CS/ECE 5780/6780: Embedded System Design

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Lecture 1: Introduction to Embedded Systems

Embedded systems: definition

An *embedded system* is:

- a special-purpose computer designed to perform dedicated functions often with real-time constraints.
- a system embedded as part of a complete system.
- really any system that is not a PC...although PCs contain several embedded systems.

Embedded systems: function

Five main categories:

- Digital signal processing
- Control
- Networking
- User interfacing
- Data storage

Most embedded systems perform more than one of these functions.

Popularity with consumers

>99% of new microprocessors are found in embedded systems.

Cnet's Top 10 Must-haves

- Apple iPhone
- Apple iPod Nano
- Vudu
- Nintendo Wii
- Apple MacBook
- Sling Media Slingbox A/V
- Sony PSP
- Samsung LN-T4665F
- Sony Handycam HDR-CX7
- Shure SE110 Sound Isolating Earphones





Popularity with other industries

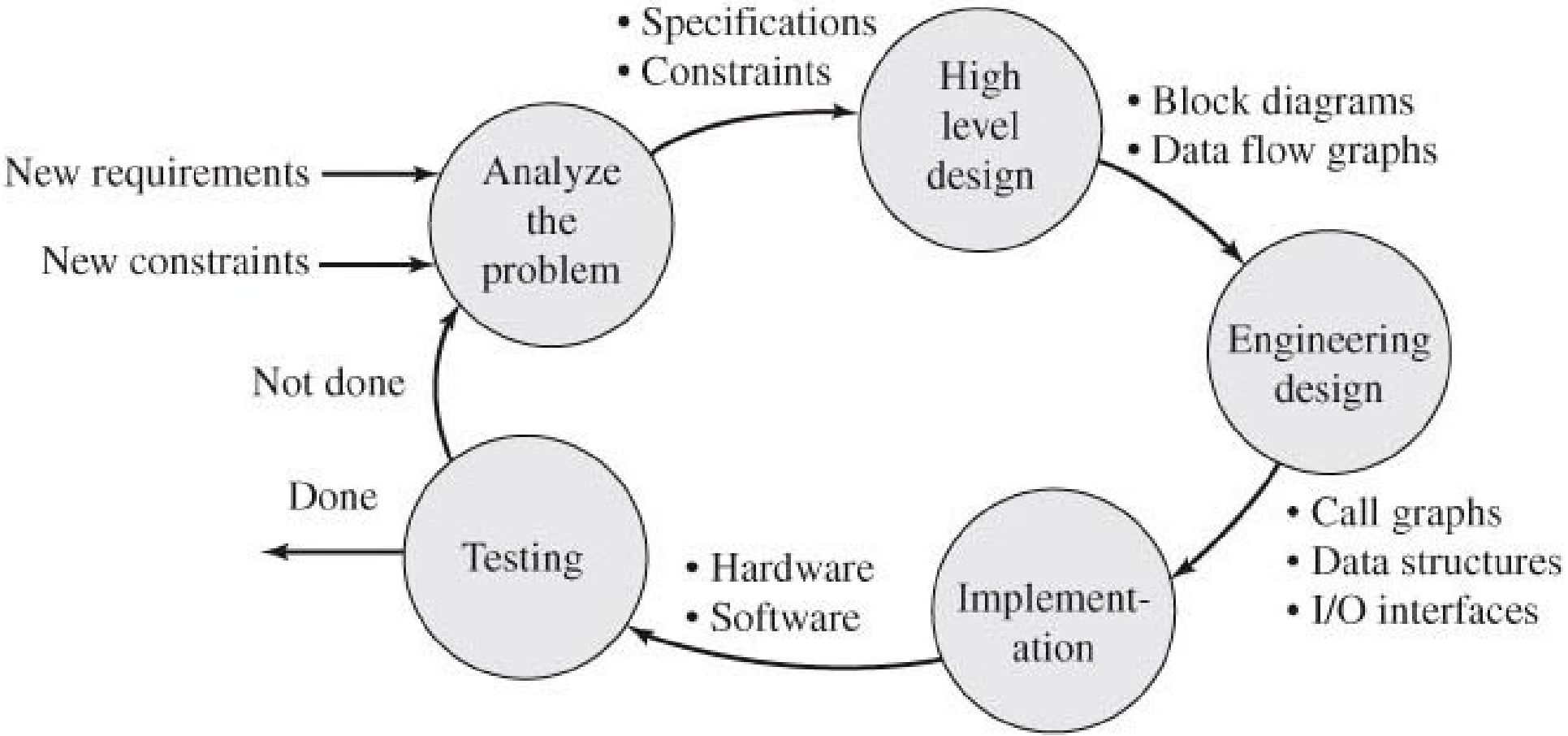
- Automotive
  - Air bag controllers
  - Anti-lock brakes
- Communications
  - Satellite phones
  - Cell phone base stations
- Industrial
  - Point-of-sale systems
  - Robotics
- Medical
  - Life-support
  - Medical testing
- Military
  - GPS
  - Missile guidance

Embedded systems design

Why is it unique?

- Computation is subject to physical constraints such as timing deadlines, memory restrictions, and power consumption requirements.
- The traditional abstraction of separating software from the hardware and environment does not work.
- Hardware, software, and control are integrally intertwined.
- Designers must understand both hardware, software, and control.
- "The Embedded Systems Design Challenge" by Henzinger and Sifakis continues this discussion.

Top-Down Design Process



Analysis Phase

Discover the requirements and constraints.

Requirements are general parameters that the system must satisfy.

Specifications are detailed, specific requirements.

Constraints are limitations under which the system must operate.

Embedded system design metrics

Nonrecurring engineering cost

Unit cost

Size & weight

Performance (accuracy, precision, resolution, response time, bandwidth)

Power

Flexibility, maintainability, reliability, testability, & compatibility

Time-to-prototype

Time-to-market

Correctness

Safety

Look & feel

High-Level Design Phase

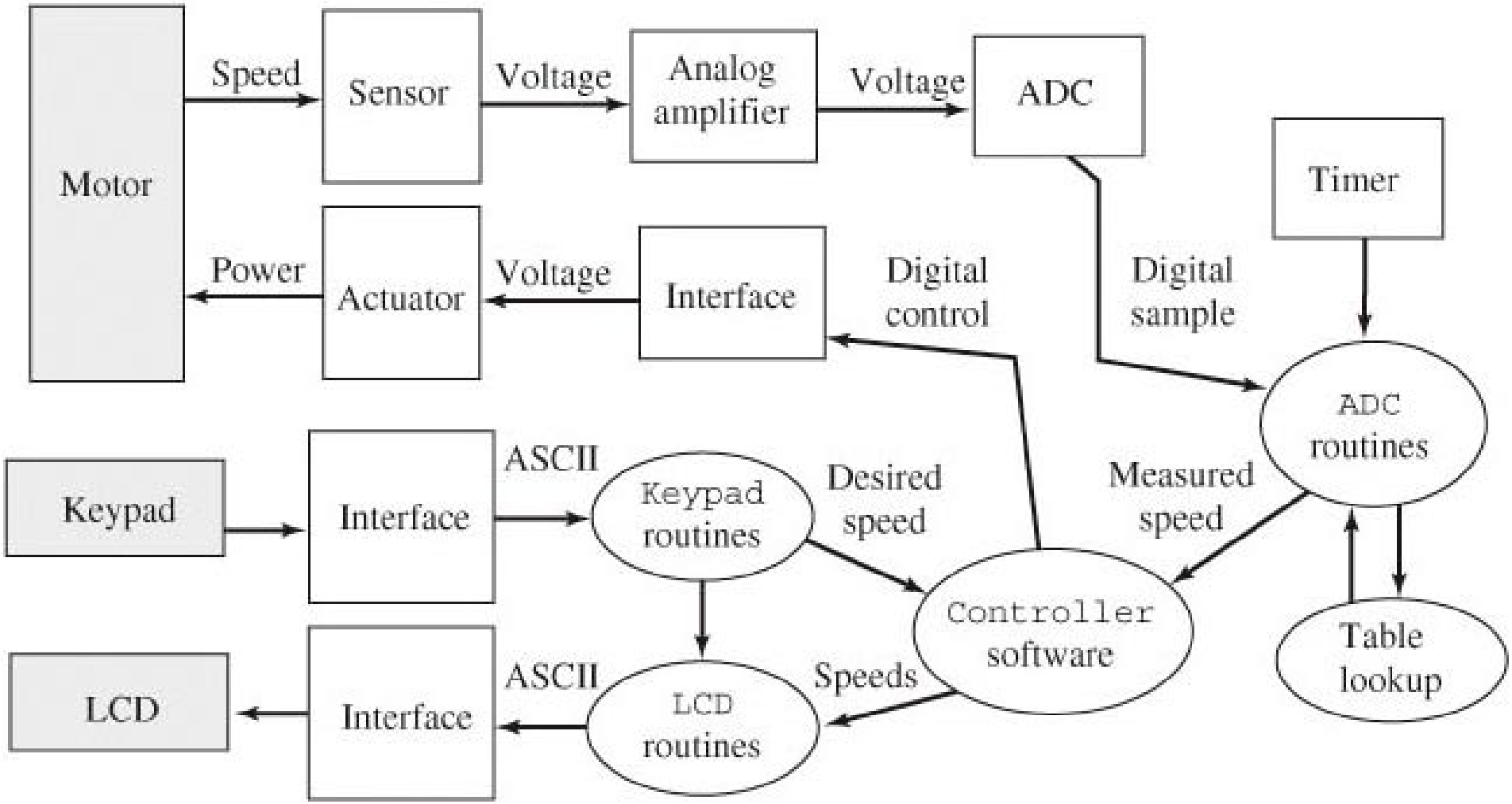
Build a conceptual model of the hardware and software system.

Design broken into modules or subcomponents.

Estimate cost, schedule, and expected performance.

Develop a *data flow graph* for the system.

Data Flow Graph for a Motor Controller



Engineering Design Phase

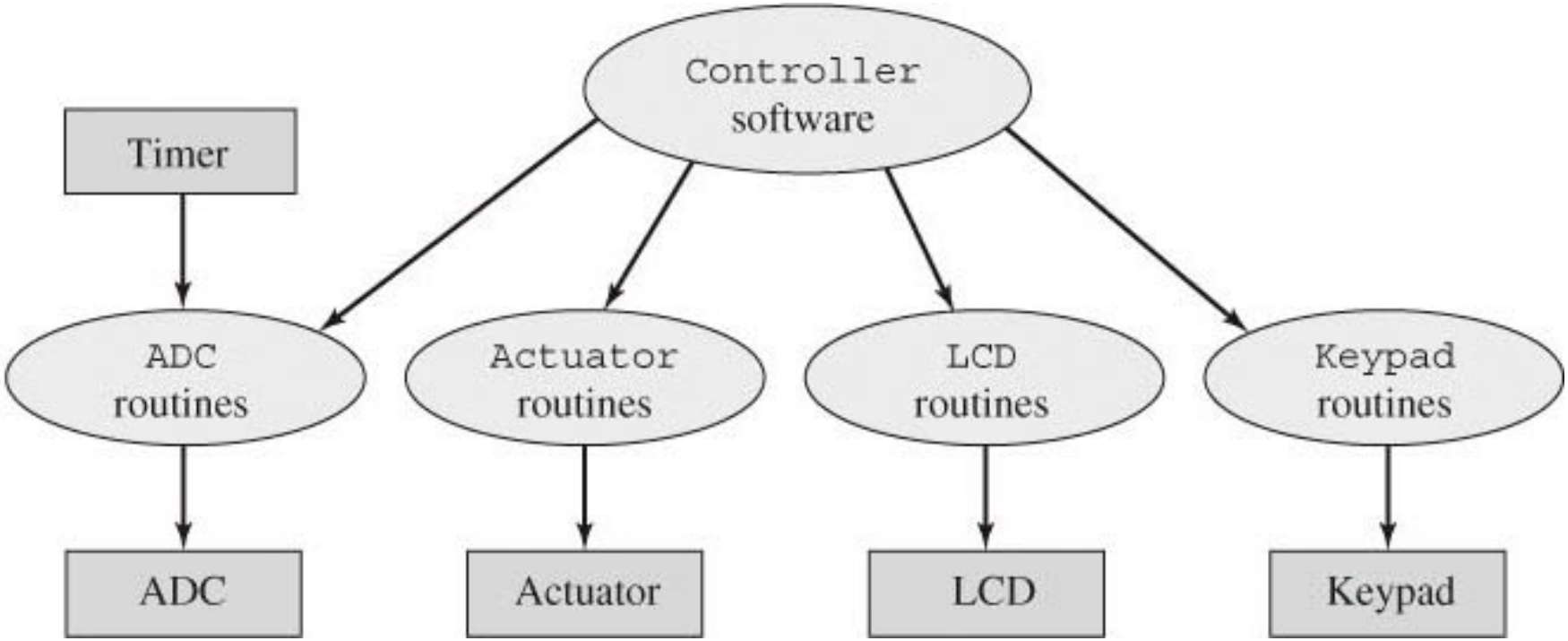
Construct a preliminary design.

This should include the hierarchical structure, basic I/O signals, shared data structures, and overall software scheme.

Build mock-ups of mechanical parts and user software interface.

Call graphs can be used to show how software and hardware interact.

Call Graph for a Motor Controller



Implementation Phase

During this phase, the design is actually built.

Implementation of subcomponents may actually be started during the earlier phases.

Debugging embedded systems can be very difficult.

Therefore, extensive use of hardware/software simulation and cosimulation is essential.

Testing Phase

During this phase, we evaluate the performance.

First, debug and validate the basic functions of the system.

Next, evaluate and optimize various performance parameters such as execution speed, accuracy, and stability.

Maintenance Phase

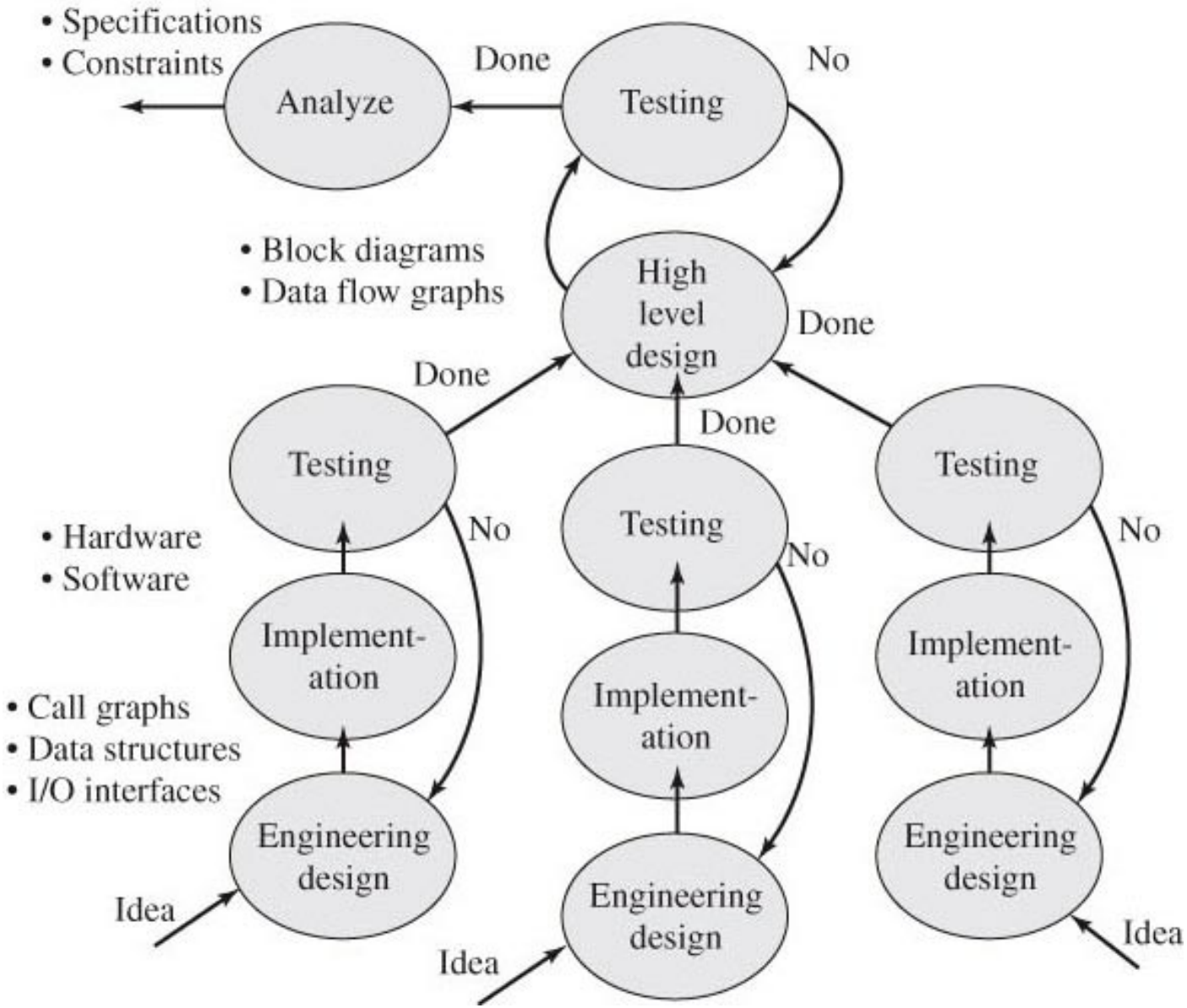
During this phase, we:

- Correct mistakes,
- Add new features,
- Optimize execution speed or program size,
- Port to new computers or operating systems, and
- Reconfigure the system to solve a similar problem.

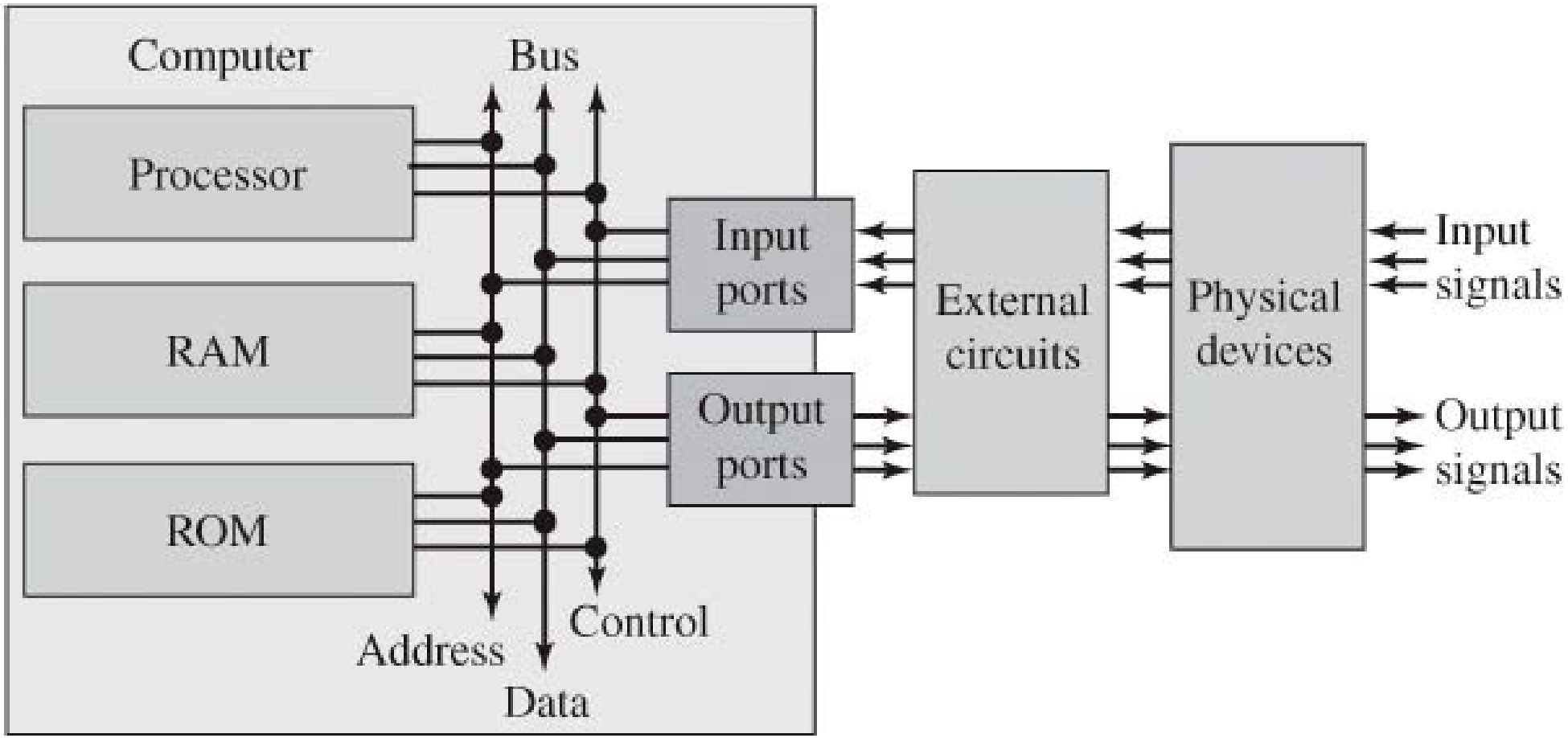
Must be able to deal with changes in requirements or constraints.

Not actually another phase, but more loops through the entire cycle.

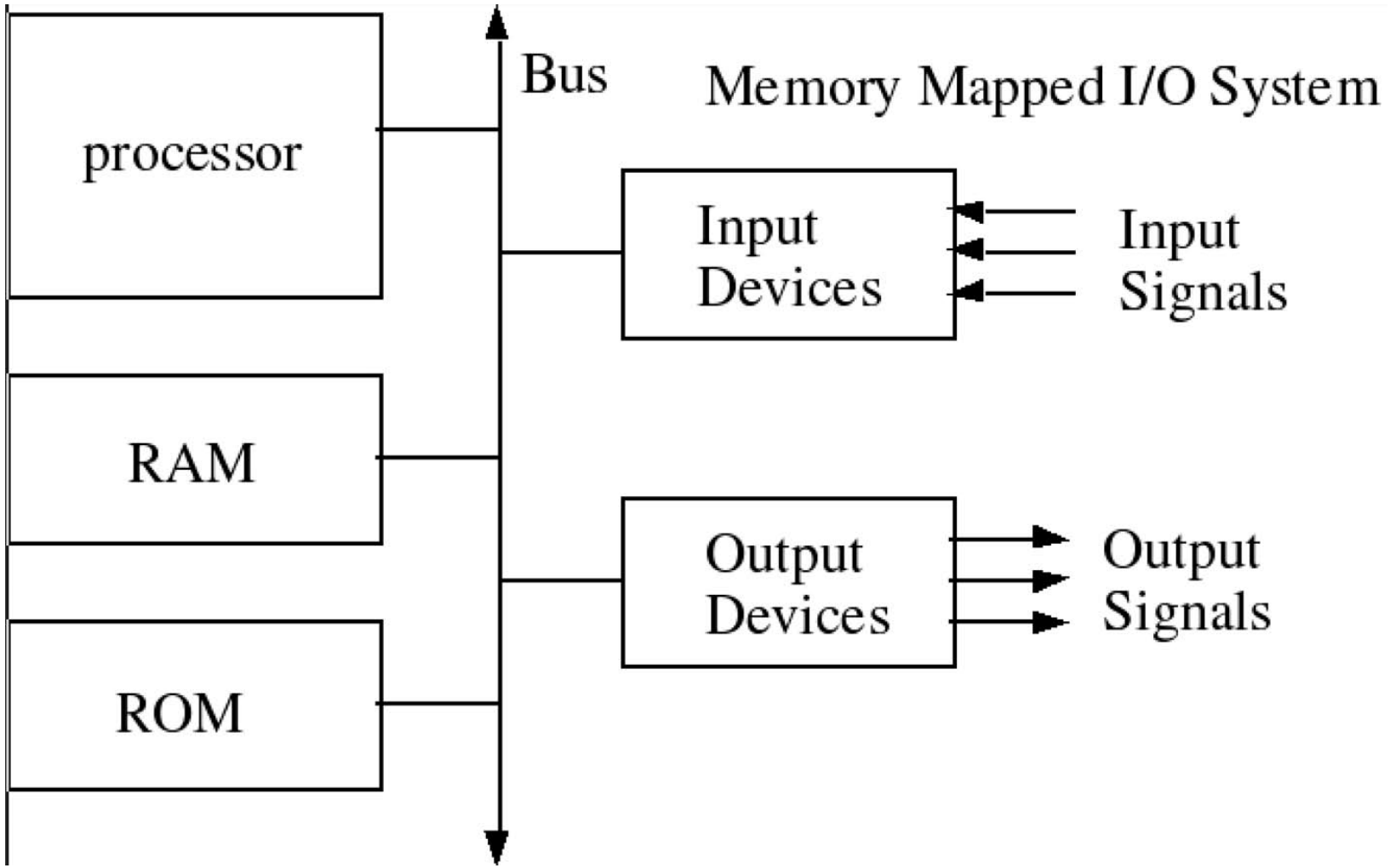
Bottom-Up Design Process



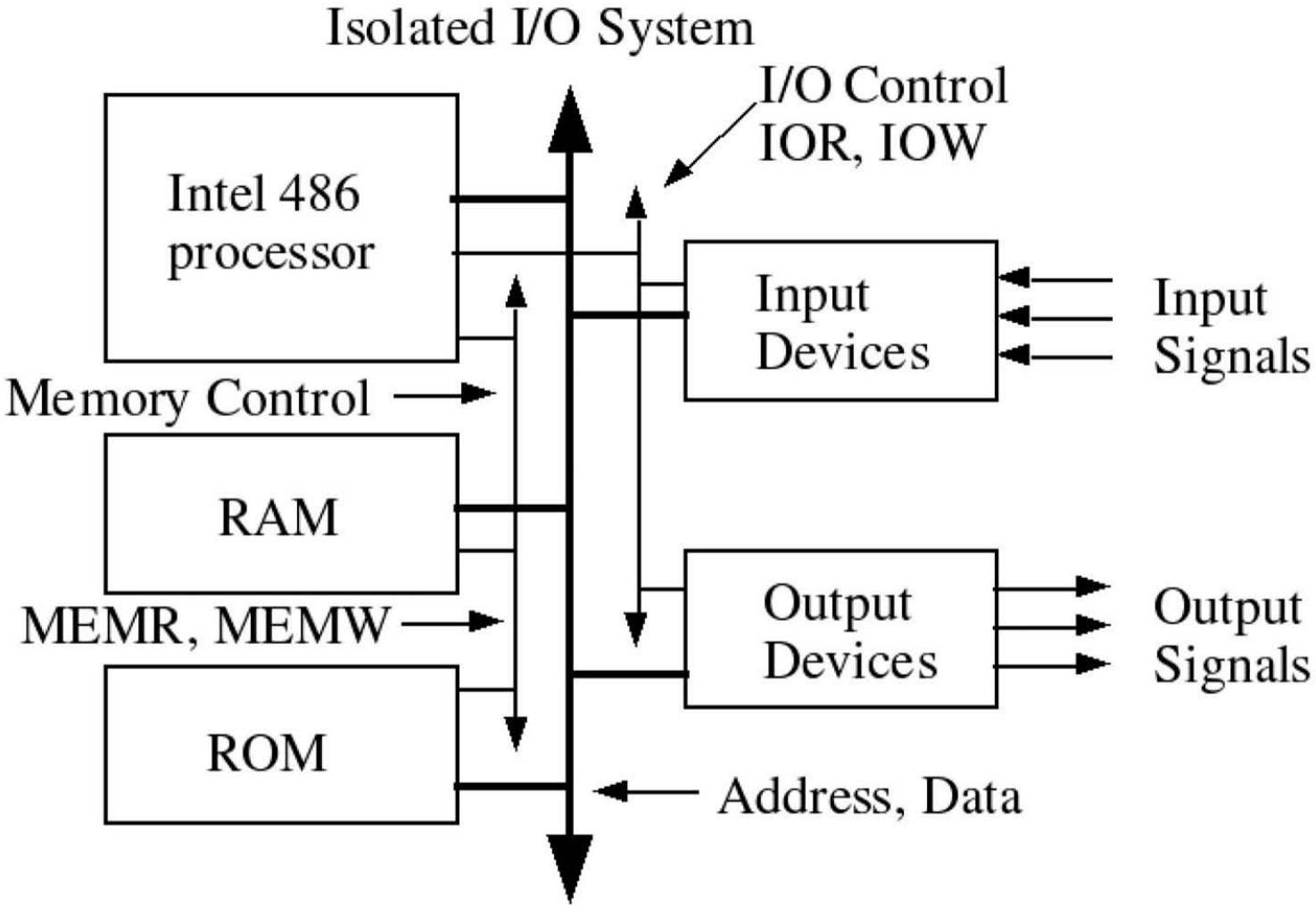
Basic Components of a Computer System



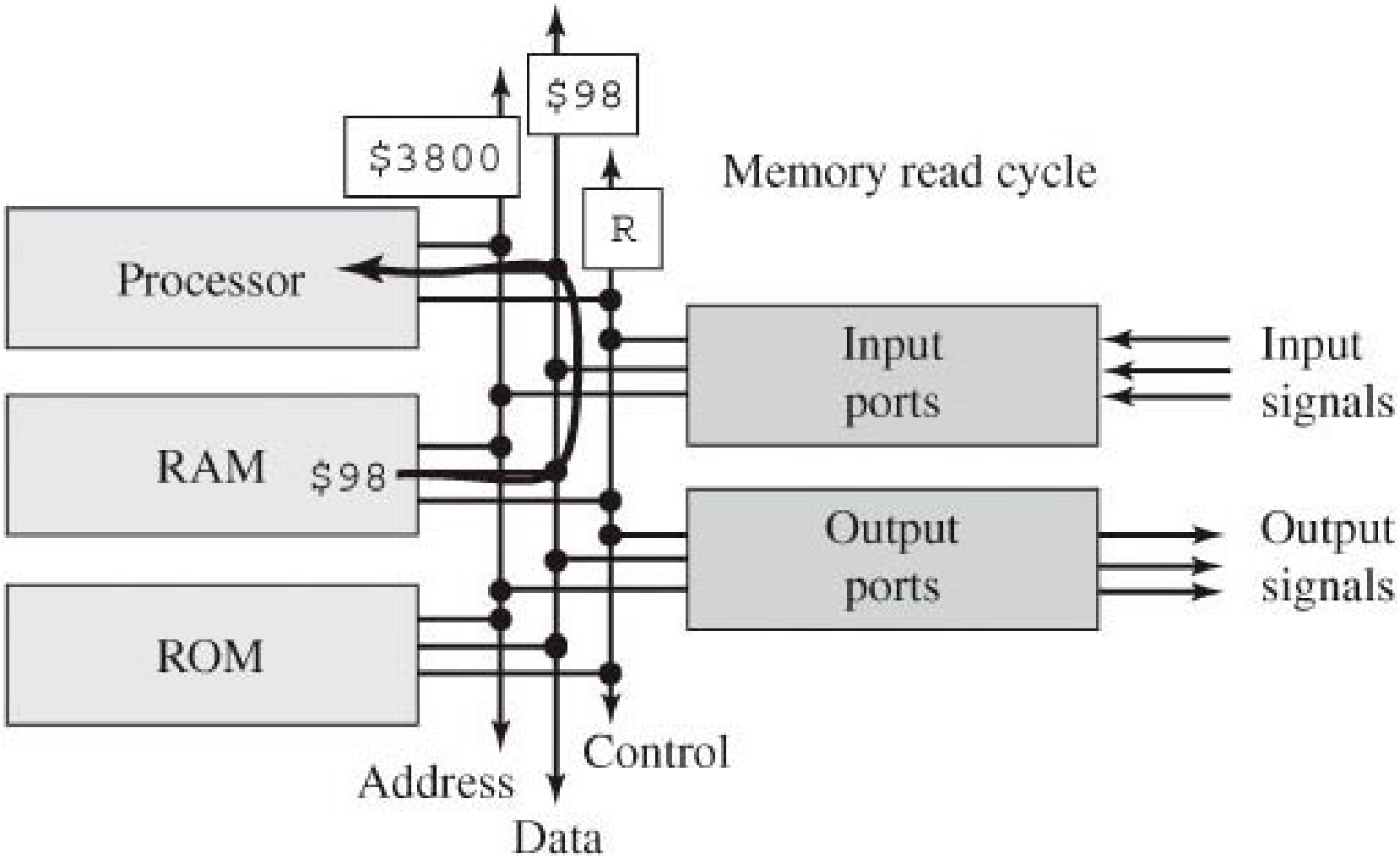
Memory-Mapped Computer System



Isolated I/O Computer System



Memory Read Cycle



DMA Read Cycle