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Chapter 18

Multicore Computers

Objectives

- **A multicore computer**, also known as a **chip multiprocessor**, combines two or more processors (called cores) on a single piece of silicon (called a die- khuôn mẫu). Typically, **each core consists** of all of the components of an **independent processor**, such as registers, ALU, pipeline hardware, and control unit, plus L1 instruction and data caches. In addition to the multiple cores, contemporary multicore chips also include L2 cache and, increasingly, L3 cache.

- Your computer is a multicore computer. Do you want to know about it?

- **After studying this chapter, you should be able to:**
  - Understand the hardware performance issues that have driven the move to multicore computers.
  - Understand the software performance issues posed by the use of multithreaded multicore computers.
  - Have an appreciation of the use of multicore organization on embedded systems, PCs and servers, and mainframes.

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18.1- Hardware Performance Issues

Increase in Parallelism and Complexity

These changes include, in chronological order

- **Pipelining**: Individual instructions are executed through a pipeline of stages so that while one instruction is executing in one stage of the pipeline, another instruction is executing in another stage of the pipeline. •

- **Superscalar**: Multiple pipelines are constructed by replicating execution resources. This enables parallel execution of instructions in parallel pipelines, so long as hazards are avoided.

- **Simultaneous multithreading (SMT)**: Register banks are replicated so that multiple threads can share the use of pipeline resources.

For each of these innovations, designers have over the years attempted to increase the performance of the system by adding complexity

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Alternative Chip Organization

There is a practical limit to how far this trend can be taken, because with more stages, there is the need for more logic, more interconnections, and more control signals

SMT: Simultaneous multithreading

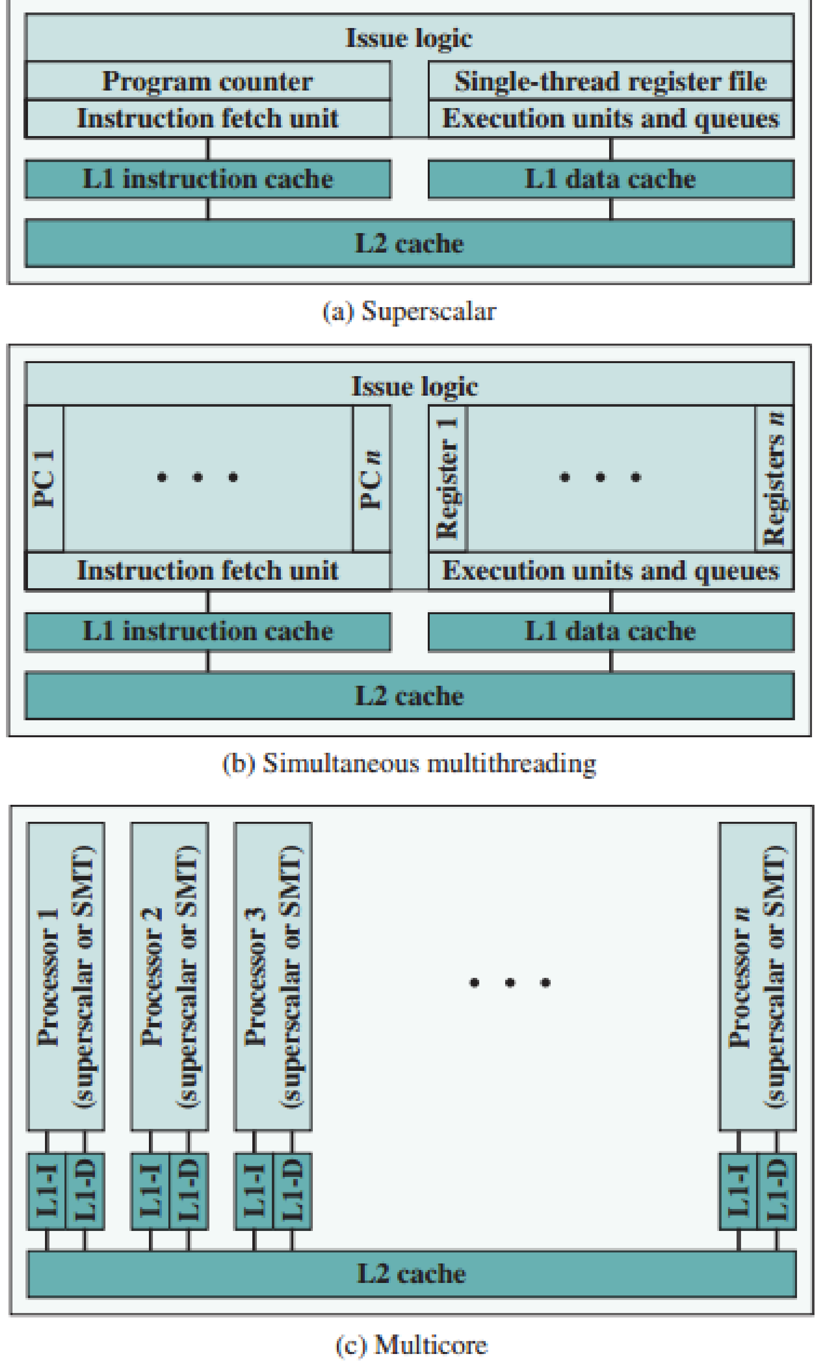

Figure 18.1 Alternative Chip Organizations

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Intel Hardware Trends

Beginning about 2000, a new flat region of the curve appears, as the limits of effective exploitation of instruction-level parallelism are reached.

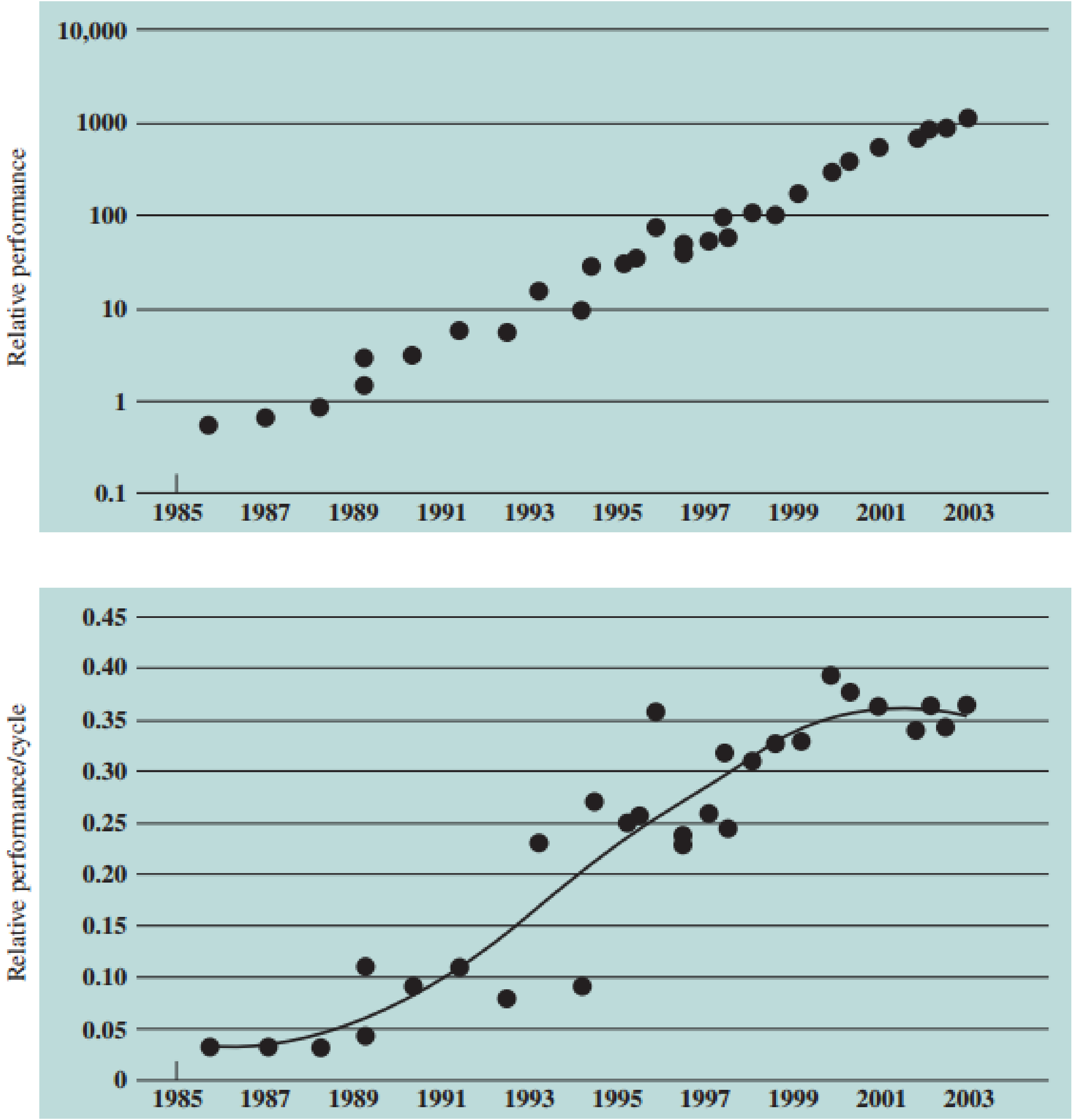

Figure 18.2 Some Intel Hardware Trends

Processor Trends

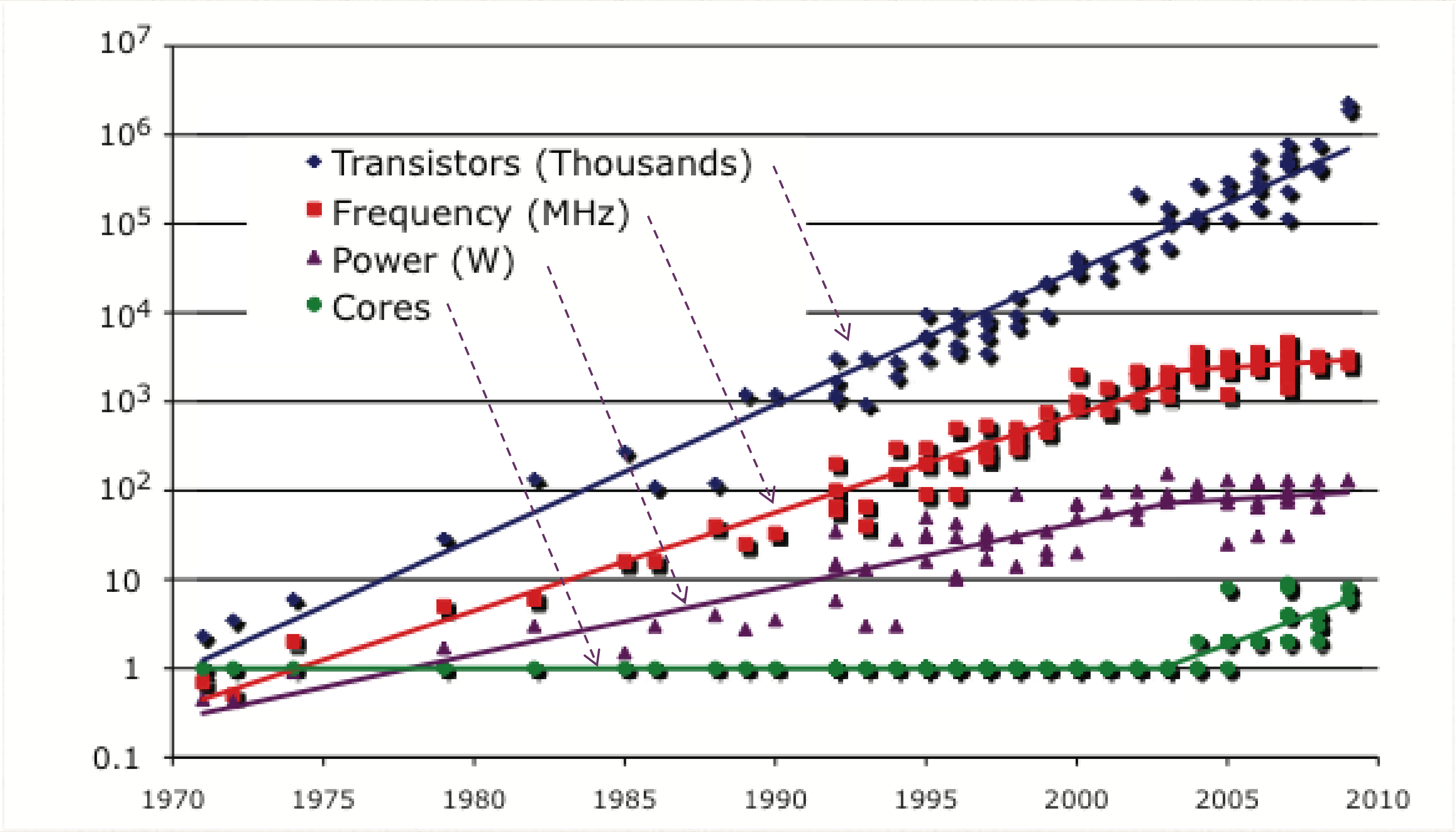

Figure 18.3 Processor Trends

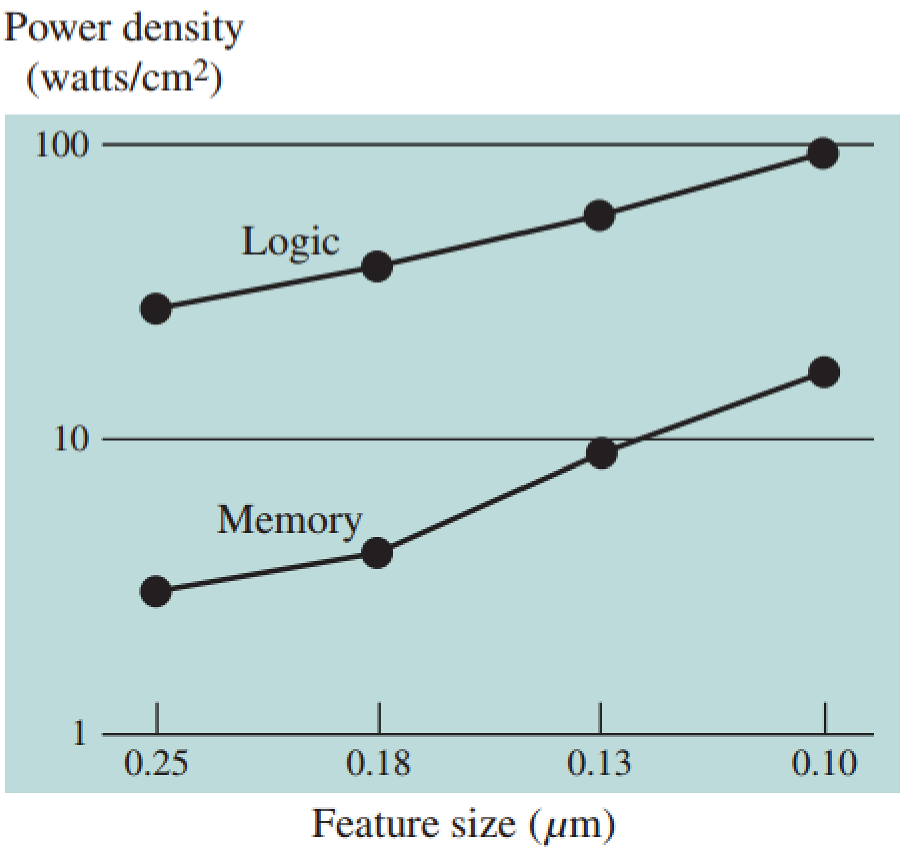

Figure 18.4 Power and Memory Considerations

Power

Memory

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Power Consumption

- By 2015 we can expect to see microprocessor chips with about 100 billion transistors on a 300 mm^2 die (base)
- Assuming that about 50-60% of the chip area is devoted to memory, the chip will support cache memory of about 100 MB and leave over 1 billion transistors available for logic
- How to use all those logic transistors is a key design issue
- Pollack's Rule
  - States that performance increase is roughly proportional to square root of increase in complexity

18.2- Software Performance Issues

Performance Effect of Multiple Cores

Amdahl's law

f: frequency, N: number of CPU

$$\text{Speed up} = \frac{\text{time to execute program on a single processor}}{\text{time to execute program on } N \text{ parallel processors}} = \frac{1}{(1-f) + \frac{f}{N}}$$

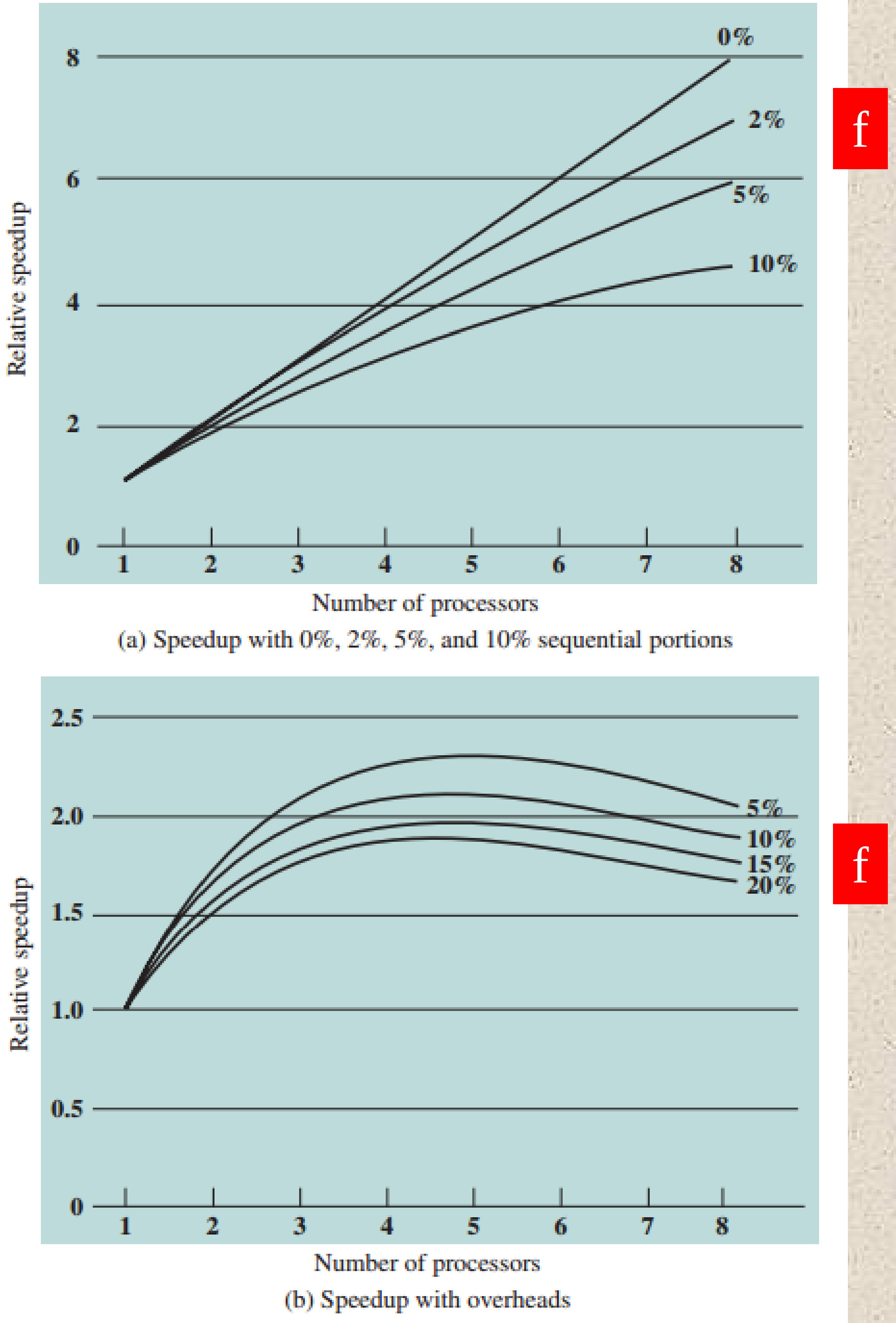
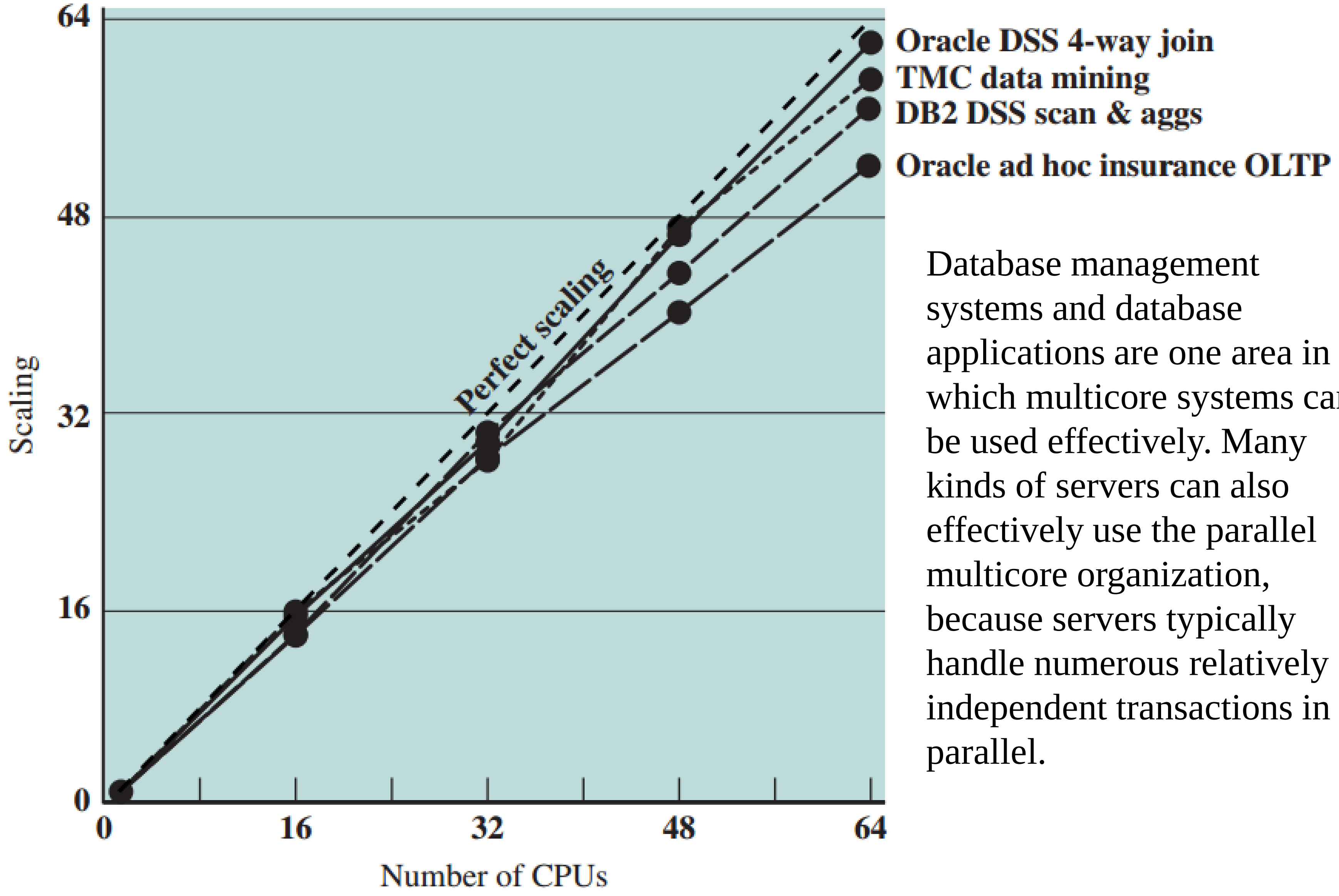


Figure 18.5 Performance Effect of Multiple Cores

Scaling of Database Workloads on Multiple-Processor hardware



Database management systems and database applications are one area in which multicore systems can be used effectively. Many kinds of servers can also effectively use the parallel multicore organization, because servers typically handle numerous relatively independent transactions in parallel.

Figure 18.6 Scaling of Database Workloads on Multiple-Processor Hardware

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Effective Applications for Multicore Processors

- **Multi-threaded native applications**
  - Characterized by having a small number of highly threaded processes
  - Lotus Domino, Siebel CRM (Customer Relationship Manager)
- **Multi-process applications**
  - Characterized by the presence of many single-threaded processes
  - Oracle, SAP, PeopleSoft
- **Java applications**
  - Java Virtual Machine is a multi-threaded process that provides scheduling and memory management for Java applications
  - Sun's Java Application Server, BEA's Weblogic, IBM Websphere, Tomcat
- **Multi-instance applications**
  - One application running multiple times
  - If multiple application instances require some degree of isolation, virtualization technology can be used to provide each of them with its own separate and secure environment

18.3- Multicore Organization

At a top level of description, the main variables in a multicore organization are as follows:

- The number of core processors on the chip
- The number of levels of cache memory
- The amount of cache memory that is shared

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Multicore Organization …

D-cache: cache storing data
I-cache: cache storing instructions

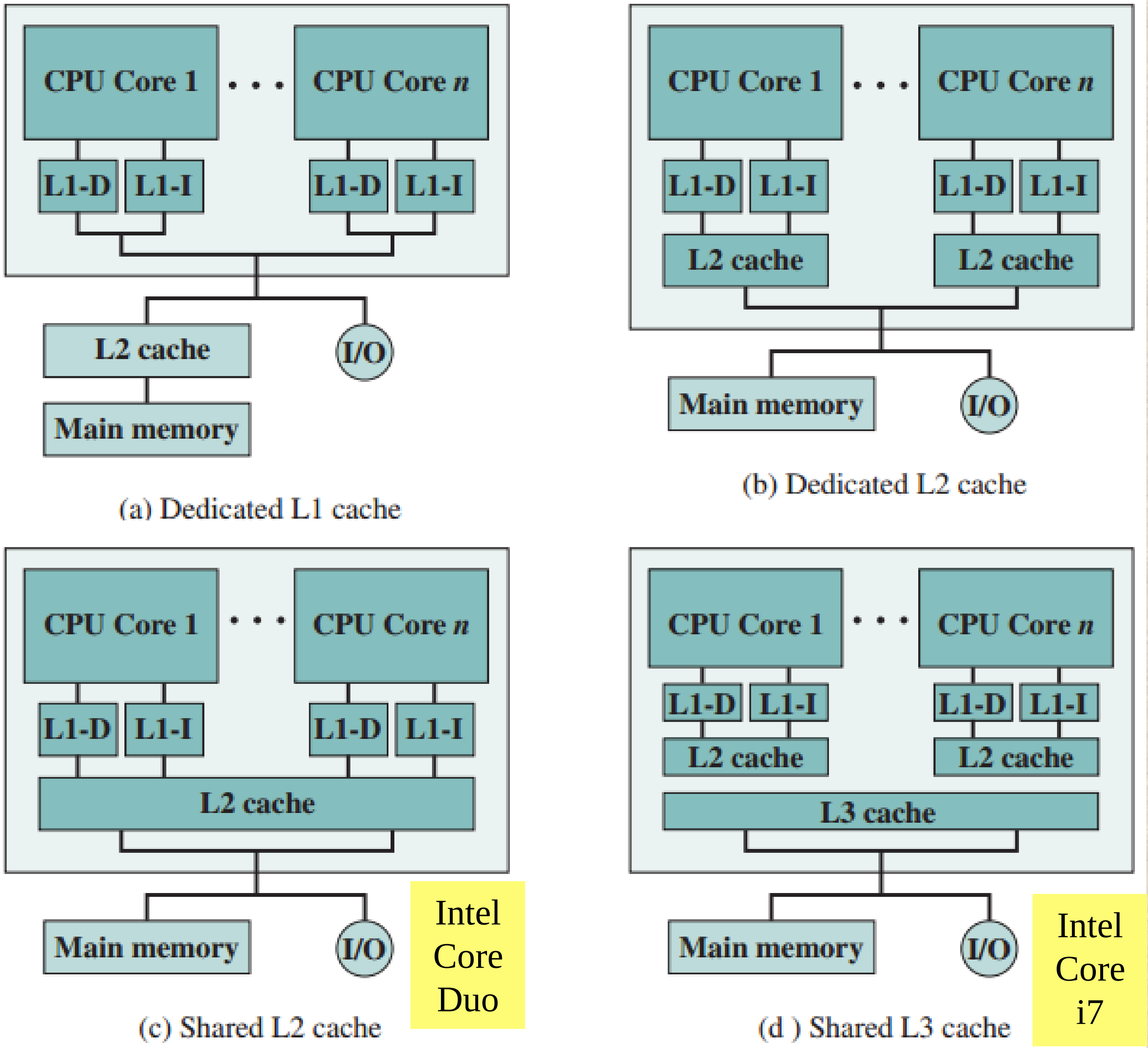

Figure 18.8 Multicore Organization Alternatives

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13.4- Intel x86 Multicore Organization

APIC: Advanced Programmable Interrupt Controller

Thermal Control: Power Management Logic

Arch.: Architecture

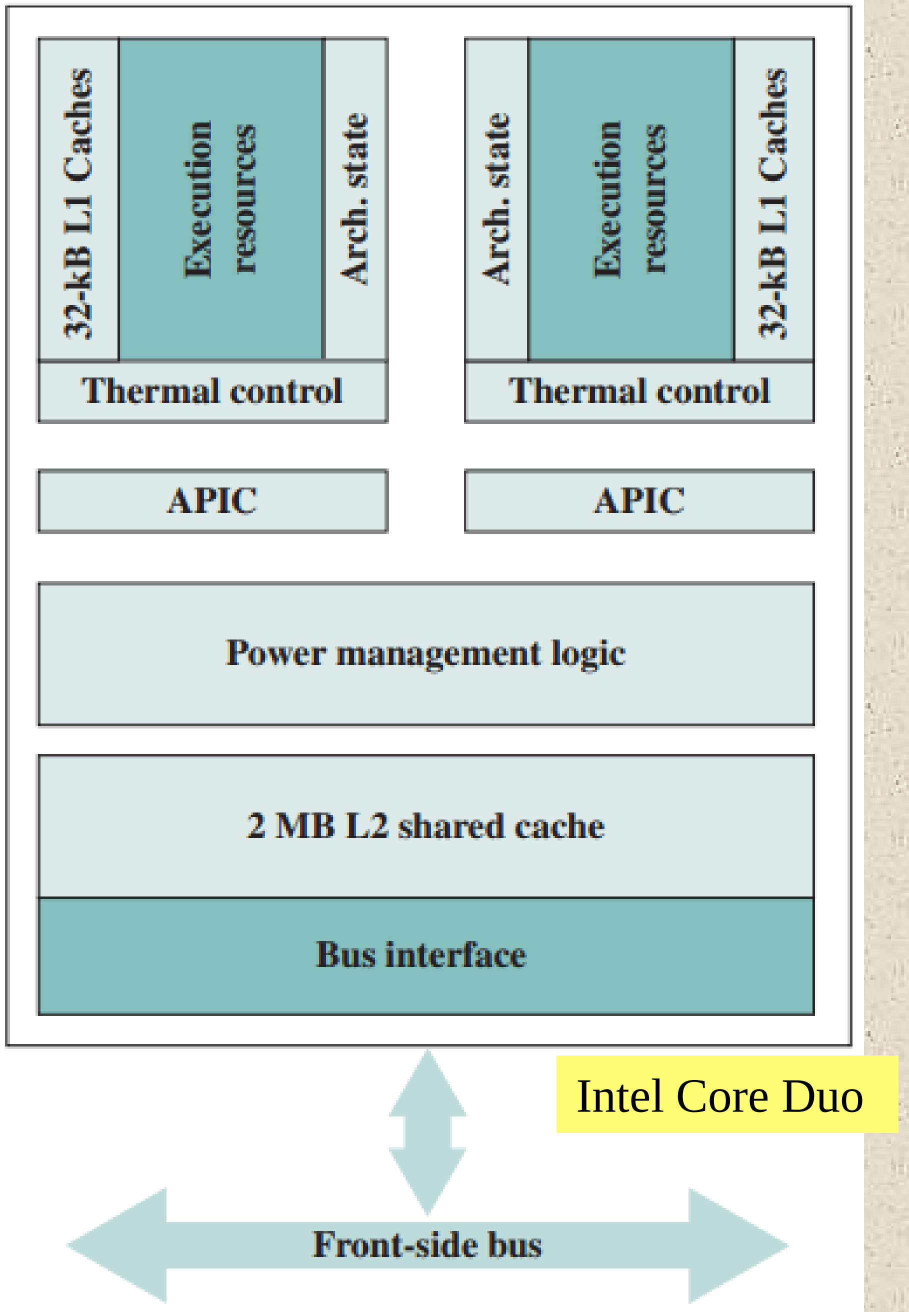

Figure 18.9 Intel Core Duo Block Diagram

Intel Core I7-990X Organization

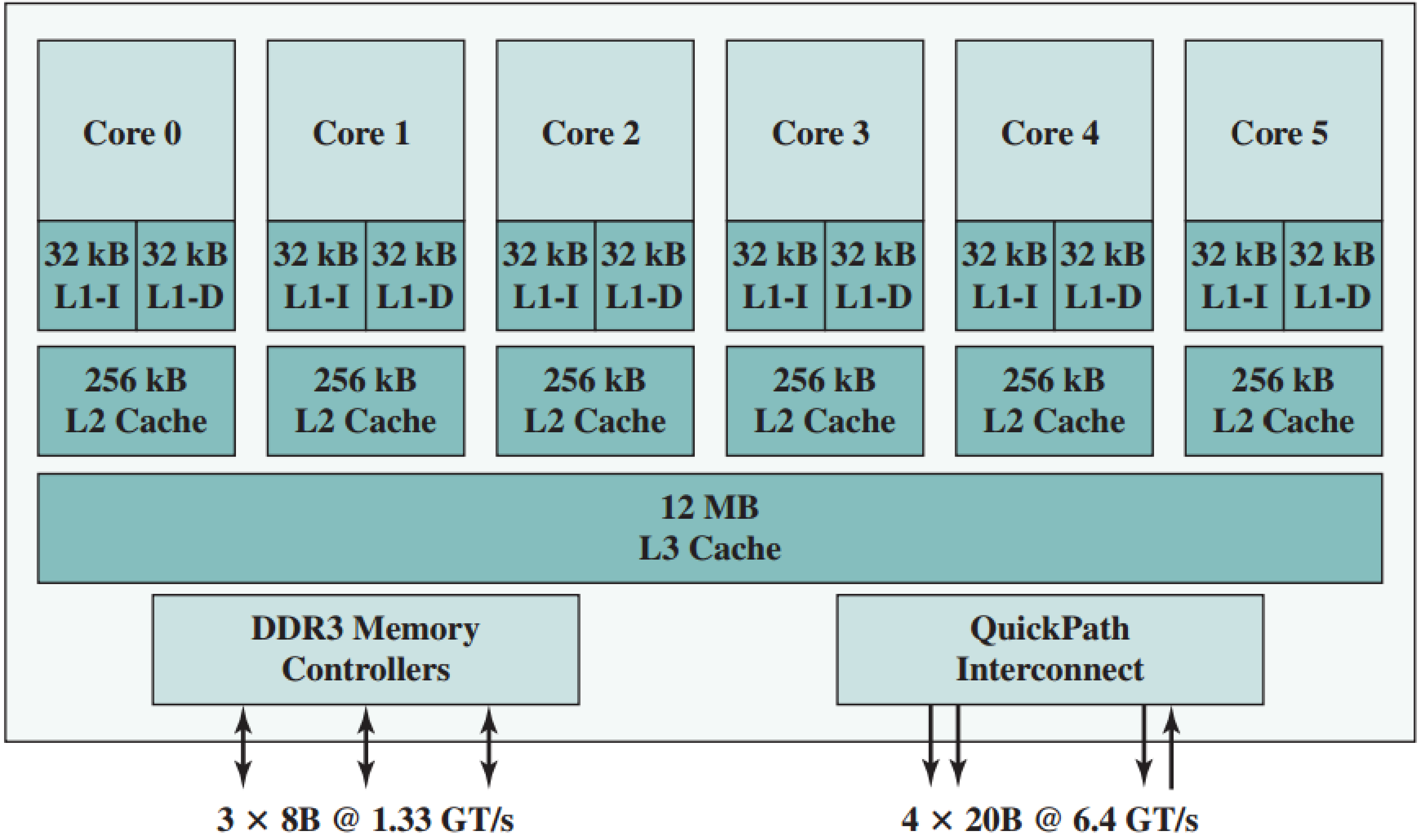

Figure 18.10 Intel Core i7-990X Block Diagram

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Exercises

- 18.1 Summarize the differences among simple instruction pipelining, superscalar, and simultaneous multithreading.
- 18.2 Give several reasons for the choice by designers to move to a multicore organization rather than increase parallelism within a single processor.
- 18.3 Why is there a trend toward giving an increasing fraction of chip area to cache memory?
- 18.5 At a top level, what are the main design variables in a multicore organization?
- 18.6 List some advantages of a shared L2 cache among cores compared to separate dedicated L2 caches for each core.

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Summary

Chapter 18

Multicore Computers

- Hardware performance issues
  - Increase in parallelism and complexity
  - Power consumption
- Software performance issues
  - Software on multicore
- Multicore organization
- Intel x86 multicore organization
  - Intel Core Duo
  - Intel Core i7-990X