Table 2.3 Example Members of the IBM 700/7000 Series

Model Number	First Delivery	CPU Technology	Memory Technology	Cycle Time (μs)	Memory Size (K)	Number of Opcodes	Number of Index Registers	Hardwired Floating Point	I/O Overlap (Channels)	Instruction Fetch Overlap	Speed (relative to 701)
701	1952	Vacuum tubes	Electrostatic tubes	30	2–4	24	0	no	no	no	1
704	1955	Vacuum tubes	Core	12	4–32	80	3	yes	no	no	2.5
709	1958	Vacuum tubes	Core	12	32	140	3	yes	yes	no	4
7090	1960	Transistor	Core	2.18	32	169	3	yes	yes	no	25
7094 I	1962	Transistor	Core	2	32	185	7	yes (double precision)	yes	yes	30
7094 II	1964	Transistor	Core	1.4	32	185	7	yes (double precision)	yes	yes	50

Table 2.4 Key Characteristics of the System/360 Family

Characteristic	Model 30	Model 40	Model 50	Model 65	Model 75
Maximum memory size (bytes)	64K	256K	256K	512K	512K
Data rate from memory (Mbytes/s)	0.5	0.8	2.0	8.0	16.0
Processor cycle time (μs)	1.0	0.625	0.5	0.25	0.2
Relative speed	1	3.5	10	21	50
Maximum number of data channels	3	3	4	6	6
Maximum data rate on one channel (Kbytes/s)	250	400	800	1250	1250

Table 2.6 Evolution of Intel Microprocessors

(a) 1970s Processors

	4004	8008	8080	8086	8088
Introduced	11/15/71	4/1/72	4/1/74	6/8/78	6/1/79
Clock speeds	108 KHz	108 KHz	2 MHz	5 MHz, 8 MHz, 10 MHz	5 MHz, 8 MHz
Bus width	4 bits	8 bits	8 bits	16 bits	8 bits
Number of transistors (microns)	2300 (10)	3500	6000 (6)	29,000 (3)	29,000 (3)
Addressable memory	640 bytes	16 KBytes	64 KBytes	1 MB	1 MB
Virtual memory	—	—	—	—	—

Table 2.6 *(continued)*

(b) 1980s Processors

	80286	386TM DX	386TM SX	486TM DX CPU
Introduced	2/1/82	10/17/85	6/16/88	4/10/89
Clock speeds	6 MHz–12.5 MHz	16 MHz–33 MHz	16 MHz–33 MHz	25 MHz–50 MHz
Bus width	16 bits	32 bits	16 bits	32 bits
Number of transistors (microns)	134,000 (1.5)	275,000 (1)	275,000 (1)	1.2 million (0.8–1)
Addressable memory	16 metabytes	4 gigabytes	4 gigabytes	4 gigabytes
Virtual memory	1 gigabyte	64 terabytes	64 terabytes	64 terabytes

(c) 1990s Processors

	486TM SX	Pentium	Pentium	Pentium II
Introduced	4/22/91	3/22/93	11/01/95	5/07/97
Clock speeds	16 MHz–133 MHz	60 MHz–166 MHz	150 MHz–200 MHz	200 MHz–300 MHz
Bus width	32 bits	32 bits	64 bits	64 bits
Number of transistors (microns)	1.185 million (1)	3.1 million (.8)	5.5 million (0.6)	7.5 million (0.35)
Addressable memory	4 gigabytes	4 gigabytes	64 gigabytes	64 gigabytes
Virtual memory	64 terabyte	64 terabytes	64 terabytes	64 terabytes

(d) Recent Processors

	Pentium III	Pentium 4
Introduced	2/26/99	11/2000
Clock speeds	450–660 MHz	1.3–1.8 GHz
Bus width	64 bits	64 bits
Number of transistors (microns)	95 million (0.25)	42 million
Addressable memory	64 gigabytes	64 gigabytes
Virtual memory	64 terabytes	64 terabytes

Source: Intel Corp. http://www.intel.com/intel/museum/25anniv/hof/tspecs.htm

2.3 PENTIUM AND POWERPC EVOLUTION

Throughout this book, we rely on many concrete examples of computer design and implementation to illustrate concepts and to illuminate trade-offs. Most of the time, the book relies on examples from two computer families: the Intel Pentium and the PowerPC. The Pentium represents the results of decades of design effort on complex instruction set computers (CISCs). It incorporates the sophisticated design principles once found only on mainframes and supercomputers and serves as an excellent example of CISC design. The PowerPC is a direct descendant of the first RISC system, the IBM 801, and is one of the most powerful and best-designed RISC-based systems on the market.

In this section, we provide a brief overview of both systems.

Pentium

In terms of market share, Intel has ranked as the number one maker of microprocessors for decades, a position it seems unlikely to yield. The evolution of its flagship microprocessor product serves as a good indicator of the evolution of computer technology in general.

Table 2.6 shows that evolution. Interestingly, as microprocessors have grown faster and much more complex, Intel has actually picked up the pace. Intel used to develop microprocessors one after another, every four years. But Intel hopes to keep rivals at bay by trimming a year or two off this development time, and has done so with the most recent Pentium generations.

It is worthwhile to list some of the highlights of the evolution of the Intel product line:

- **8080:** The world's first general-purpose microprocessor. This was an 8-bit machine, with an 8-bit data path to memory. The 8080 was used in the first personal computer, the Altair.

- **8086:** A far more powerful, 16-bit machine. In addition to a wider data path and larger registers, the 8086 sported an instruction cache, or queue, that prefetches a few instructions before they are executed. A variant of this processor, the 8088, was used in IBM's first personal computer, securing the success of Intel.
- **80286:** This extension of the 8086 enabled addressing a 16-MByte memory instead of just 1 MByte.
- **80386:** Intel's first 32-bit machine, and a major overhaul of the product. With a 32-bit architecture, the 80386 rivaled the complexity and power of minicomputers and mainframes introduced just a few years earlier. This was the first Intel processor to support multitasking, meaning it could run multiple programs at the same time.
- **80486:** The 80486 introduced the use of much more sophisticated and powerful cache technology and sophisticated instruction pipelining. The 80486 also offered a built-in math coprocessor, offloading complex math operations from the main CPU.
- **Pentium:** With the Pentium, Intel introduced the use of superscalar techniques, which allow multiple instructions to execute in parallel.
- **Pentium Pro:** The Pentium Pro continued the move into superscalar organization begun with the Pentium, with aggressive use of register renaming, branch prediction, data flow analysis, and speculative execution.
- **Pentium II:** The Pentium II incorporated Intel MMX technology, which is designed specifically to process video, audio, and graphics data efficiently.
- **Pentium III:** The Pentium III incorporates additional floating-point instructions to support 3D graphics software.
- **Pentium 4:** The Pentium 4 includes additional floating-point and other enhancements for multimedia.[2]
- **Itanium:** This new generation of Intel processor makes use of a 64-bit organization with the IA-64 architecture, which is discussed in detail in Chapter 15.

PowerPC

In 1975, the 801 minicomputer project at IBM pioneered many of the architecture concepts used in RISC systems. The 801, together with the Berkeley RISC I processor, launched the RISC movement. The 801, however, was simply a prototype intended to demonstrate design concepts. The success of the 801 project led IBM to develop a commercial RISC workstation product, the RT PC. The RT PC, introduced in 1986, adapted the architectural concepts of the 801 to an actual product. The RT PC was not a commercial success, and it had many rivals with comparable or better performance. In 1990, IBM produced a third system, which built on the lessons of the 801 and the RT PC. The IBM RISC System/6000 was a RISC-like superscalar machine marketed as a high-performance workstation; shortly after its introduction, IBM began to refer to this as the POWER architecture.

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[2]With the Pentium 4, Intel switched from Roman numerals to Arabic numerals for model numbers.

For its next step, IBM entered into an alliance with Motorola, developer of the 68000 series of microprocessors, and Apple, which used the Motorola chip in its Macintosh computers. The result is a series of machines that implement the PowerPC architecture. This architecture is derived from the POWER architecture. Changes were made to add key missing features and to enable more efficient implementation by eliminating some instructions and relaxing the specification to eliminate some troublesome special cases. The resulting PowerPC architecture is a superscalar RISC system. The PowerPC is used in millions of Apple Macintosh machines and in numerous embedded chip applications. An example of the latter is IBM's family of network management chips, which can be embedded in network equipment to provide common management access for users with multivendor platforms.

The following are the principal members of the PowerPC family (Table 2.8):

- **601:** The purpose of the 601 was to bring the PowerPC architecture to the marketplace as quickly as possible. The 601 is a 32-bit machine.
- **603:** Intended for low-end desktop and portable computers. It is also a 32-bit machine, comparable in performance with the 601, but with lower cost and a more efficient implementation.
- **604:** Intended for desktop computers and low-end servers. Again, this is a 32-bit machine, but it uses much more advanced superscalar design techniques to achieve greater performance.
- **620:** Intended for high-end servers. The first member of the PowerPC family to implement a full 64-bit architecture, including 64-bit registers and data paths.
- **740/750:** Also known as the G3 processor. This processor integrates two levels of cache in the main processor chip, providing significant performance improvement over a comparable machine with off-chip cache organization.
- **G4:** This processor increases the parallelism and internal speed of the processor chip.

Table 2.8 PowerPC Processor Summary

	601	603/603e	604/604e	740/750 (G3)	G4
First ship date	1993	1994	1994	1997	1999
Clock speeds (MHz)	50–120	100–300	166–350	200–366	500
L1 cache	—	16 Kbyte inst 16 Kbyte data	32 Kbyte inst 32 Kbyte data	32 Kbyte instr 32 Kbyte data	32 Kbyte instr 32 Kbyte data
Backside L2 cache support	—	—	—	256 Kbyte–1 Mbyte	256 Kbyte–1 Mbyte
Number of transistors (10^6)	2.8	1.6–2.6	3.6–5.1	6.35	—