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CHAPTER

The What, Why, and How of MPSoCs

Ahmed Amine Jerraya and Wayne Wolf

1.1

INTRODUCTION

Multiprocessor systems-on-chips (MPSoCs) are the latest incarnation of very large-scale integration (VLSI) technology. A single integrated circuit can contain over 100 million transistors, and the International Technology Roadmap for Semiconductors predicts that chips with a billion transistors are within reach. Harnessing all this raw computing power requires designers to move beyond logic design into computer architecture. The demands placed on these chips by applications require designers to face problems not confronted by traditional computer architecture: real-time deadlines, very low-power operation, and so on. These opportunities and challenges make MPSoC design an important field of research.

The other chapters in this book examine various aspects of MPSoC design in detail. This chapter surveys the field and tries to put the problems of MPSoC design into perspective. We will start with a brief introduction to MPSoC applications. We will then look at the hardware and software architectures of MPSoCs. We will conclude with a survey of the remaining chapters in the book.

1.2

WHAT ARE MPSoCS?

We first need to define *system-on-chip* (SoC). An SoC is an integrated circuit that implements most or all of the functions of a complete electronic system. The most fundamental characteristic of an SoC is complexity. A memory chip may have many transistors, but its regular structure makes it a component and not a system.

Exactly what components are assembled on the SoC varies with the application. Many SoCs contain analog and mixed-signal circuitry for input/output (I/O). Although some high-performance I/O applications require a separate analog interface chip that serves as a companion to a digital SoC, most of an SoC is digital because that is the only way to build such complex functions reliably. The system may contain memory, instruction-set processors (central processing units [CPUs]), specialized logic, busses, and other digital functions. The architecture of the system is generally tailored to the application rather than being a general-purpose chip: we will discuss the motivations for custom, heterogeneous architectures in the next section.

Systems-on-chips can be found in many product categories ranging from consumer devices to industrial systems:

- ◆ Cell phones use several programmable processors to handle the signal-processing and protocol tasks required by telephony. These architectures must be designed to operate at the very low-power levels provided by batteries.
- ◆ Telecommunications and networking use specialized systems-on-chips, such as network processors, to handle the huge data rates presented by modern transmission equipment.
- ◆ Digital televisions and set-top boxes use sophisticated multiprocessors to perform real-time video and audio decoding and user interface functions.
- ◆ Television production equipment uses systems-on-chips to encode video. Encoding high-definition video in real time requires extremely high computation rates.
- ◆ Video games use several complex parallel processing machines to render gaming action in real time.

These applications do not use general-purpose computer architectures either because a general-purpose machine is not cost-effective or because it would simply not provide the necessary performance. Consumer devices must sell for extremely low prices. Today, digital video disc (DVD) players sell for US \$50, which leaves very little money in the budget for the complex video decoder and control system that playing DVDs requires. At the high end, general-purpose machines simply can't keep up with the data rates for high-end video and networking; they also have a hard time providing reliable real-time performance.

So what is an MPSoC? It is simply a system-on-chip that contains multiple instruction-set processors (CPUs). In practice, most SoCs are MPSoCs because it is too difficult to design a complex system-on-chip without making use of