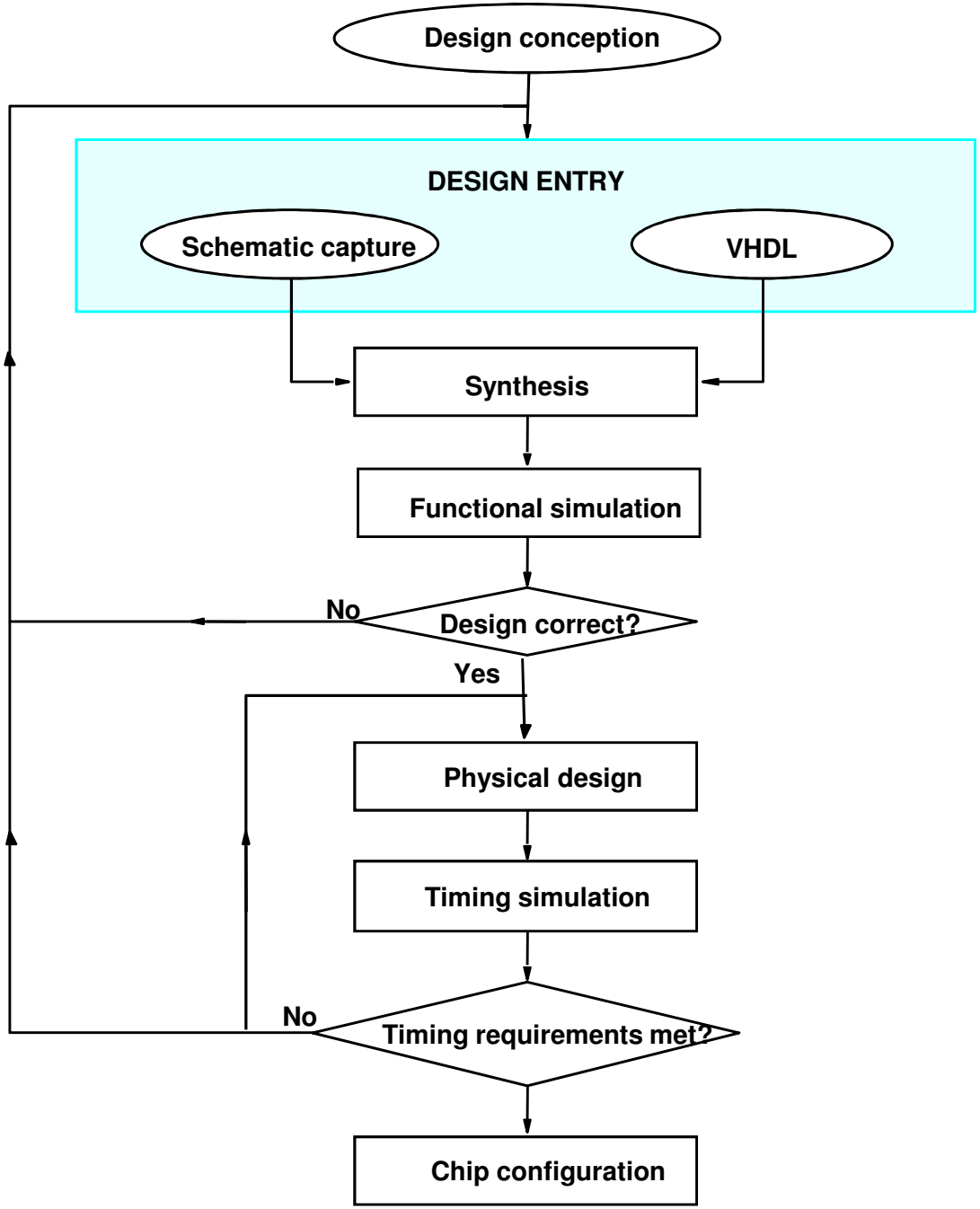
- **Implementation:** Having completed timing simulation a prototype of the circuit is implemented.
  - The prototype is tested.
  - Minor errors are corrected on the prototype.
  - Large problems require a redesign.

Completion of PCB development.



CAD tools

- A CAD system has tools for performing the following tasks:
  - Design entry
  - Synthesis
  - Functional simulation
  - Logic synthesis and optimization
  - Physical design
  - Timing simulation
  - Chip configuration



A typical CAD system.

CAD tools

- The starting point in the process of designing a digital circuit is the conception of what the circuit is supposed to do and the formulation of its general structure.
- This step is done manually. The rest is done by CAD tools.

CAD tools

- **Design entry:** a description of the circuit being designed should be entered into CAD system
  - **Schematic Capture:** The word schmetaic refers to a diagram of a circuit in which circuit elements, such as logic gates, are depicted as graphical symbols and connections between circuit elenments are drwan as lines
  - **Hardware description languages (HDL):** used to describe hardware rather than a program to be executed on a computer
    - Two HDLs are IEEE standards: VHDL (Very high speed integrated circuit HDL) and Verilog HDL.

CAD tools

- **Synthesis:** the process of generating a logic circuit
  - The process of translating, or compiling, VHDL code into a network of logic gates is part of synthesis
  - Logic synthesis and optimization produces an equivalent but better circuit
  - The measure of what makes one circuit better depends on the needs of a design project and the technology chosen for implementation

- **Step 3: Functional simulation:** is used to verify the functionality of the circuit based on input provided by the designer
  - This simulation is performed before any optimization and propagation delays are ignored.
  - **Goal:** validate the basic operations of the circuit

CAD tools

- **Physical design:** how to implement the circuit in the target technology
  - This step consists of **placement** and **routing**
    - **Placement:** where in the target device each logic function in the optimized circuit will be realized
    - **Routing:** which wires in the chip are to be used to realize the required interconnections

CAD tools

- **Timing simulation:** determines the propagation delays that are expected in the implemented circuit
  - Timing simulation: ensures that the implemented circuit meets the required performance
  - Some of timing errors can be corrected by using the synthesis tool
  - If the logic synthesis tool cannot resolve the timing problem, it is necessary to return to the beginning of the design flow to consider other alternatives
- **Chip Configuration:** configure the target chip to implement the circuit.
  - This step is called chip *configuration* or *programming*.