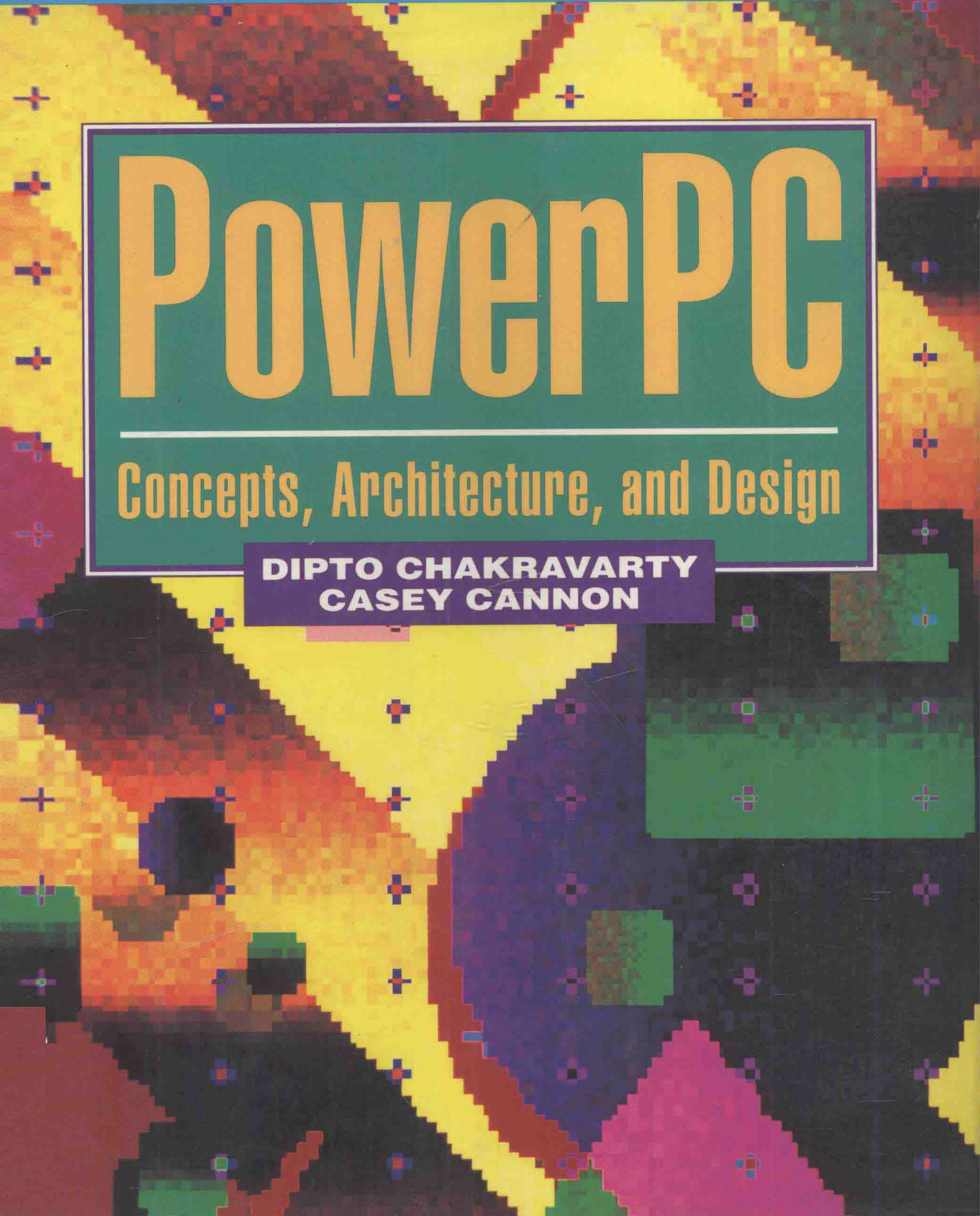
J. Ranade Workstation Series

PowerPC

Concepts, Architecture, and Design

DIPTO CHAKRAVARTY
CASEY CANNON



PowerPC

Concepts, Architecture, and Design

Dipto Chakravarty

Casey Cannon

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To Bapi
—D.C.
To my family for their enthusiasm
and to Don Meyer for his encouragement
—C.C.

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Preface

This book is a general-purpose reference for the computer professionals who wish to understand the PowerPC technology, which has evolved as a result of the IBM-Motorola-Apple alliance. The text is designed to serve as a single source of reference about the PowerPC hardware and its operating environments. A layer-by-layer introduction of the hardware, middleware, and software options unveils the diverse capabilities and features of this revolutionary technology. The subtitle, *Concepts, Architecture, and Design,* is quite appropriate, as the book contains a comprehensive overview of the hardware and the software *concepts* from both user as well as system perspectives. The text introduces the hierarchical *architecture* of the PowerPC microprocessor and explains the *design* rationales for the facilities and features that enable PowerPC to achieve the paramount level of performance.

Architecture and implementation of a computer are two distinct entities. Perhaps the most popular distinction between the terms was made in a *Communications of the ACM* journal.*

Computer architecture

> . . . is defined as the attributes and behavior of a computer as seen by a machine language programmer. This definition includes the instruction set, instruction formats, operations codes, addressing modes, and all register and memory locations that may be directly manipulated by a machine language programmer.

Implementation

> . . . is defined as the actual hardware structure, logic design, and data path organization of a particular embodiment of the architecture.

Thus, architecture is a definition that describes the behavior of all possible implementations, as compared to implementation that typically references a single microprocessor. The discussions of PowerPC architecture and its implementations have been kept separate for maximum benefit to the reader. A survey of operating systems and user interfaces has been provided to present to the reader with a system-level picture of the PowerPC-based computer systems.

* *Communications of the ACM,* vol. 36, no. 2, p. 33, February 1993.

WHY THIS BOOK

The publicity generated concerning the PowerPC microprocessor has resulted in the dissemination of a wide variety of information among vendors and developers in the computer industry. What has not been disseminated is a reference that ties all the aspects of this nascent technology together in a comprehensive source of reference. *Hence, this book.*

OBJECTIVES OF THIS BOOK

The first objective of this book is to describe the principles of the PowerPC architecture (and its implementations), which evolved out of the POWER architecture. Introduced in 1990, the POWER technology used in the RISC System/6000 product line acquired a quick reputation for itself in the marketplace by virtue of its advanced RISC-based design and achievable level of performance. PowerPC is a flexible derivative of the POWER architecture and shares a wide spectrum of traits with its parent architecture.

The second objective of this book is to depict a system-level picture of computers based on the PowerPC processor with emphasis on the operating systems, software development tools, standards, and user interfaces. An array of technologies is available today, in terms of hardware as well as software, that can be optimized by using PowerPC as its core. With a proliferation of PowerPC-based computer systems in the marketplace, end users will be faced with a choice of whether to opt for a computer that is PowerPC reference platform compliant or a computer that uses the PowerPC as its core. Both types of systems offer the power of the PowerPC microprocessor, the difference being in the varying degrees of compatibility that exist among the applications.

USES OF THIS BOOK

The intended use of this book is threefold:

- It can be used by the computer professionals working on or transitioning to the PowerPC-based development environment.
- It can be read by the general audience of the computer community wishing to get acquainted with PowerPC technology. The material delves into adequate depth to serve a novice as well as a knowledgeable user.
- It can be used as supplemental reading material in a computer system architecture course.

ORGANIZATION OF THIS BOOK

The first part of the book introduces the PowerPC in light of RISC technology. The second part explains the PowerPC architecture and discusses its available and planned implementations, including a comparative study with the POWER offerings to explain how POWER developed into the PowerPC. The third part of the book covers the user interfaces, standards, and tools. It also discusses the several operating systems that can/will run on the PowerPC. The final chapter wraps up the concepts by giving a tutorial on how to go about building one's own PowerPC platform. The contents of each of the parts are stand-alone and can be studied individually.

The book is organized into 12 chapters:

1. Presenting the PowerPC
2. RISC Technology
3. Architectural Definition
4. Processor Implementations
5. User Interfaces
6. Choice of Operating Systems
7. Development Tools
8. Supported Standards
9. Design of AIX: A PowerOpen Implementation
10. AIX Process Subsystem Internals
11. AIX File, Memory, and I/O Subsystem Internals
12. What You Need to Build a PowerPC

Chapter 1 introduces the PowerPC, discusses its evolution through the formation of the IBM-Motorola-Apple alliance, compares its standing with the Pentium, and addresses some of the important highlights such as the PowerOpen Environment, the application binary interface (ABI), and the application programming interface (API) definitions. Chapter 2 discusses the RISC technology in light of its unique traits, performance tradeoffs with CISC, pipelined implementation of the execution units, and the significance of reduced instruction set cycles. Chapter 3 explains how the layered architecture defines the varying degree of compatibility from an instruction set level, to the virtual environment level, all the way up to the operating environment level. Chapter 4 describes the implementations of the PowerPC architecture, such as the 601, 603, 604, and the 620, while contrasting them with some of the POWER implementations, the RS 1, RS .9, and RSC. Chapter 5 discusses the functionality and illustrates the leading industry standards of user interfaces including the Common Desktop Environment, Wabi, X Windows, and Macintosh Application Services.

Chapter 6 reviews the PowerOpen Application Binary Interface and then highlights five of the 32-bit operating systems that the PowerPC platform is intended to support, including Taligent, Windows NT, Solaris, AIX, and Workplace OS. Chapter 7 provides a broad overview of the most widely used development tools for UNIX operating systems, including discussions of (among others) the XL C optimizing compiler, assembler, and debuggers. Chapter 8 discusses the compatibility, portability, and interoperability standards for the PowerPC, followed by an overview of the interconnectivity functionalities of the PowerPC. Chapters 9, 10, and 11 cover in detail the PowerOpen-compliant AIX operating system, which is based on the COSE (Common Open Software Environment) version of UNIX. Chapter 9 presents the design of AIX, with in-depth discussions on components of the kernel, structural layout and characteristic features of the kernel, internal representation of files, related kernel tables, interprocess communication mechanisms, and allied data structures. Chapter 10 explains AIX process management principles, with emphasis on process structure, process state, context switching, scheduling principles, affiliated kernel structures and their positioning in the kernel address space, the art of monitoring processes by traversing through the *kmem* (running kernel's memory), and handling of threads. Chapter 11 discusses the file, memory, I/O, and device subsystems of the AIX kernel. It begins with a detailed discussion on the AIX file system in light of its memory mapped files, journaled file system, and the logical volume manager. The memory architecture topics include the addressability of the segmented memory, followed by the virtual memory management, page replacement, and memory load control schemes. The I/O subsystem topics include asynchronous I/O and I/O pacing, followed by the device subsystem, which discusses device drivers and the object data manager. In conclusion, Chapter 12 wraps up the concepts, architecture, and design of the PowerPC by providing a description of the devices and interfaces that are recommended for designing and building a PowerPC based computer system.

The content of Chapter 1 serves as an introduction to PowerPC for everyone. The material in Chapters 2, 3, and 4 will be of maximum benefit to hardware engineers who need to know about the registers and the architectural traits of the PowerPC microprocessor. The information in Chapters 5, 6, 7, and 8 are meant for end users and system integrators/designers. Chapters 9, 10, and 11 are geared for UNIX gurus who wish to understand how the internals of the PowerOpen compliant AIX operating system works. The content of Chapter 12 provides an account of the aspects to be considered when building one's own PowerPC-based computer system.

In conclusion, this book can be thought of as a single source of information about all technical aspects of the PowerPC. Professionals requiring an immersion training in PowerPC, as well as those keen on gaining an insight into the internals of this complex system, will benefit from this book.

A few caveats need to be mentioned. No attempts have been made to cover details of implementation-specific hardware components or release-specific software components. Such attributes are likely to change over a period of time. For an implementation-specific dependency of a microprocessor, or a release-specific dependency of an operating system or software component, one is encouraged to refer to the corresponding product reference manuals. Although we have avoided predicting the future development of the hardware and software, trends in many of the characteristics are obvious. In that case, this book will serve as the baseline technical reference for future products based on the PowerPC architecture.

The IBM-Motorola-Apple alliance has resulted in the birth of the PowerPC, and, consequently, has brought the RISC technology to the desktop computing world. By blending together the cost-performance and scalable aspects of the architecture, along with the interoperable software base, the PowerPC has made the biggest impact in the personal computer industry since the original Intel-based personal computer itself.

Acknowledgments

The genesis of PowerPC has generated an enthusiastic community worldwide. The technology, which evolved as a result of the IBM-Motorola-Apple alliance, is rapidly penetrating the computer industry's relentless pursuit for cost-performance computing.

The inspiration and support for writing this book came from our colleagues and friends too numerous to mention. Of the many individuals who helped us author this book, we would like to express our gratitude to our colleagues at IBM, Motorola, and Apple who willingly answered questions about this emerging subject.

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—*D.C.*

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—*C.C.*

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