Microprocessors

Lecture 1

Third Class

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The **Intel Microprocessors**

8086/8088, 80186/80188, 80286, 80386, 80486 Pentium, Pentium Pro Processor, Pentium II, Pentium 4, and Core2 with 64-bit Extensions

Architecture, Programming, and Interfacing

EIGHTH EDITION

Barry B. Brey

PEARSON

Chapter 1: Introduction to the Microprocessor and Computer

Outline

- Overview of Intel Microprocessors
- Discussion of History of Computers
- Function of Microprocessor
- Basic Information about Microprocessor
- Memory and I/O Space
- Buses

Objectives

- Converse by using appropriate computer terminology such as bit, byte, data, real memory system, protected mode memory system, Windows, DOS, I/O.
- Detail history of the computer and list applications performed by computer systems.
- Provide an overview of the various 80X86 and Pentium family members.

Objectives

- Draw the block diagram of a computer system and explain the purpose of each block.
- Describe the function of the microprocessor and detail its basic operation.
- Define the contents of the memory system in the personal computer.
- Convert between binary, decimal, and hexadecimal numbers.
- Differentiate and represent numeric and alphabetic information as integers, floating-point, BCD, and ASCII data.

Historical Background

- **Mechanical Age**
- **Electromechanical Age**
- **Electronic Age**

Mechanical Age

- Idea of computing system not new.
- Calculating with a machine dates to 500 BC.
- Babylonians invented the **abacus.**
  - first mechanical calculator
  - strings of beads perform calculations
- Used by ancient priests to keep track of storehouses of grain.
  - still in use today

Mechanical Age

- In 1642 mathematician Blaise Pascal invented a calculator constructed of gears and wheels.
  - each gear contained 10 teeth
- When moved one complete revolution, a second gear advances one place.
  - same principle used in automobile odometer
- Basis of all mechanical calculators.
- PASCAL programming language is named in honor of Blaise Pascal.

Mechanical Age

- First practical geared mechanical machines to compute information date to early 1800s.
  - humans dreamed of mechanical machines that could compute with a program
- One early pioneer of mechanical computing machinery was Charles Babbage.
  - aided by Ada Byron, Countess of Lovelace
- Commissioned in 1823 by Royal Astronomical Society to build programmable calculating machine.
  - to generate Royal Navy navigational tables

Mechanical Age

- He began to create his **Analytical Engine.**
- Steam-powered mechanical computer.
  - stored a thousand 20-digit decimal numbers
- Variable program could modify function of the machine to perform various calculating tasks.
  - input through punched cards, much as computers in the 1950s and 1960s used punched cards
- It is assumed idea of punched cards is from Joseph Jacquard, a Frenchman.
  - used punched cards as input to a weaving machine he invented in 1801

Mechanical Age

- *Jacquard's loom* used punched cards to select intricate weaving patterns in cloth it produced.
  - punched cards programmed the loom
- After many years of work Babbage's dream began to fade.
  - machinists of his day unable to create the parts needed to complete his work
- Analytical Engine required more than 50,000 machined parts.
  - they could not be made with enough precision to allow his engine to function reliably

Electromechanical Age

- 1800s saw advent of the electric motor.
  - conceived by Michael Faraday
- Also a multitude of electrically motor-driven adding machines based on the Pascal mechanical calculator.
  - common office equipment until 1970s
- Introduced by Bomar Corporation the **Bomar Brain**, was a handheld electronic calculator.
  - first appeared in early 1970s

Electromechanical Age

- Monroe also pioneer of electronic calculators, making desktop models.
  - four-function; size of cash registers
- In 1889, Herman Hollerith developed the punched card for storing data.
  - apparently also borrowed Jacquard ideas
- Also developed mechanical machine that counted, sorted, and collated information stored on punched cards.
  - driven by one of the new electric motors

Electromechanical Age

- Calculating by machine intrigued US govt.
  - Hollerith commissioned to use system to store and tabulate 1890 census information
- In 1896 Hollerith formed Tabulating Machine Company.
  - developed line of machines using punched cards for tabulation
- After a number of mergers, Tabulating Machine Co. was formed into International Business Machines Corporation.
  - referred to more commonly as IBM, Inc.

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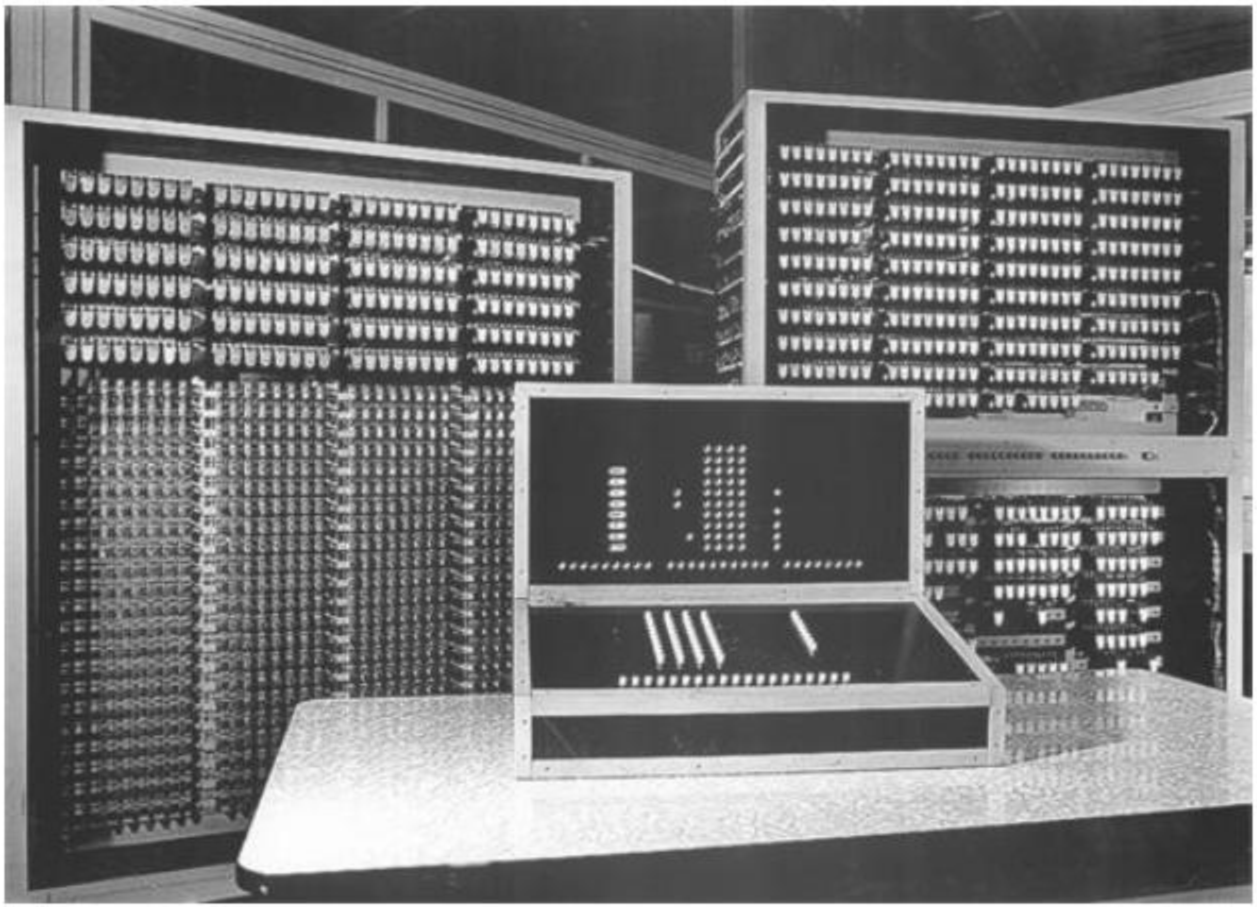
  - referred to more commonly as IBM, Inc.
- Punched cards used in early computer systems often called **Hollerith cards.**
  - in honor of Herman Hollerith
- 12-bit code used on a punched card is called the **Hollerith code.**

Electromechanical Age

- Mechanical-electric machines dominated information processing world until 1941.
  - construction of first electronic calculating machine
- German inventor Konrad Zuse, invented the first modern electromechanical computer.
- His Z3 calculating computer probably invented for aircraft and missile design.
  - during World War II for the German war effort
- Z3 a relay logic machine clocked at 5.33 Hz.
  - far slower than latest multiple GHz microprocessors

Electromechanical Age

Figure 1–1 The Z3 computer developed by Konrad Zuse uses a 5.33 hertz clocking frequency. (Photo courtesy of Horst Zuse, the son of Konrad.)



Electromechanical Age

- Had Zuse been given adequate funding, likely would have developed a much more powerful computer system.
- In 1936 Zuse constructed a mechanical version of his system.
- In 1939 constructed first electromechanical computer system, called the Z2.
  - Zuse today receiving belated honors for pioneering work in the area of digital electronics

Electronic Age

- First electronic computer placed in operation to break secret German military codes.
- recently discovered through declassification of military documents of 1943.
- System invented by Alan Turing.
  - used vacuum tubes,
- Turing called his machine **Colossus.**
  - probably because of its size

Electronic Age

- Although design allowed it to break secret German military codes generated by the mechanical **Enigma machine**, it could not solve other problems.
- Colossus not programmable
- A fixed-program computer system
  - today often called a **special-purpose computer**
- First general-purpose, programmable electronic computer system developed 1946.
  - at University of Pennsylvania

Electronic Age

- **Electronic Numerical Integrator and Calculator (ENIAC)**, a huge machine.
  - over 17,000 vacuum tubes; 500 miles of wires
  - weighed over 30 tons
  - about 100,000 operations per second
- Programmed by rewiring its circuits.
  - process took many workers several days
  - workers changed electrical connections on plug-boards like early telephone switchboards
- Required frequent maintenance.
  - vacuum tube service life a problem

Electronic Age

- December 23, 1947, John Bardeen, William Shockley, and Walter Brattain develop the transistor at Bell Labs.
- Followed by 1958 invention of the integrated circuit (IC) by Jack Kilby of Texas Instruments.
- IC led to development of digital integrated circuits in the 1960s.
  - RTL, or resistor-to-transistor logic
- First microprocessor developed at Intel Corporation in 1971.

Electronic Age

- Intel engineers Federico Faggin, Ted Hoff, and Stan Mazor developed the 4004 microprocessor.
- U.S. Patent 3,821,715.
- Device started the microprocessor revolution continued today at an ever-accelerating pace.

Microprocessor Age- 4004

- World's first microprocessor the Intel 4004.
- A 4-bit microprocessor-programmable controller on a chip.
- Addressed 4096, 4-bit-wide memory locations.
  - a **bit** is a binary digit with a value of one or zero
  - 4-bit-wide memory location often called a **nibble**
- The 4004 instruction set contained 45 instructions.

Microprocessor Age-4004

- Fabricated with then-current state-of-the-art P-channel MOSFET technology.
- Executed instructions at 50 KIPs (**kilo-instructions per second**).
  - slow compared to 100,000 instructions per second by 30-ton ENIAC computer in 1946
- Difference was that 4004 weighed less than an ounce.
- 4-bit microprocessor debuted in early game systems and small control systems.
  - early shuffleboard game produced by Bailey

Microprocessor Age-4004

- Main problems with early microprocessor were speed, word width, and memory size.
- Evolution of 4-bit microprocessor ended when Intel released the 4040, an updated 4004.
  - operated at a higher speed; lacked improvements in word width and memory size
- Texas Instruments and others also produced 4-bit microprocessors.
  - still survives in low-end applications such as microwave ovens and small control systems
  - Calculators still based on 4-bit BCD (**binary-coded decimal**) codes

Microprocessor Age- 8008

- With the microprocessor a commercially viable product, Intel released 8008 in 1971.
  - extended 8-bit version of 4004 microprocessor
- Addressed expanded memory of 16K bytes.
  - A **byte** is generally an 8-bit-wide binary number and a **K** is 1024.
  - memory size often specified in K bytes
- Contained additional instructions, 48 total.
- Provided opportunity for application in more advanced systems.
  - engineers developed demanding uses for 8008

Microprocessor Age-8008

- Somewhat small memory size, slow speed, and instruction set limited 8008 usefulness.
- Intel introduced 8080 microprocessor in 1973.
  - first of the modem 8-bit microprocessors
- Motorola Corporation introduced MC6800 microprocessor about six months later.
- 8080—and, to a lesser degree, the MC6800—ushered in the age of the microprocessor.
  - other companies soon introduced their own versions of the 8-bit microprocessor

Microprocessor Age-8080

Table 1–1 Early 8-bit microprocessors

Manufacturer	*Part Number*
Fairchild	F-8
Intel	8080
MOS Technology	6502
Motorola	MC6800
National Semiconductor	IMP-8
Rockwell International	PPS-8
Zilog	Z-8

Microprocessor Age-8080

- Only Intel and Motorola continue to create new, improved microprocessors.
  - IBM also produces Motorola-style microprocessors
- Motorola sold its microprocessor division.
  - now called Freescale Semiconductors, Inc.
- Zilog still manufactures microprocessors.
  - microcontrollers and embedded controllers instead of general-purpose microprocessors

Microprocessor Age - 8080

- 8080 addressed four times more memory.
  - 64K bytes vs l6K bytes for 8008
- Executed additional instructions; 10x faster.
  - addition taking 20 μs on an 8008-based system required only 2.0 μs on an 8080-based system
- TTL (transistor-transistor logic) compatible.
  - the 8008 was not directly compatible
- Interfacing made easier and less expensive.

Microprocessor Age - 8080

- The MITS Altair 8800, was released in 1974.
  - number 8800 probably chosen to avoid copyright violations with Intel
- BASIC language interpreter for the Altair 8800 computer developed in 1975.
  - Bill Gates and Paul Allen, founders of Microsoft Corporation
- The assembler program for the Altair 8800 was written by Digital Research Corporation.
  - once produced DR-DOS for the personal computer

Microprocessor Age - 8085

- In 1977 Intel Corporation introduced an updated version of the 8080—the 8085.
- Last 8-bit, general-purpose microprocessor developed by Intel.
- Slightly more advanced than 8080; executed software at an even higher speed.
  - 769,230 instructions per second vs 500,000 per second on the 8080).

Microprocessor Age - 8085

- Main advantages of 8085 were its internal clock generator and system controller, and higher clock frequency.
  - higher level of component integration reduced the 8085's cost and increased its usefulness
- Intel has sold over 100 million of the 8085.
  - its most successful 8-bit, general-purpose microprocessor.
  - also manufactured by many other companies, meaning over 200 million in existence
- Applications that contain the 8085 will likely continue to be popular.

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Modern Microprocessor Age - 8086

- In 1978 Intel released the 8086; a year or so later, it released the 8088.
- Both devices are 16-bit microprocessors.
  - executed instructions in as little as 400 ns (2.5 **millions of instructions per second**)
  - major improvement over execution speed of 8085
- 8086 & 8088 addressed 1M byte of memory.
  - 16 times more memory than the 8085
  - **1M-byte memory** contains 1024K byte-sized memory locations or 1,048,576 bytes

Modern Microprocessor Age - 8086

- Higher speed and larger memory size allowed 8086 & 8088 to replace smaller minicomputers in many applications.
- Another feature was a 4- or 6-byte instruction cache or queue that prefetched instructions before they were executed.
  - queue sped operation of many sequences of instruction
  - basis for the much larger instruction caches found in modem microprocessors.

Modern Microprocessor Age - 8086

- Increased memory size and additional instructions in 8086/8088 led to many sophisticated applications.
- Improvements to the instruction set included multiply and divide instructions.
  - missing on earlier microprocessors
- Number of instructions increased.
  - from 45 on the 4004, to 246 on the 8085
  - over 20,000 variations on the 8086 & 8088

Modern Microprocessor Age - 8086

- These microprocessors are called CISC (**complex instruction set computers**).
  - additional instructions eased task of developing efficient and sophisticated applications
- 16-bit microprocessor also provided more internal register storage space.
  - additional registers allowed software to be written more efficiently
  - evolved to meet need for larger memory systems

Modern Microprocessor Age - 8086

- Popularity of Intel ensured in 1981 when IBM chose the 8088 in its personal computer.
- Spreadsheets, word processors, spelling checkers, and computer-based thesauruses were memory-intensive .
  - required more than 64K bytes of memory found in 8-bit microprocessors to execute efficiently
  - The 16-bit 8086 and 8088 provided 1M byte of memory for these applications

Microprocessor Age - 80286

- Even the 1M-byte memory system proved limiting for databases and other applications.
  - Intel introduced the 80286 in 1983
  - an updated 8086
- Almost identical to the 8086/8088.
  - addressed 16M-byte memory system instead of a 1M-byte system
- Instruction set almost identical except for a few additional instructions.
  - managed the extra 15M bytes of memory

Microprocessor Age - 80286

- 80286 clock speed increased in 8.0 Mhz version.
  - executed some instructions in as little as 250 ns (4.0 MIPs)
- Some changes to internal execution of instructions led to eightfold increase in speed for many instructions.

Microprocessor Age - 80286

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  - executed some instructions in as little as 250 ns (4.0 MIPs)
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Microprocessor Age - 80386

- Applications demanded faster microprocessor speeds, more memory, and wider data paths.
- Led to the 80386 in 1986 by Intel.
  - major overhaul of 16-bit 8086–80286 architecture
- Intel's first practical microprocessor to contain a 32-bit data bus and 32-bit memory address.
  - Intel produced an earlier, unsuccessful 32-bit microprocessor called iapx-432

Microprocessor Age - 80386

- Through 32-bit buses, 80386 addressed up to 4G bytes of memory.
  - **1G** memory = 1024M, or 1,073,741,824 locations
  - 1,000,000 typewritten, double-spaced pages of ASCII text data
- 80386SX addressed 16M bytes of memory through a 16-bit data and 24-bit address bus.
- 80386SL/80386SLC addressed 32M bytes memory via 16-bit data, 25-bit address bus.
- 80386SLC contained an internal cache to process data at even higher rates.

Microprocessor Age - 80386

- Intel released 80386EX in 1995.
- Called an **embedded PC.**
  - contains all components of the AT class computer on a single integrated circuit
- 24 lines for input/output data.
- 26-bit address bus; 16-bit data bus.
- DRAM refresh controller.
- Programmable chip selection logic

Microprocessor Age - 80386

- Applications needing higher speeds and large memory systems include software systems that use a GUI, or **graphical user interface**
- Modern graphical displays contain 256,000 or more picture elements (pixels, or pels).
- VGA (**variable graphics array**) resolution is 640 pixels per scanning line by 480 lines.
  - resolution used to display computer boot screen
- To display one screen of information, each picture element must be changed.
  - requires a high-speed microprocessor

Microprocessor Age - 80386

- GUI packages require high microprocessor speeds and accelerated video adapters for quick and efficient manipulation of video text and graphical data.
  - the most striking system is Microsoft Windows
- GUI often called a WYSIWYG (**what you see is what you get**) display.

Microprocessor Age - 80386

- 32-bit microprocessor needed due to size of its data bus.
  - transfers real (single-precision floating-point) numbers that require 32-bit-wide memory
- To process 32-bit real numbers, the microprocessor must efficiently pass them between itself and memory.
  - with 8-bit data bus, takes four read or write cycles
  - only one read or write cycle is required for 32 bit
- Significantly increases speed of any program that manipulates real numbers.

Microprocessor Age - 80386

- High-level languages, spreadsheets, and database management systems use real numbers for data storage.
  - also used in graphical design packages that use vectors to plot images on the video screen
  - CAD (**computer-aided drafting/design**) systems as AUTOCAD, ORCAD
- 80386 had higher clocking speeds and included a memory management unit.
  - allowed memory resources to be allocated and managed by the operating system

Microprocessor Age - 80386

- 80386 included hardware circuitry for memory management and assignment.
  - improved efficiency, reduced software overhead
  - earlier microprocessors left memory management completely to the software
- Instruction set, memory management upward-compatible with 8086, 8088, and 80286.
  - additional instructions referenced 32-bit registers and managed the memory system
- Features allowed older, 16-bit software to operate on the 80386 microprocessor.

Microprocessor Age - 80486

- In 1989 Intel released the 8048.
- Highly integrated package.
- 80386-like microprocessor.
- 80387-like numeric coprocessor.
- 8K-byte cache memory system.

Microprocessor Age - 80486

- Internal structure of 80486 modified so about half of its instructions executed in one clock instead of two clocks.
  - in a 50 MHz version, about half of instructions executed in 25 ns (50 MIPs)
  - 50% over 80386 operated at same clock speed
- Double-clocked 80486DX2 executed instructions at 66 MHz, with memory transfers at 33 MHz.
  - called a double-clocked microprocessor

Microprocessor Age - 80486

- A triple-clocked version improved speed to 100 MHz with memory transfers at 33 MHz.
  - about the same speed as 60 MHz Pentium.
- Expanded 16K-byte cache.
  - in place of standard 8K-byte cache
- Advanced Micro Devices (AMD) produced a triple-clocked version with a bus speed of 40 MHz and a clock speed of 120 MHz.
- The future promises rates 10 GHz or higher.

Microprocessor Age - 80486

- Other versions called OverDrive processors.
  - a double-clocked 80486DX that replaced an 80486SX or slower-speed 80486DX
  - functioned as a doubled-clocked version of the microprocessor

Microprocessor Age - Pentium

- Introduced 1993, Pentium was similar to 80386 and 80486 microprocessors.
- Originally labeled the P5 or 80586.
  - Intel decided not to use a number because it appeared to be impossible to copyright a number
- Introductory versions operated with a clocking frequency of 60 MHz & 66 MHz, and a speed of 110 MIPs.

Microprocessor Age - Pentium

- Double-clocked Pentium at 120 MHz and 133 MHz, also available.
  - fastest version produced 233 MHz Pentium a three and one-half clocked version
- Cache size was increased to 16K bytes from the 8K cache found in 80486.
- 8K-byte instruction cache and data cache.
- Memory system up to 4G bytes.
- Data bus width increased to a full 64 bits.
- Data bus transfer speed 60 MHz or 66 MHz.
  - depending on the version of the Pentium

Microprocessor Age - Pentium

- Wider data bus width accommodated double-precision floating-point numbers used in high-speed, vector-generated graphical displays.
  - should allow virtual reality software and video to operate at more realistic rates
- Widened data bus and higher speed allow full-frame video displays at scan rates of 30 Hz or higher.
  - comparable to commercial television

Microprocessor Age - Pentium

- Recent Pentium versions also included additional instructions.
  - multimedia extensions, or MMX instructions
- Intel hoped MMX would be widely used
  - few software companies have used
  - no high-level language support for instructions
- OverDrive (P24T) for older 80486 systems.
- 63 MHz version upgrades 80486DX2 50 MHz systems; 83 MHz upgrades 66 MHz systems.
  - system performs somewhere between a 66 MHz Pentium and a 75 MHz Pentium

Microprocessor Age - Pentium

- Pentium OverDrive represents ideal upgrade path from the 80486 to the Pentium.
  - executes two instructions not dependent on each other, simultaneously per clocking period
  - dual integer processors most ingenious feature
  - contains two independent internal integer processors called superscaler technology
- Jump prediction speeds execution of program loops; internal floating-point coprocessor handles floating-point data.
- These portend continued success for Intel.

Microprocessor Age - Pentium

- Intel may allow Pentium to replace some RISC (**reduced instruction set computer**) machines.
- Some newer RISC processors execute more than one instruction per clock.
  - through superscaler technology
- Motorola, Apple, and IBM produce PowerPC, a RISC with two integer units and a floating-point unit.
  - boosts Macintosh performance, but slow to efficiently emulate Intel microprocessors

Microprocessor Age - Pentium

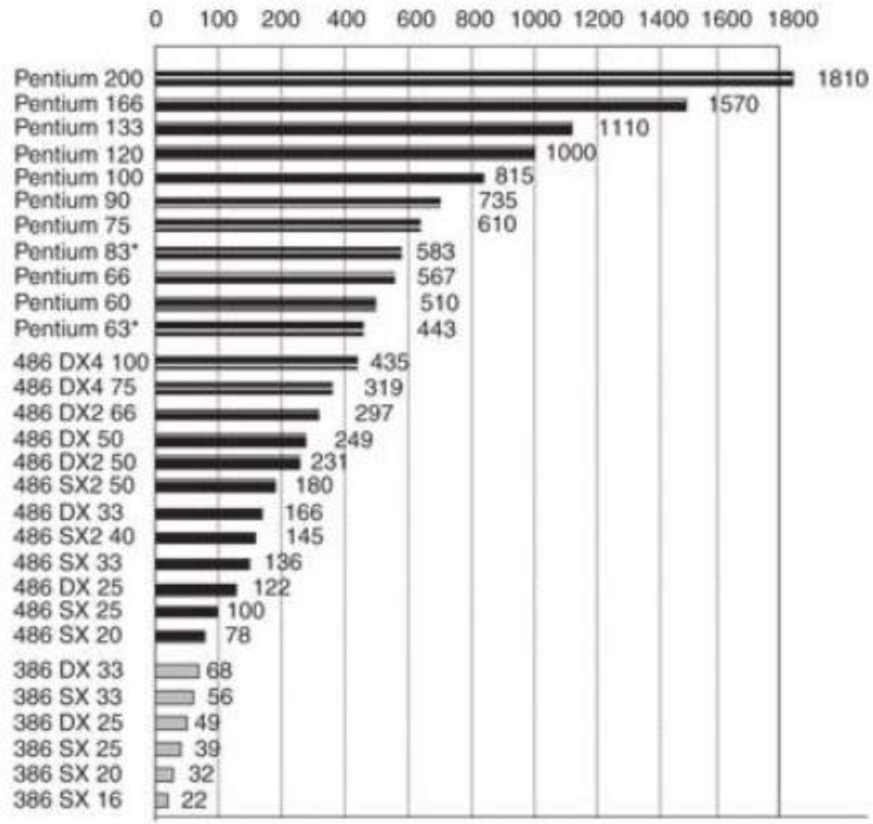
- Currently 6 million Apple Macintosh systems
- 260 million personal computers based on Intel microprocessors.
- 1998 reports showed 96% of all PCs shipped with the Windows operating system.
- Apple computer replaced PowerPC with the Intel Pentium in most of its computer systems.
  - appears that PowerPC could not keep pace with the Pentium line from Intel

Microprocessor Age – Rating Index

- To compare speeds of microprocessors, Intel devised the iCOMP- rating index.
  - composite of SPEC92, ZD Bench, Power Meter
- The iCOMP1 rating index is used to rate the speed of all Intel microprocessors through the Pentium.
- Figure 1–2 shows relative speeds of the 80386DX 25 MHz version through the Pentium 233 MHz version.

Microprocessor Age – Rating Index

Figure 1–2 The Intel iCOMP-rating index.



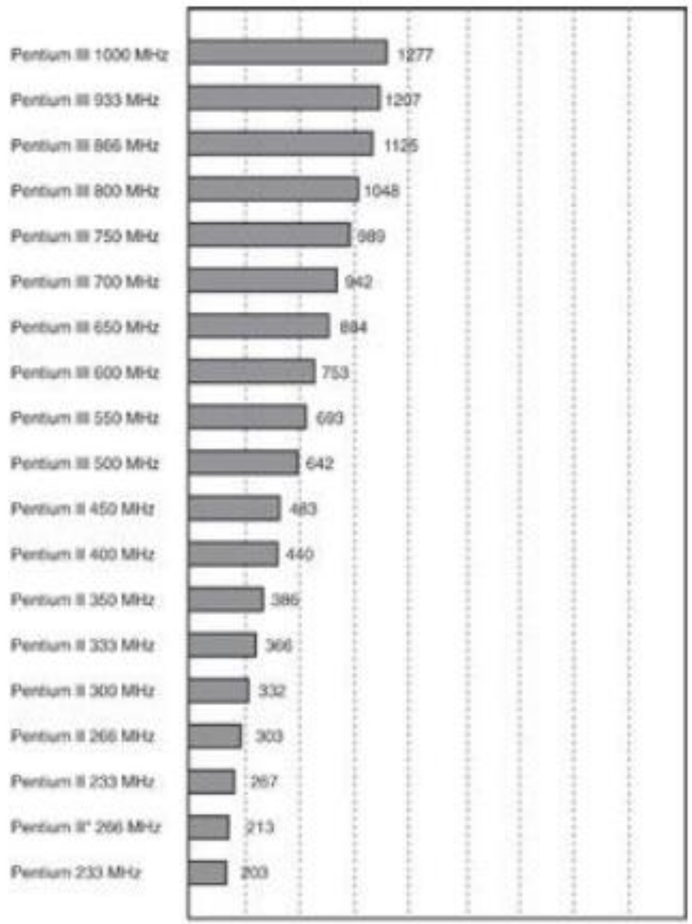
Note: *Pentium OverDrive, the first part of the scale is not linear, and the 166 MHz and 200 MHz are MMX technology.

Microprocessor Age – Rating Index

- Since release of Pentium Pro and Pentium II, Intel has switched to the iCOMP2- rating.
  - scaled by a factor of 10 from the iCOMP1 index
- Figure 1–3 shows iCOMP2 index listing the Pentium III at speeds up to 1000 MHz.
- Figure 1–4 shows SYSmark 2002 for the Pentium III and Pentium 4.
- Intel has not released benchmarks that compare versions of the microprocessor since the SYSmark 2002.
  - newer available do not compare versions

Microprocessor Age – Rating Index

Figure 1–3 The Intel iCOMP2-rating index.



Note: *Pentium II Celeron, no cache. iCOMP2 numbers are shown above. To convert to iCOMP3, multiply by 2.568.

Microprocessor Age – Pentium Pro

- A recent entry, formerly named the P6.
- 21 million transistors, integer units, floating-point unit, clock frequency 150 and 166 MHz
- Internal 16K level-one (L1) cache.
  - 8K data, 8K for instructions
  - Pentium Pro contains 256K level-two (L2) cache
- Pentium Pro uses three execution engines, to execute up to three instructions at a time.
  - can conflict and still execute in parallel

Microprocessor Age – Pentium Pro

- Pentium Pro optimized to efficiently execute 32-bit code.
  - often bundled with Windows NT rather than normal versions of Windows 95
  - Intel launched Pentium Pro for server market
- Pentium Pro can address 4G-byte or a 64G-byte memory system.
  - 36-bit address bus if configured for a 64G memory system

Microprocessor Age – Pentium II and Pentium Xeon

- Pentium II, released 1997, represents new direction for Intel.
- Intel has placed Pentium II on a small circuit board, instead of being an integrated circuit.
  - L2 cache on main circuit board of not fast enough to function properly with Pentium II
- Microprocessor on the Pentium II module actually Pentium Pro with MMX extensions.

Microprocessor Age – Pentium II and Pentium Xeon

- In 1998 Intel changed Pentium II bus speed.
  - newer Pentium II uses a 100 MHz bus speed
- Higher speed memory bus requires 8 ns SDRAM.
  - replaces 10 ns SDRAM with 66 MHz bus speed

Microprocessor Age – Pentium II and Pentium Xeon

- Intel announced Xeon in mid-1998.
  - specifically designed for high-end workstation and server applications
- Xeon available with 32K L1 cache and L2 cache size of 512K, 1M, or 2M bytes.
- Xeon functions with the 440GX chip set.
- Also designed to function with four Xeons in the same system, similar to Pentium Pro.
- Newer product represents strategy change.
  - Intel produces a professional and home/business version of the Pentium II

Microprocessor Age – Pentium III

- Faster core than Pentium II; still a P6 or Pentium Pro processor.
- Available in slot 1 version mounted on a plastic cartridge.
- Also socket 370 version called a flip-chip which looks like older Pentium package.
- Pentium III available with clock frequencies up to 1 GHz.

Microprocessor Age – Pentium III

- Slot 1 version contains a 512K cache; flip-chip version contains 256K cache.
- Flip-chip version runs at clock speed; Slot 1 cache version runs at one-half clock speed.
- Both versions use 100 Mhz memory bus.
  - Celeron memory bus clock speed 66 MHz
- Front side bus connection, microprocessor to memory controller, PCI controller, and AGP controller, now either 100 or 133 MHz.
  - this change has improved performance
  - memory still runs at 100 MHz

Microprocessor Age – Pentium 4 and Core 2

- Pentium 4 first made available in late 2000.
  - most recent version of Pentium called Core2
  - uses Intel P6 architecture
- Pentium 4 available to 3.2 GHz and faster.
  - supporting chip sets use RAMBUS or DDR memory in place of SDRAM technology
- Core2 is available at speeds of up to 3 GHz.
  - improvement in internal integration, at present the 0.045 micron or 45 nm technology

Microprocessor Age – Pentium 4 and Core 2

- A likely change is a shift from aluminum to copper interconnections inside the microprocessor.
- Copper is a better conductor.
  - should allow increased clock frequencies
  - especially true now that a method for using copper has surfaced at IBM
- Another event to look for is a change in the speed of the front side bus.
  - increase beyond current maximum 1033 MHz

Microprocessor Age – Multiple Core microprocessors

- Recent modifications to Pentium 4 and Core2 include a 64-bit core and multiple cores.
- 64-bit modification allows address of over 4G bytes of memory through a 64-bit address.
  - 40 address pins in these newer versions allow up to 1T (terabytes) of memory to be accessed
- Also allows 64-bit integer arithmetic.
  - less important than ability to address more memory

Microprocessor Age – Multiple Core microprocessors

- Biggest advancement is inclusion of multiple cores.
  - each core executes a separate task in a program
- Increases speed of execution if program is written to take advantage of multiple cores.
  - called **multithreaded** applications
- Intel manufactures dual and quad core versions; number of cores will likely increase to eight or even sixteen.

Microprocessor Age – Multiple Core microprocessors

- Multiple cores are current solution to providing faster microprocessors.
- Intel recently demonstrated Core2 containing 80 cores, using 45 nm fabrication technology.
- Intel expects to release an 80-core version some time in the next 5 years.
- Fabrication technology will become slightly smaller with 35 nm and possibly 25 nm technology.

Future of Microprocessors

- No one can make accurate predictions.
- Success of Intel should continue.
- Change to RISC technology may occur; more likely improvements to new hyper-threading technology.
  - joint effort by Intel and Hewlett-Packard
- New technology embodies CISC instruction set of 80X86 family.
  - software for the system will survive

Future of Microprocessors

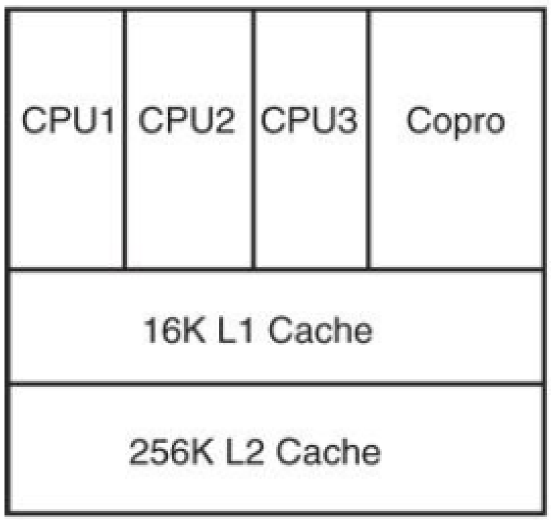
- Basic premise is many microprocessors communicate directly with each other.
  - allows parallel processing without any change to the instruction set or program
- Current superscaler technology uses many microprocessors; all share same register set.
  - new technology contains many microprocessors
  - each contains its own register set linked with the other microprocessors' registers
- Offers true parallel processing without writing any special program.

Future of Microprocessors

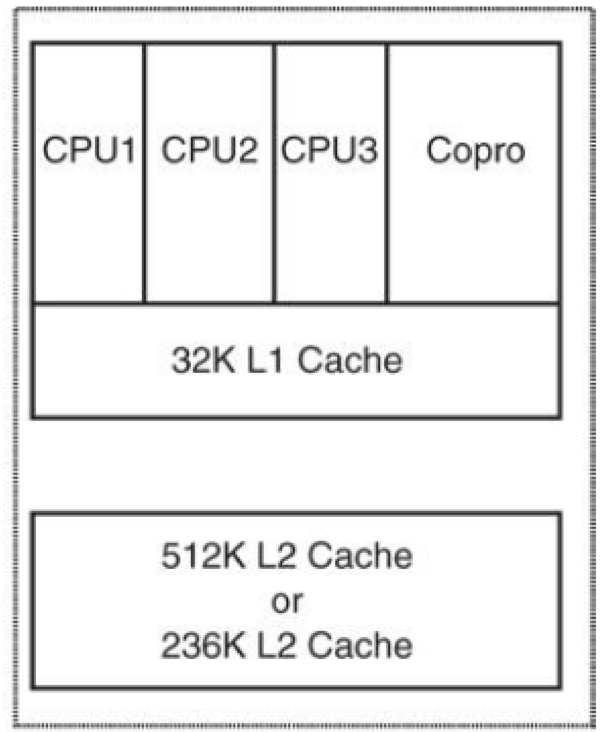
- In 2002, Intel released a new architecture 64 bits in width with a 128-bit data bus.
- Named Itanium; joint venture called EPIC (Explicitly Parallel Instruction Computing) of Intel and Hewlett-Packard.
- The Itanium architecture allows greater parallelism than traditional architectures.
- 128 general-purpose integer and 128 floating-point registers; 64 predicate registers.
- Many execution units to ensure enough hardware resources for software.

Future of Microprocessors

Figure 1–5a Conceptual views of the 80486, Pentium Pro, Pentium II, Pentium III, Pentium 4, and Core2 microprocessors.



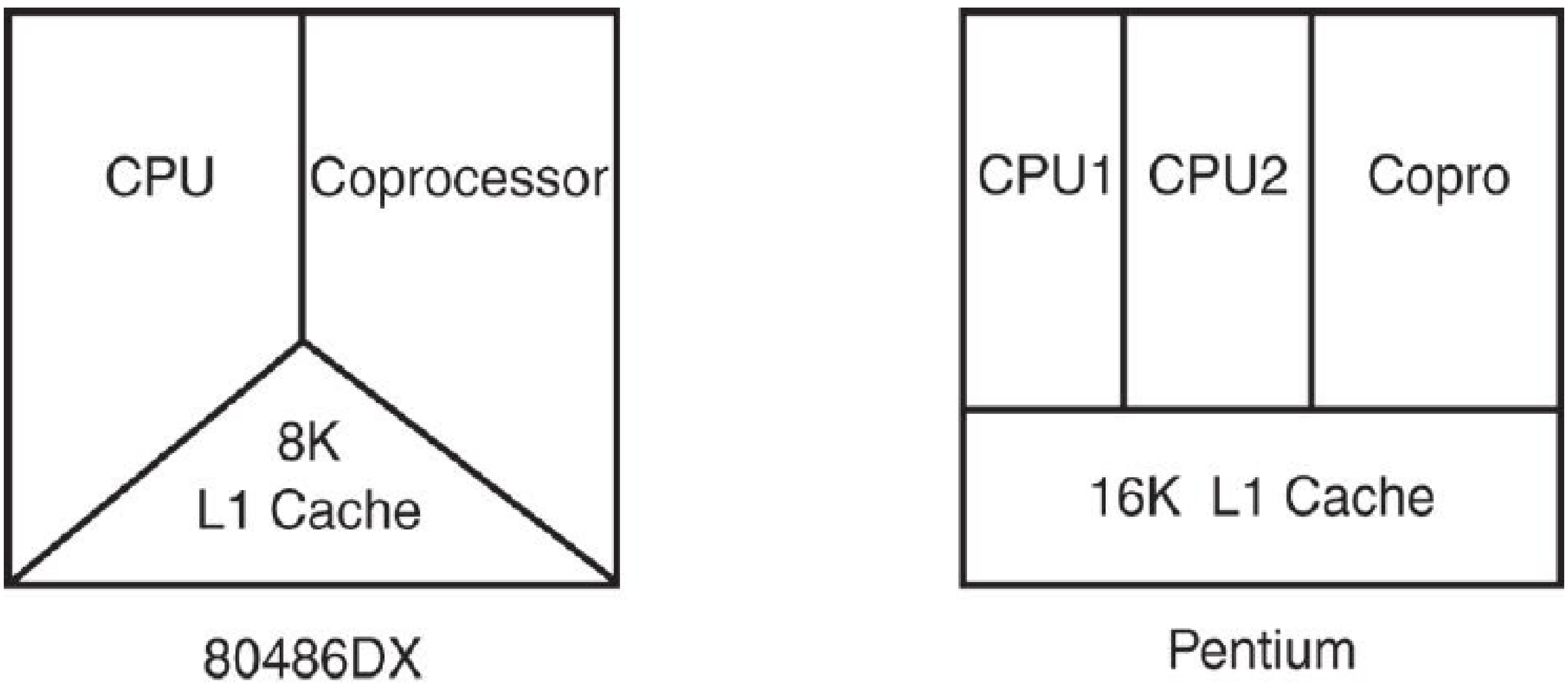
Pentium Pro



Pentium II, Pentium III, Pentium 4, or Core2 Module

Future of Microprocessors

Figure 1–5b Conceptual views of the 80486, Pentium Pro, Pentium II, Pentium III, Pentium 4, and Core2 microprocessors.



Future of Microprocessors

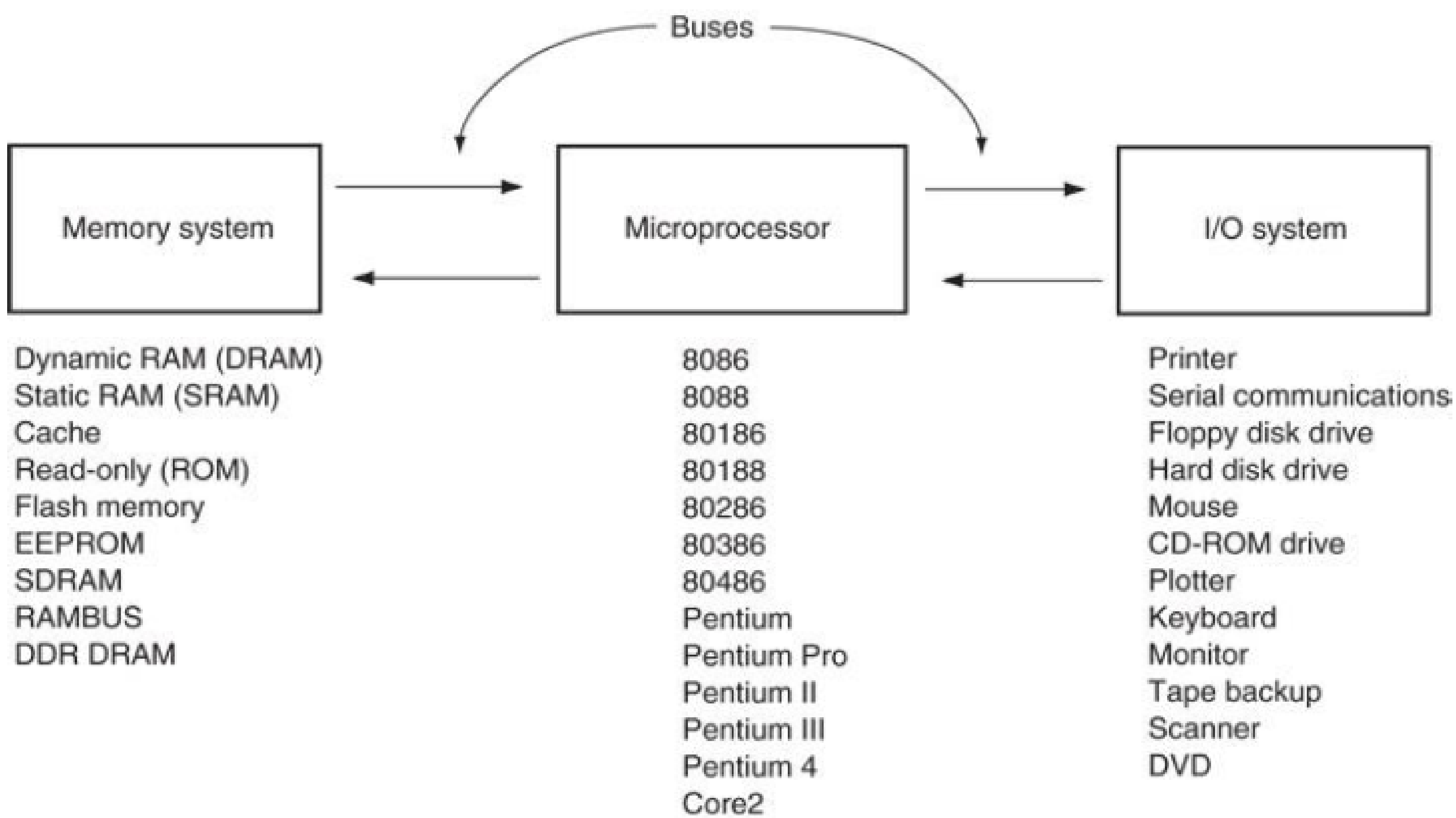
- Speed of mass storage another problem.
  - transfer speed of hard disk drives has changed little in past few years
  - new technology needed for mass storage
- Flash memory could be solution.
  - write speed comparable to hard disk memory
- Flash memory could store the operation system for common applications.
  - would allow operating system to load in a second or two instead of many seconds now required

The Microprocessor Based Personal Computer System

- Computers have undergone many changes recently.
- Machines that once filled large areas reduced to small desktop computer systems because of the microprocessor.
  - although compact, they possess computing power only dreamed of a few years ago
- Figure 1–6 shows block diagram of the personal computer.
- Applies to any computer system, from early mainframe computers to the latest systems.
- Diagram composed of three blocks interconnected by buses.
  - a **bus** is the set of common connections that carry the same type of information

Future of Microprocessors

Figure 1–6 The block diagram of a microprocessor-based computer system.

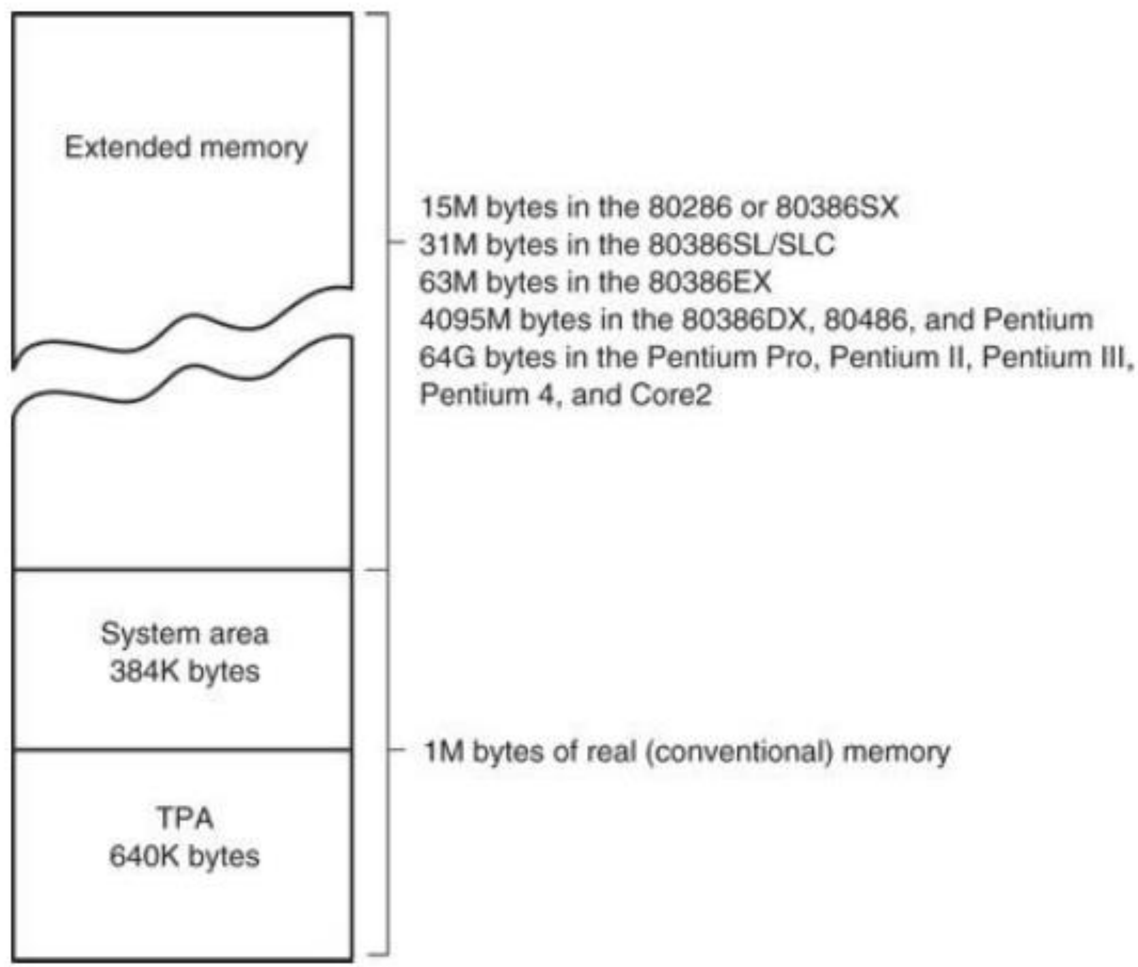


The Memory and I/O System

- Memory structure of all Intel-based personal computers similar.
- Figure 1–7 illustrates memory map of a personal computer system.
- This map applies to any IBM personal computer.
  – also any IBM-compatible clones in existence

The Memory and I/O System

Figure 1–7 The memory map of a personal computer.



The Memory and I/O System

- Main memory system divided into three parts:
  - TPA (transient program area)
  - system area
  - XMS (extended memory system)
- Type of microprocessor present determines whether an extended memory system exists.
- First 1M byte of memory often called the real or conventional memory system.
  - Intel microprocessors designed to function in this area using real mode operation

The Memory and I/O System

- 80286 through the Core2 contain the TPA (640K bytes) and system area (384K bytes).
  - also contain extended memory
  - often called AT class machines
- The PS/l and PS/2 by IBM are other versions of the same basic memory design.
- Also referred to as ISA (industry standard architecture) or EISA (extended ISA).
- The PS/2 referred to as a micro-channel architecture or ISA system.
  - depending on the model number

The Memory and I/O System

- Pentium and ATX class machines feature addition of the PCI (**peripheral component interconnect**) bus.
  - now used in all Pentium through Core2 systems
- Extended memory up to 15M bytes in the 80286 and 80386SX; 4095M bytes in 80486 80386DX, Pentium microprocessors.
- The Pentium Pro through Core2 computer systems have up to 1M less than 4G or 1 M less than 64G of extended memory.
- Servers tend to use the larger memory map.

The Memory and I/O System

- Many 80486 systems use **VESA** local, VL bus to interface disk and video to the microprocessor at the local bus level.
  - allows 32-bit interfaces to function at same clocking speed as the microprocessor
  - recent modification supporting 64-bit data bus has generated little interest
- ISA/EISA standards function at 8 MHz.
- PCI bus is a 32- or 64-bit bus.
  - specifically designed to function with the Pentium through Core2 at a bus speed of 33 MHz.

The Memory and I/O System

- Three newer buses have appeared.
- USB (**universal serial bus**).
  - intended to connect peripheral devices to the microprocessor through a serial data path and a twisted pair of wires
- Data transfer rates are 10 Mbps for USB1.
- Increase to 480 Mbps in USB2.
- AGP (**advanced graphics port**) for video cards.
- The port transfers data between video card and microprocessor at higher speeds.
  - 66 MHz, with 64-bit data path
- Latest AGP speed 8X or 2G bytes/second.
  - video subsystem change made to accommodate new DVD players for the PC.

The Memory and I/O System

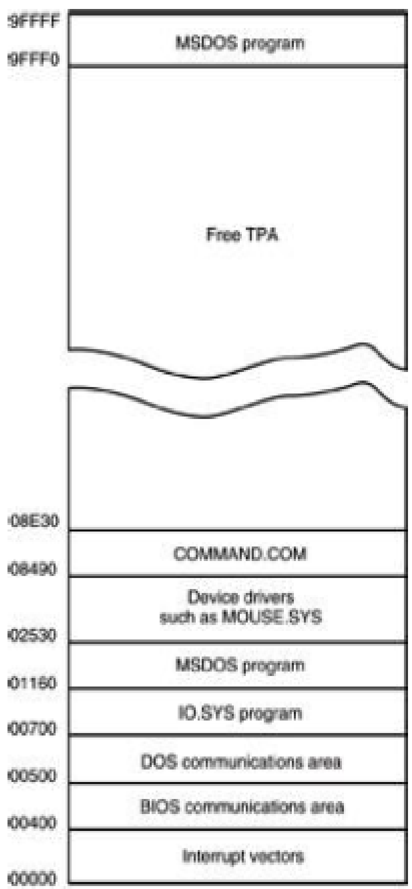
- Latest new buses are serial ATA interface (**SATA**) for hard disk drives; PCI Express bus for the video card.
- The SATA bus transfers data from PC to hard disk at rates of 150M bytes per second; 300M bytes for SATA-2.
  - serial ATA standard will eventually reach speeds of 450M bytes per second
- PCI Express bus video cards operate at 16X speeds today.

The Transit Programmable Area

- The transient program area (TPA) holds the DOS (**disk operating system**) operating system; other programs that control the computer system.
  - the TPA is a DOS concept and not really applicable in Windows
  - also stores any currently active or inactive DOS application programs
  - length of the TPA is 640K bytes

The Transit Programmable Area

Figure 1–8 The memory map of the TPA in a personal computer. (Note that this map will vary between systems.)



- DOS memory map shows how areas of TPA are used for system programs, data and drivers.
  - also shows a large area of memory available for application programs
  - hexadecimal number to left of each area represents the memory addresses that begin and end each data area

The Transit Programmable Area

- Hexadecimal memory addresses number each byte of the memory system.
  - a hexadecimal number is a number represented in radix 16 or base 16
  - each digit represents a value from 0 to 9 and from A to F
- Often a hexadecimal number ends with an H to indicate it is a hexadecimal value.
  - 1234H is 1234 hexadecimal
  - also represent hexadecimal data as 0xl234 for a 1234 hexadecimal

The Transit Programmable Area

- Interrupt vectors access DOS, BIOS (basic I/O system), and applications.
- Areas contain transient data to access I/O devices and internal features of the system.
  - these are stored in the TPA so they can be changed as DOS operates
- The IO.SYS loads into the TPA from the disk whenever an MSDOS system is started.
- IO.SYS contains programs that allow DOS to use keyboard, video display, printer, and other I/O devices often found in computers.
- The IO.SYS program links DOS to the programs stored on the system BIOS ROM.

The Transit Programmable Area

- **Drivers** are programs that control installable I/O devices.
  - mouse, disk cache, hand scanner, CD-ROM memory (**Compact Disk Read-Only Memory**), DVD (**Digital Versatile Disk**), or installable devices, as well as programs
- Installable drivers control or drive devices or programs added to the computer system.
- DOS drivers normally have an extension of .SYS; MOUSE.SYS.
- DOS version 3.2 and later files have an extension of .EXE; EMM386.EXE.

The Transit Programmable Area

- Though not used by Windows, still used to execute DOS applications, even with Win XP.
- Windows uses a file called SYSTEM.INI to load drivers used by Windows.
- Newer versions of Windows have a registry added to contain information about the system and the drivers used.
- You can view the registry with the REGEDIT program.

The Transit Programmable Area

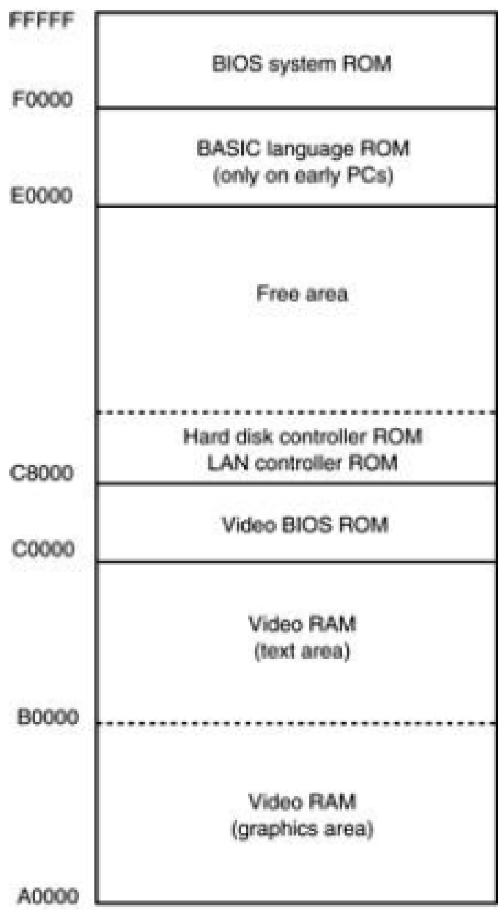
- COMMAND.COM (**command processor**) controls operation of the computer from the keyboard when operated in the DOS mode.
- COMMAND.COM processes DOS commands as they are typed from the keyboard.
- If COMMAND.COM is erased, the computer cannot be used from the keyboard in DOS mode.
  - never erase COMMAND.COM, IO.SYS, or MSDOS.SYS to make room for other software
  - your computer will not function

The System Area

- Smaller than the TPA; just as important.
- The **system area** contains programs on read-only (ROM) or flash memory, and areas of read/write (RAM) memory for data storage.
- Figure 1–9 shows the system area of a typical personal computer system.
- As with the map of the TPA, this map also includes the hexadecimal memory addresses of the various areas.

The System Area

Figure 1–9 The system area of a typical personal computer.



- First area of system space contains video display RAM and video control programs on ROM or flash memory.
  - area starts at location A0000H and extends to C7FFFH
  - size/amount of memory depends on type of video display adapter attached

The System Area

- Display adapters generally have video RAM at A0000H–AFFFFH.
  - stores graphical or bit-mapped data
- Memory at B0000H–BFFFFH stores text data.
- The video BIOS on a ROM or flash memory, is at locations C0000H–C7FFFH.
  - contains programs to control DOS video display
- C8000H–DFFFFH is often open or free.
  - used for expanded memory system (EMS) in PC or XT system; upper memory system in an AT

The System Area

- Expanded memory system allows a 64K-byte page frame of memory for use by applications.
  - page frame (D0000H - DFFFFH) used to expand memory system by switching in pages of memory from EMS into this range of memory addresses
- Locations E0000H–EFFFFH contain cassette BASIC on ROM found in early IBM systems.
  - often open or free in newer computer systems
- Video system has its own BIOS ROM at location C0000H.

The System Area

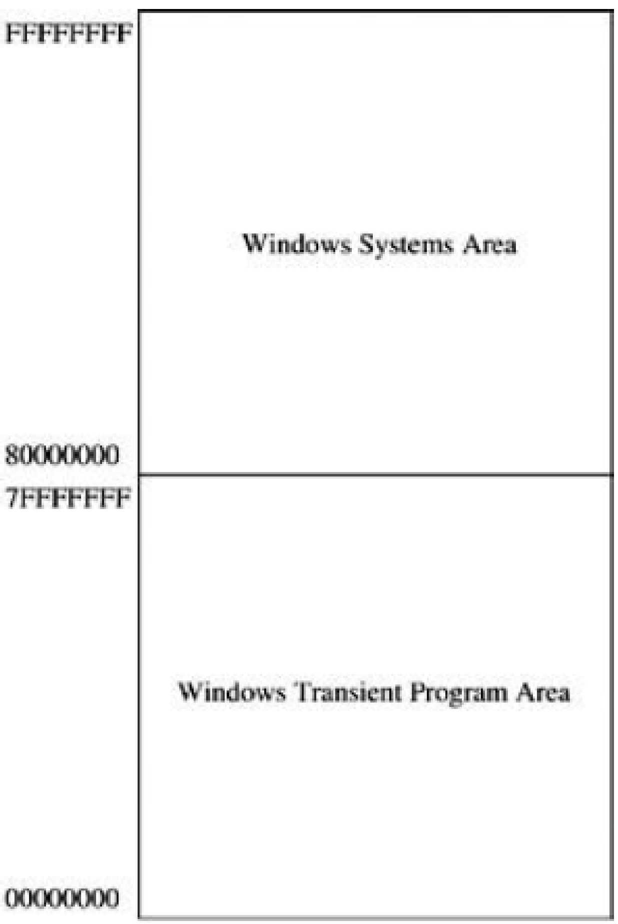
- System BIOS ROM is located in the top 64K bytes of the system area (F0000H–FFFFFH).
  - controls operation of basic I/O devices connected to the computer system
  - does not control operation of video
- The first part of the system BIOS (F0000H–F7FFFH) often contains programs that set up the computer.
- Second part contains procedures that control the basic I/O system.

Windows Systems

- Modern computers use a different memory map with Windows than DOS memory maps.
- The Windows memory map in Figure 1–10 has two main areas; a TPA and system area.
- The difference between it and the DOS memory map are sizes and locations of these areas.

Windows Systems

Figure 1–10 The memory map used by Windows XP.



- TPA is first 2G bytes from locations 00000000H to 7FFFFFFFH.
- Every Windows program can use up to 2G bytes of memory located at linear addresses 00000000H through 7FFFFFFFH.
- System area is last 2G bytes from 80000000H to FFFFFFFFH.

Windows Systems

- Memory system physical map is much different.
- Every process in a Windows Vista, XP, or 2000 system has its own set of page tables.
- The process can be located anywhere in the memory, even in noncontiguous pages.
- The operating system assigns physical memory to application.
  - if not enough exists, it uses the hard disk for any that is not available

I/O Space

Figure 1–11 Some I/O locations in a typical personal computer.

- Access to most I/O devices should always be made through Windows, DOS, or BIOS function calls.
- The map shown is provided as a guide to illustrate the I/O space in the system.

I/O Space

- I/O devices allow the microprocessor to communicate with the outside world.
- I/O (input/output) space in a computer system extends from I/O port 0000H to port FFFFH.
  - **I/O port address** is similar to a memory address
  - instead of memory, it addresses an I/O device
- Figure 1–11 shows the I/O map found in many personal computer systems.

I/O Space

- The area below I/O location 0400H is considered reserved for system devices
- Area available for expansion extends from I/O port 0400H through FFFFH.
- Generally, 0000H - 00FFH addresses main board components; 0100H - 03FFH handles devices located on plug-in cards or also on the main board.
- The limitation of I/O addresses between 0000 and 03FFH comes from original standards specified by IBM for the PC standard.

Microprocessor

- Called the CPU (**central processing unit**).
- The controlling element in a computer system.
- Controls memory and I/O through connections called buses.
  - buses select an I/O or memory device, transfer data between I/O devices or memory and the microprocessor, control I/O and memory systems
- Memory and I/O controlled via instructions stored in memory, executed by the microprocessor.

Microprocessor

- Microprocessor performs three main tasks:
  - data transfer between itself and the memory or I/O systems
  - simple arithmetic and logic operations
  - program flow via simple decisions
- Power of the microprocessor is capability to execute billions of millions of instructions per second from a program or software (**group of instructions**) stored in the memory system.
  - stored programs make the microprocessor and computer system very powerful devices

Microprocessor

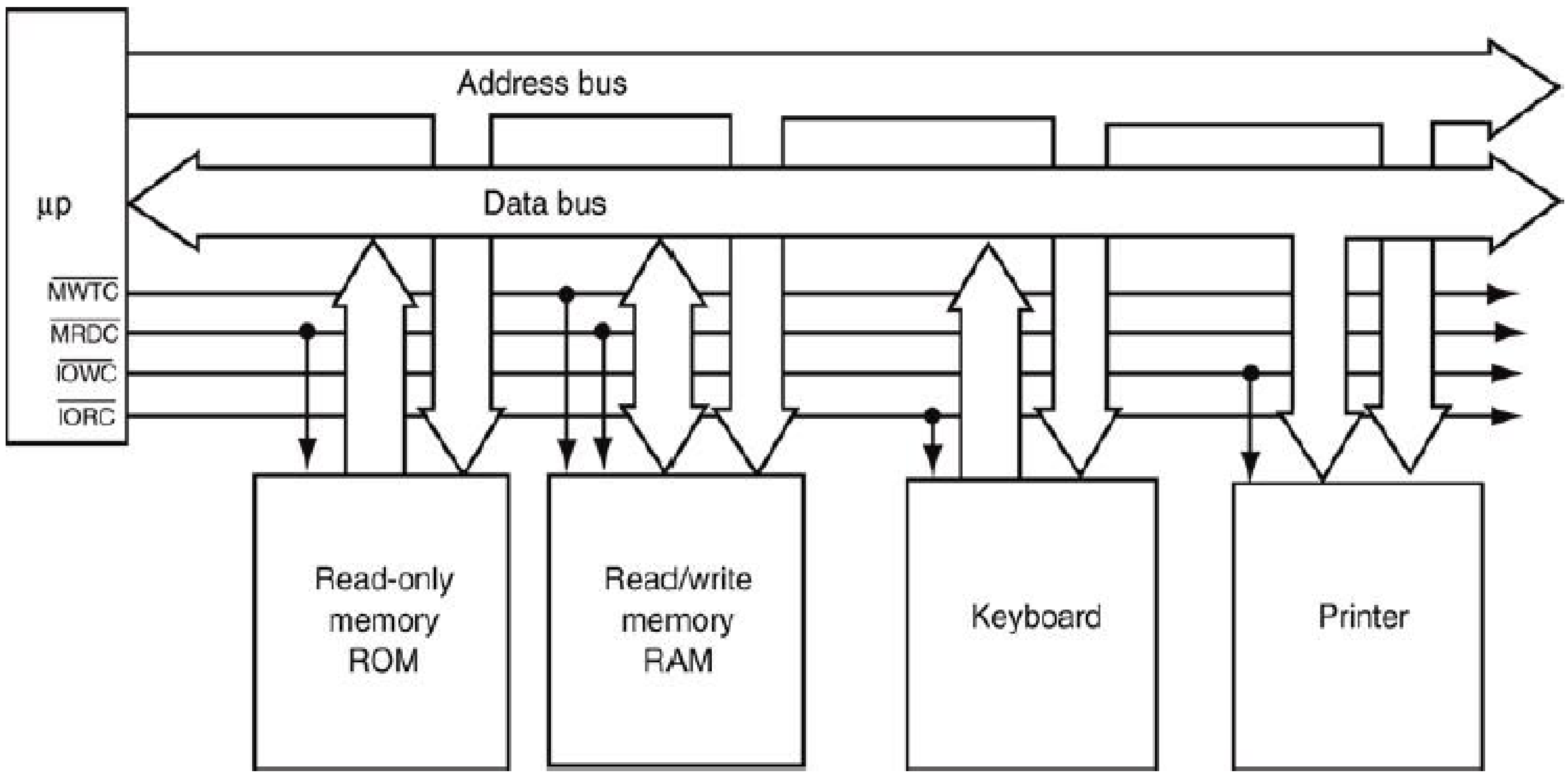
- Another powerful feature is the ability to make simple decisions based upon numerical facts.
  - a microprocessor can decide if a number is zero, positive, and so forth
- These decisions allow the microprocessor to modify the program flow, so programs appear to think through these simple decisions.

Buses

- A common group of wires that interconnect components in a computer system.
- Transfer address, data, & control information between microprocessor, memory and I/O.
- Three buses exist for this transfer of information: address, data, and control.
- Figure 1–12 shows how these buses interconnect various system components.

Buses

Figure 1–12 The block diagram of a computer system showing the address, data, and control bus structure.



Buses

- The address bus requests a memory location from the memory or an I/O location from the I/O devices.
  - if I/O is addressed, the address bus contains a 16-bit I/O address from 0000H through FFFFH.
  - if memory is addressed, the bus contains a memory address, varying in width by type of microprocessor.
- 64-bit extensions to Pentium provide 40 address pins, allowing up to 1T byte of memory to be accessed.

Buses

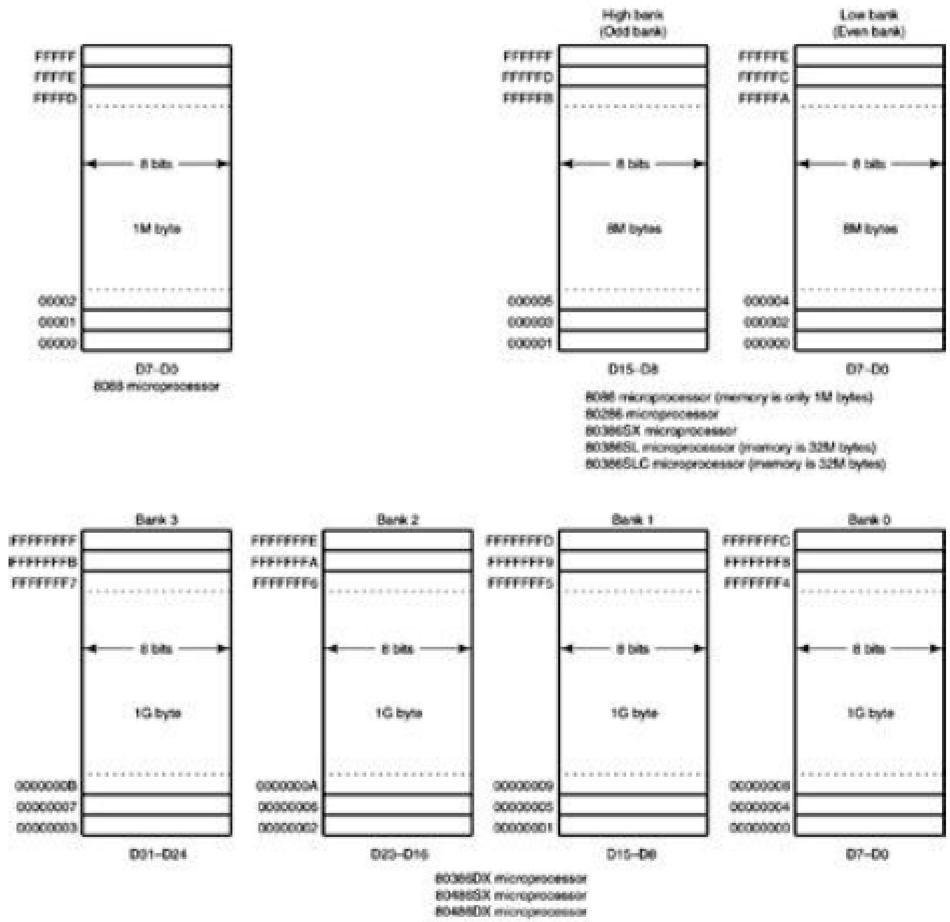
- The data bus transfers information between the microprocessor and its memory and I/O address space.
- Data transfers vary in size, from 8 bits wide to 64 bits wide in various Intel microprocessors.
  - 8088 has an 8-bit data bus that transfers 8 bits of data at a time
  - 8086, 80286, 80386SL, 80386SX, and 80386EX transfer 16 bits of data
  - 80386DX, 80486SX, and 80486DX, 32 bits
  - Pentium through Core2 microprocessors transfer 64 bits of data

Buses

- Advantage of a wider data bus is speed in applications using wide data.
- Figure 1–13 shows memory widths and sizes of 8086 through Core2 microprocessors.
- In all Intel microprocessors family members, memory is numbered by byte.
- Pentium through Core2 microprocessors contain a 64-bit-wide data bus.

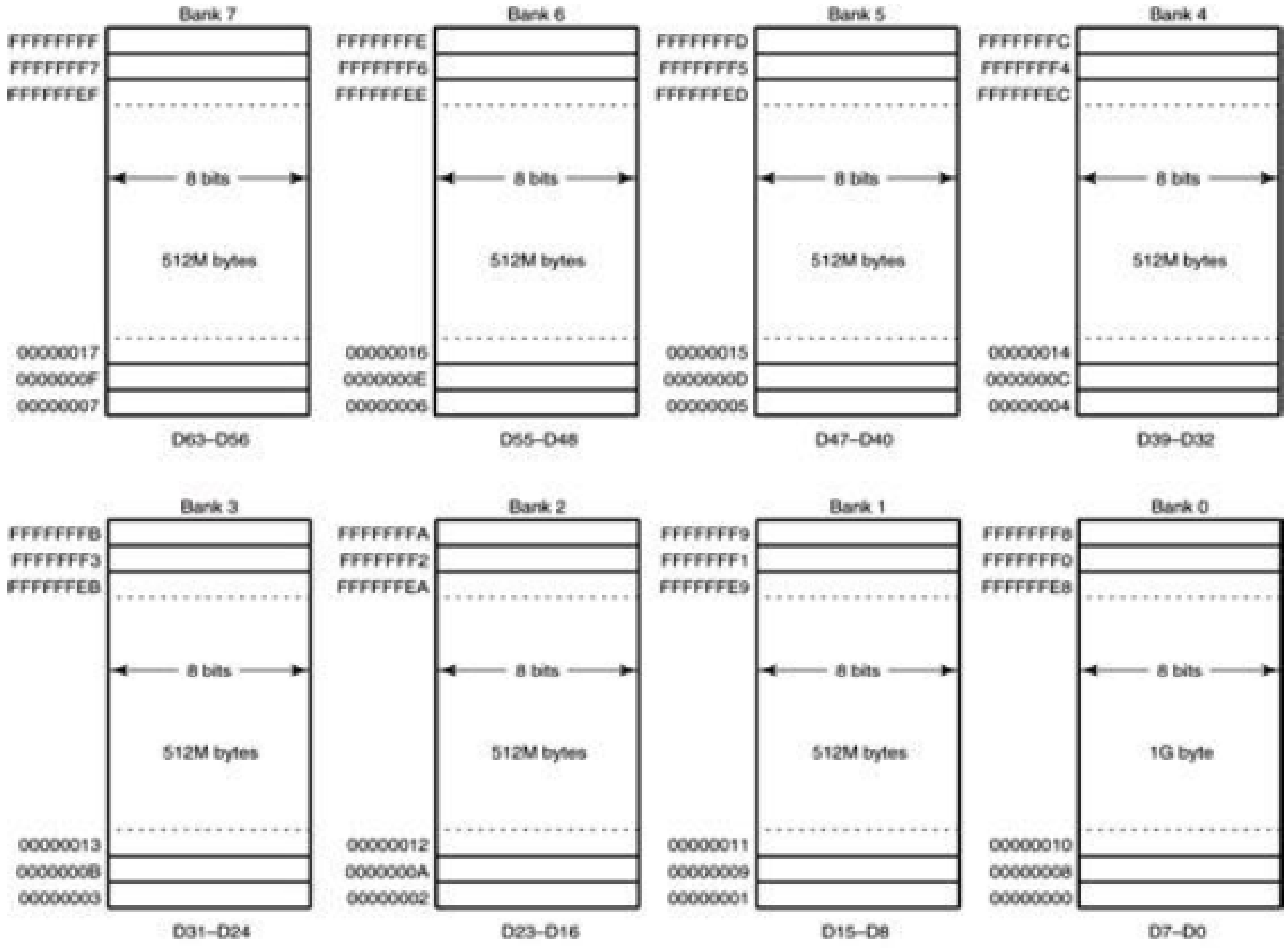
Buses

Figure 1–13a The physical memory systems of the 8086 through the Core2 microprocessors.



Buses

Figure 1–13b The physical memory systems of the 8086 through the Core2 microprocessors.



Pentium–Core2 microprocessors

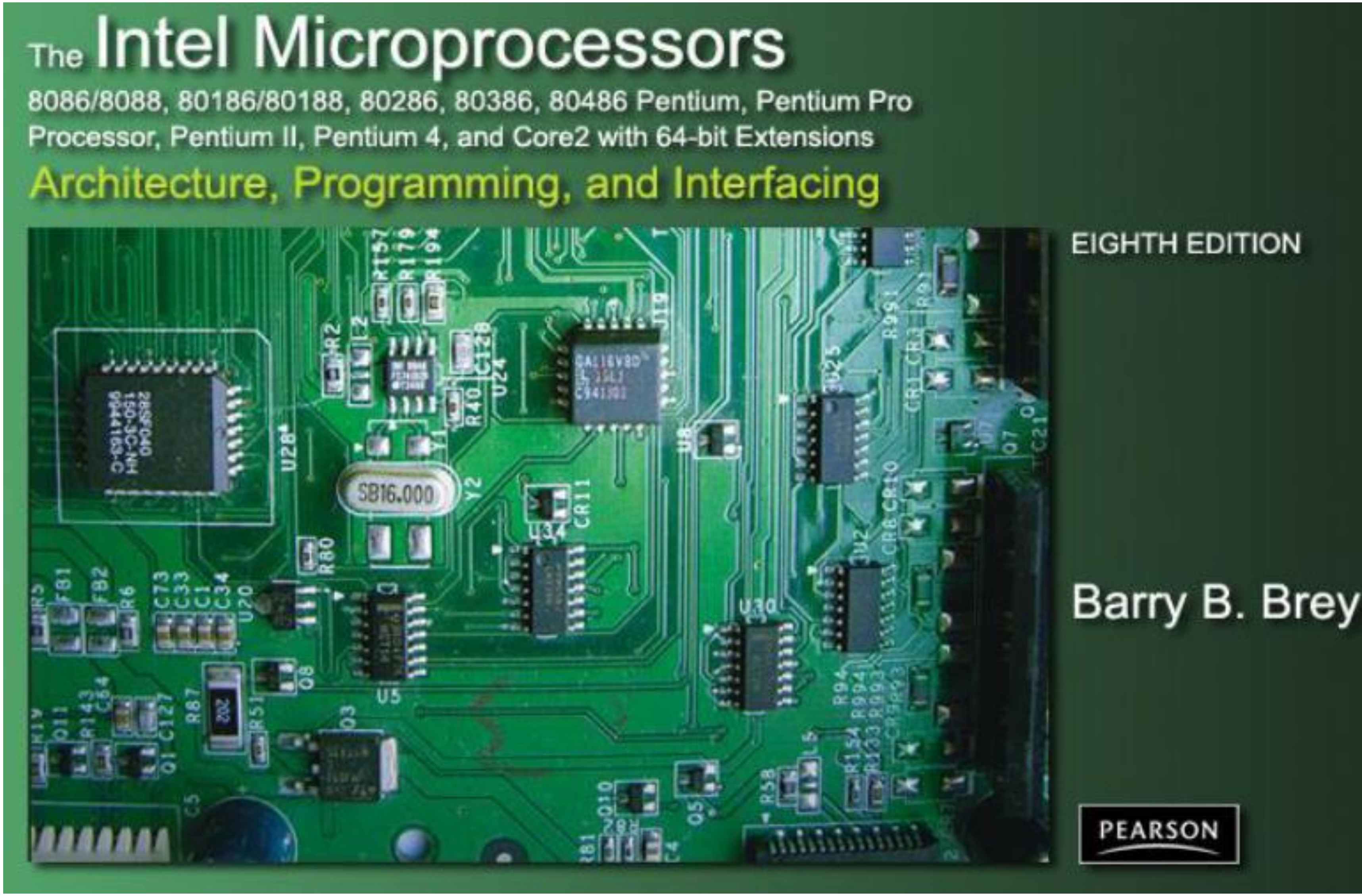
Buses

- Control bus lines select and cause memory or I/O to perform a read or write operation.
- In most computer systems, there are four control bus connections:
- $\overline{MRDC}$ (**memory read control**)
- $\overline{MWTC}$ (**memory write control**)
- $\overline{IORC}$ (**I/O read control**)
- $\overline{IOWC}$ (**I/O write control**).
- overbar indicates the control signal is active-low; (active when logic zero appears on control line)

Buses

- The microprocessor reads a memory location by sending the memory an address through the address bus.
- Next, it sends a memory read control signal to cause the memory to read data.
- Data read from memory are passed to the microprocessor through the data bus.
- Whenever a memory write, I/O write, or I/O read occurs, the same sequence ensues.

References


The Intel Microprocessors
8086/8088, 80186/80188, 80286, 80386, 80486 Pentium, Pentium Pro Processor, Pentium II, Pentium 4, and Core2 with 64-bit Extensions
Architecture, Programming, and Interfacing
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End of Lecture 1